REPORT
FROM THE
SELECT COMMITTEE
ON THE
NORTH BRITISH RAILWAY (TAY BRIDGE) BILL;
TOGETHER WITH THE
PROCEEDINGS OF THE COMMITTEE,
AND
MINUTES OF EVIDENCE.

Ordered, by The House of Commons, to be Printed,
4 August 1880.
Ordered,—[Thursday, 8th July 1880]:—That the North British Railway (Tay Bridge) Bill be read a second time, and committed to a Select Committee of Seven Members; Four to be nominated by the House and Three by the Committee of Selection.

That it be an Instruction to the Committee, that they have power to inquire and report as to whether the Tay Bridge should be rebuilt in its present position, or whether there is any situation more suitable, having due regard to the safety of the travelling public and the convenience of the locality.

That their special attention be directed to the interests of the navigation, and that the height of the bridge shall be so fixed as not injuriously to interfere with the river navigation.

That they shall consider generally in what way any bridge that may be authorised should be constructed so as to secure its permanent safety.

That the Reports of the Court of Inquiry held by direction of the Board of Trade, and also the Report of Mr. Rothery, on the Tay Bridge Disaster, together with the Evidence taken by that Court, be referred to the Committee.

That the Committee have power to send for Persons, Papers, and Records.

That Four be the Quorum of the Committee.

Committee nominated—[Tuesday, 13th July 1880]—of—

Mr. Joseph Pease.
Mr. W. L. Jackson.
Mr. Stuart Rendel.
Sir William Palliser.
Sir Massey Lopes.
Mr. John Cross.
Mr. Stafford Howard.

Nominated by The House.

Added by the Committee of Selection.

Ordered,—[Thursday, 15th July 1880]:—That Mr. John Cross be discharged from attendance on the Committee.—Committee of Selection.

That Mr. Arthur P. Vivian be added to the Committee.

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THE SELECT COMMITTEE on the NORTH BRITISH RAILWAY (TAY BRIDGE) BILL, who were instructed that they have power to inquire and report as to whether the TAY BRIDGE should be rebuilt in its present position, or whether there is any situation more suitable, having due regard to the safety of the travelling public and the convenience of the locality; who were also instructed to pay special attention to the interests of the Navigation, and that the height of the Bridge shall be so fixed as not injuriously to interfere with the River Navigation; and to consider generally in what way any Bridge that may be authorised should be constructed so as to secure its permanent safety;—HAVE agreed to the following REPORT:—

1. The Committee have been placed in an unusual and difficult position by the withdrawal of all independent opposition to the Bill. The Board of Trade as a public Department were represented by counsel. Witnesses were called by them, whose evidence was of great service to the Committee. Local witnesses were also heard on questions affecting the river navigation. The absence of opposition has, therefore, thrown more responsibility on the Committee.

2. Having carefully considered the details of the scheme proposed by the Bill, as well as the evidence which has been adduced by the Promoters, they have arrived at the following conclusions on the points referred to them:

   (1.) That the Bridge over the River Tay should, in the interests of the public and of the Railway Company, be re-constructed.

   (2.) That the present site of the Bridge is on the whole the most suitable.

   (3.) That the reconstruction of the Bridge at the lower elevation of 77 feet over 4 spans of 245 feet from centre to centre of piers, instead of 68 feet above high water spring tides, will occasion no undue interference with the navigation of the River, more especially as the Promoters have signified their intention, in case the Bridge is rebuilt at the lower level, to provide a tug gratuitously for all vessels of and above 70 tons register passing up and down within a mile of the Bridge, and to keep the navigable channel clear.

3. The fourth point referred to them, viz., "In what way any bridge that may be authorised should be constructed, so as to secure its permanent safety," has occupied the chief time and attention of the Committee, inasmuch as it involved very serious responsibility; and after careful consideration they have unanimously come to the decision that they should not be justified in sanctioning the scheme presented to them by the Bill.

4. One of the main features of the scheme submitted to the Committee was to secure a wider base for the superstructure, by sinking new caissons parallel with those already existing, and uniting these foundations by a brick arch, upon which brick piers supporting wrought-iron girders were to be raised.

On considering this scheme, distinct elements of uncertainty immediately suggested themselves, viz.:

1. That to raise brick piers on these foundations was to return to the original design of Sir Thomas Bouch, which he had abandoned as soon as he discovered the real nature of the strata with which he had to deal, when he substituted iron work for brick, in order to lighten the weight upon the caissons.
2. That beyond a general inspection and a concurrence of opinion in their favour, there was no certain evidence that the caissons still occupied their original positions.

3. That no test had been applied to any of them in order to ascertain whether they would bear the much larger weight per foot of bearing surface that it was proposed by the brick piers to place upon them.

It appeared also to the Committee that such a combination of old and new work, especially in such a locality, and with such a foundation, was one which essentially required not only most careful consideration, but actual preliminary tests, before it could with safety be decided upon by the Railway Company, or sanctioned by Parliament.

5. It clearly appeared from the evidence that some of the existing caissons were not sunk to a sufficient depth, and that a very considerable scour had already taken place in the vicinity of some of them. It had become, and still continues necessary from time to time to place large quantities of rubble round them to prevent their being undermined.

6. The Committee are of opinion that the safety of the public might best be consulted by the Bridge being rebuilt upon entirely new foundations; but, evidence having been adduced that, subject to certain conditions, by sheet piling or otherwise, the existing caissons might be secured and utilised. This opinion might be open to reconsideration, if hereafter it should be proved that the existing caissons had been thoroughly tested and found trustworthy, or a carefully considered plan brought forward for rendering them secure.

7. The Committee have no doubt that a bridge properly constructed would resist the lateral pressure of any wind; but they have not taken direct evidence as to wind pressure, as this subject was fully considered before the Court of Inquiry on the Tay Bridge Disaster, and is now under the consideration of a Committee of the Board of Trade.

8. No provision for giving any shelter to the train from the wind during its passage over the Bridge was included in the scheme before the Committee. This subject they consider most important, and it will no doubt receive the attention of the Company's engineer in preparing plans for the re-construction of the Bridge.

9. The Committee are of opinion that the undertaking given by the Promoters to remove the existing Railway junction from off the Bridge should be embodied in any future scheme, that the gradient on the north side should be reduced, as proposed, from 1 in 74 to 1 in 101, and that it should be a statutory obligation on the part of the Railway Company to maintain a tug boat in the manner proposed by them for the gratuitous use of all vessels of 70 tons and upwards, for a mile on each side of the Bridge, and also to maintain a clear waterway under the four spans of the Bridge.

10. In deciding to reject the Bill, the Committee have also been in some measure influenced by the want of independent engineering evidence adduced in its favour, and by the great discrepancy between the plans and estimates submitted to them, and those deposited in the offices of Parliament.

11. In the event of the Promoters coming to Parliament next Session, the Committee are of opinion that the passage of the Bill would be much facilitated, and the interest of the public best promoted, if the Company had obtained the previous approval of their scheme by two or three independent engineers of unquestionable standing and experience.

The Select Committee further report, that they have examined the allegations contained in the Preamble of the Bill, but the same have not been proved to their satisfaction.

4 August 1880.
APPENDIX

TO THE

REPORTS OF THE COURT

AND

EVIDENCE TAKEN UPON THE INQUIRY

INTO THE

TAY BRIDGE DISASTER.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY,
FOR HER MAJESTY'S STATIONERY OFFICE.

1880.

Price 12s.
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MINUTES OF PROCEEDINGS

TAKEN BEFORE

HENRY CADOGAN ROTHERY, ESQ, Wreck Commissioner; COLONEL WILLIAM YOLLAND, K.E., Chief Inspector of Railways; and WILLIAM HENRY BARLOW, ESQ, President of the Institute of Civil Engineers,

UPON

A FORMAL INVESTIGATION DIRECTED BY THE BOARD OF TRADE, TO BE HELD INTO THE CAUSES OF, AND CIRCUMSTANCES ATTENDING, THE ACCIDENT TO THE TAY BRIDGE, DUNDEE, ON SUNDAY, 28TH DECEMBER 1879.

AT THE ASSIZE COURT, DUNDEE.

FIRST DAY.

Saturday, 3rd January 1880.

Mr. Trayner (instructed by Mr. Walter Morton, solicitor for the Board of Trade, and his agent, Mr. J. J. Grant) appeared for the Board of Trade.

Mr. J. B. Balfour (instructed by Mr. Adam Johnston and Mr. Thomas Thornton) appeared for the North British Railway Company.

Mr. Dunbar (Prosecutor Fiscal) appeared to watch the case for the Lord Advocate.

(Mr. Trayner, Sir.)—I appear on behalf of the Board of Trade, who have, as you are aware, ordered a formal inquiry into the causes of, and the circumstances attending, the recent very appalling disaster to the Tay Bridge. This inquiry has been ordered under the provisions contained in the Regulation of Railways Act, 1871, and the Court is in possession of the order itself. The Board of Trade is naturally very anxious that this inquiry should be of a very exact and exhaustive character; and I am instructed that, so far as I am able, it should be exhaustive, especially with regard to the facts and circumstances surrounding the accident itself.

The accident was of a kind, not only peculiarly disastrous, but unhappily very appalling in its results, and those who are charged with the public interests are extremely desirous of doing everything that can be done by way of inquiry with regard to the practical results which that may lead to, to prevent, so far as human skill can prevent, the possibility of a recurrence of such a disaster. But while I am charged on behalf of the Board of Trade to make a very careful and exhaustive inquiry into the circumstances, I think it right to communicate at once the fact that it will be impossible to exhaust; indeed, probably until some portion of the destroyed bridge is recovered, it is not desirable to enter upon the inquiry which will necessarily follow as to what were the probable causes of this disaster which we all deplore.

I shall, therefore, with the leave of the Court, confine the inquiry, so far as it can at present be carried, to what I have indicated, namely, the mere surrounding facts which may be locally ascertained.

I do not think it necessary to detain the Court with any opening with respect to the nature or character or probable result of the evidence I shall tender, because, as the witnesses must be examined in our presence, it would be really anticipating and repeating what you must hear from the witnesses themselves who may be summoned to attend. So far as the Board of Trade has been able to do so, it has gathered together the evidence of those persons who can in any way throw light upon the subject of this investigation, and their evidence will be laid before you as briefly, yet as completely, as it is in my power to do it; and I shall ask the leave of the Court, without further preface, to proceed with the inquiry and examine the witnesses who have been instructed to attend this investigation.

(The Commissioner.)—The Court would be very glad to have an opportunity of examining the state of the bridge at the present time, and we think, looking at the extreme uncertainty of the weather, it might possibly be better that we should take the opportunity which the present fine weather affords us of going to inspect it at once, if that meets with the concurrence of the other counsel.

(Mr. Balfour.)—I may say that every possible facility will be afforded by the North British Railway Company for the conduct of this inquiry, and that every information in their power will be given.

(The Commissioner to Mr. Dunbar.)—In your opinion will that be the proper course to take?

(Mr. Dunbar.)—I think so, Sir.

(The Commissioner.)—It might, I think, shorten the
Mr. Charles Meik sworn.

1. You are an assistant, I believe, to Sir Thomas Bouch, Civil Engineer? —Yes.

2. As his assistant, I believe, you are personally in possession of the different plans of the Tay Bridge? —I have some of them.

3. These of them that you have, will you be good enough to give us, and the remainder that you have elsewhere will you be good enough to send to us? —Of course I cannot send any plans without Sir Thomas Bouch's permission.

4. You, have, I believe, amongst the plans a tracing of the bridge from end to end, will you kindly refer to it? —I am afraid I have left some of the tracings at the hotel. I was not aware that I was to attend here this morning.

5. (The Commissioner.) Perhaps Mr. Balfour will undertake to give in, on Sir Thomas Bouch's behalf, these plans?

6. (Mr. Balfour.) Certainly, they shall be handed in.

7. The Court adjourned to 2 o'clock.

Mr. C. Meik.

Examined by Mr. Trayner.

1. You are an assistant, I believe, to Sir Thomas Bouch, Civil Engineer? —Yes.

2. As his assistant, I believe, you are personally in possession of the different plans of the Tay Bridge? —I have some of them.

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5. (The Commissioner.) Perhaps Mr. Balfour will undertake to give in, on Sir Thomas Bouch's behalf, these plans?

6. (Mr. Balfour.) Certainly, they shall be handed in.

7. The Court adjourned to 2 o'clock.

Upon reassembling —

5. (Mr. Trayner to the witness.) Have you got now the tracing I asked for before the Court adjourned? —I have got now all the plans.

6. Will you be kind enough to put them all in? —Yes (handing in the same).

7. You have a tracing of the bridge, showing the number of piers and the number of spaces, have you not? —Yes.

8. Look at that, and tell me this; what is the length of the bridge, excluding the land arches? —As nearly as possible 3,450 yards.

9. In the course of that length, how many piers are there? —By the drawing it shows 86.

10. On the tracing which you have in your hand are all the piers numbered consecutively from No. 1 to the last number? —Yes, they are.

11. Just tell me, if you please, from which pier do the numbers reckon; is it from the south side to the north side? —Yes.

12. What is the number of the last pier from the south side, as the bridge now stands? —No. 28.

13. Is that where the break commenced; No. 28 is still standing entire? —Yes.

14. The piers are all more or less away from No. 28 to No. 41, are they not? —Yes.

15. No. 41 is the next standing pier? —Yes.

16. The base on which the cast-iron supports or piers are erected is in every case brick, which is uninjured? —Yes, so far as I have observed.

17. Have you noticed whether there are two or more which have the stone coping injured? —I cannot say the exact number.

18. Now with regard to the bridge itself, is it not level, is it, from end to end? —No.

19. Begin now at the north side, and tell me this; the incline rises from the north, does it not? —Yes.

20. Can you tell me now far from the north coast, or to what pier the incline goes? —From the north end?

21. Yes, rising from the north shore, to what pier does the incline extend? —Pier No. 36.

22. What is the incline from the north shore to the pier No. 36? —One in 73.56.

23. Then from there on wards is there any further incline, or is the bridge nearly level there? —There is a slight incline from No. 37 to No. 36, but it is very slight.

24. That is an incline 1 in 130, is it not? —Yes.

25. Then from No. 36 southwards to No. 29 it is level, I understand? —It is level from pier No. 36; then there is an incline to pier No. 29; it falls 1 in 490.

26. From No. 29 to No. 6, where the fall is, after you get to that point, what is the state of the bridge? —It falls 1 in 353. From pier No. 29 to pier No. 6 it falls 1 in 253.

27. From pier No. 6 to pier No. 3 it is level, I think? —It shows level.

28. From pier No. 3 on the shore to the south it rises gradually? —It rises from pier No. 3 to the abutment 1 in 100.

29. Have you given us the whole of the plans, the working plans and the other plans, for the erection of the bridge? —I have given you the plans which I brought from Edinburgh, which relate to the portion of the bridge in question.

30. Of the whole bridge? —I have not given you all the plans.

31. Will you let us have the other plans to supplement the whole act? —Yes.

32. Mr. Balfour stated that he had no questions to put to the witness.

(The Commissioner to Mr. Dunbar.) Have you no question to put? —Mr. Dunbar stated that he had not, and that he was simply instructed to watch the case on behalf of the Lord Advocate.

33. (Mr. Barlow.) Have you with you a drawing of the expansion joint? —There is a drawing here showing the rollers.

34. The mode in which the attachment is made? —The mode in which the plates are attached to the girders.

35. That will be put in, will it? —Yes.

The witness withdrew.

William Friend sworn.

Examined by Mr. Trayner.

35. You are a ticket collector in the service of the North British Railway Company? —Yes.

36. Where are you stationed? —At St. Fort.
would be coming by the Tay Bridge route?—Yes, only for Dundee.
39. Do you remember last Sunday night, when the Edinburgh train came up in the ordinary course, the train that was lost?—Yes.
40. Were you on duty at the ticket collecting box that night?—Yes.
41. I believe you collected part of the tickets of the passengers?—Yes.
42. Who else was there assisting you in collecting the tickets?—Mr. Morris, the station agent, and Alexander Ingles, the porter.
43. Did you notice what the train consisted of?—I could not say positively, but the two first carriages next to the engine were third-class carriages; the next was a first-class carriage; the next to that was a third-class carriage, and a second-class next to the break. I cannot say how many there were, whether there was one between them or not.
44. You have given us pretty accurately the marshalling of the train, namely, two third-class carriages behind the engine, behind them a first-class carriage, then a third-class, and then a second-class, and at last a guard’s van?—Yes.
45. At what time did the train reach St. Fort on Sunday night?—True to her time.
46. What was she due?—I believe about 7 or 7.10.
47. She was up to time?—Yes.
48. From what part of the train did you collect tickets?—The fore part; the part nearest to the engine.
49. Did you collect no tickets except from the two first carriages and the other third-class carriage?—Yes. I missed the first, and Alexander Ingles took the first-class carriage; he joined Morris at the third class next to the first.
50. How many tickets did you take up altogether?—
51. Yourself?—No, altogether.
52. In the carriages where you took the tickets, were the passengers mostly adults, or were there any children?—There was one man I noticed with three or four children, no more.
53. Would you notice that from the fact of their having half-tickets, would you not?—Yes, because one man had one little one in his arms and two or three sitting round him.
54. Those were the only children that you saw in the train, were they?—Yes.
55. Is it the case that he gave you half-tickets for some of those children?—There were half-tickets taken, and I believe they were from him.
56. What carriage was that man in who had the children with him?—In the second third-class carriage.
57. That would be the second one from the engine?—Yes.
58. In those other carriages where you collected tickets, did you see any other children besides the three or four that you have mentioned?—No.
59. The rest of the passengers, so far as you saw, were adults?—Yes.
60. Did you look into the first-class carriage at all?—No.
61. You cannot tell whether there was any one in it or not, from your own observation?—No.
62. Ingles, I believe, looked in that carriage?—Yes.
63. Were there any season ticket holders?—Two.
64. Were there any passengers from whom you got no tickets?—No.
65. Were there any other passengers that you came personally in contact with, who did not give up their tickets, but merely showed them?—There were five or six for Broughty Ferry.
66. They only exhibited their tickets at St. Fort, and did not deliver them up?—Yes.
67. Did I understand you to say that there were 56 people from whom tickets were actually collected besides the persons who held season tickets, and the five or six passengers who returned their tickets until they reached their journey’s end?—Yes; 56 were given at St. Fort.
68. That includes the two halves, which would make the total more than 56 persons?—The two halves would make one ticket.
69. So that there would be 57 persons from whom you took tickets?—Counting children?
70. Yes?—I suppose there would be.
71. Was there anything about the train itself that night which attracted your attention more than ordinarily?—No.
72. Did you see the driver of the engine?—No, I did not see the guard that night.
73. You would see the guard, would you not?—No, I did not see the guard that night.
74. Did you not see him on the platform when you were taking tickets?—No.
75. Was there anything about the train itself, and the way in which it was marshalled, or the music in which it approached your ticket-collecting box that was at all calculated to excite attention more than upon any other occasion?—No.
76. All about your collecting box was in, I suppose, its usual order?—Just the same.
77. It was, I suppose, as far as the line was concerned, in good order?—Yes.
Mr. Balfour stated that he had no question to ask the witness.
78. (The Commissioner.) You said that you collected 56 tickets?—Yes.
79. Amongst which there were two halves?—Yes.
80. And you saw five or six, I think you said, tickets of the passengers for Broughty Ferry in those carriages you yourself inspected?—Yes.
81. There might have been passengers for Broughty Ferry in the other carriages, I suppose?—Yes.
82. So far as you know, there were only five or six that you saw?—Yes.

The witness withdrew.

Alexander Ingles, sworn.

Examined by Mr. Trayner.

83. You are a porter at St. Fort?—Yes.
84. I believe you are in the habit of assisting in the collection of tickets when a train comes in there?—Yes.
85. You only collect tickets there of passengers going to Dundee?—Yes.
86. Passengers for Newport on the one side or Broughty Ferry on the other retain their tickets until they reach their destination, do they not?—Yes.
87. Do you remember Sunday night last the last Edinburgh train coming up?—Yes.
88. Do you remember at what o’clock it was?—It was just about eight.
89. You assisted in collecting the tickets on that occasion, did you?—Yes.
90. What carriages did you go to, to collect tickets?—The carriage next the van I commenced with.
91. What kind of carriage was that?—Second class.
92. What was the next carriage?—Third class.
93. Immediately next to the second class?—Yes.
94. Then you went to the first-class carriage?—Yes.
95. Was that where your collecting ceased?—Yes.
96. Did you take the tickets from all the passengers in the third-class carriage that you first went to?—No; I did not.
97. Were there some of them who did not give up their tickets?—Yes.
98. How many were there?—Four.
99. Where were they for?—Newport.
100. Then with the exception of those four passengers did you get tickets from all the others? —Yes.

101. And those tickets you handed to Friend, who was the ticket collector? —Yes.

102. Were they all adults from whom you took tickets? —Yes.

103. Were there any children? —There were no children that I observed.

104. Was there just one second-class carriage in the end part of the train which you took charge of? —Yes.

105. Were there any tickets taken by you in the second-class carriage? —Yes.

The witness withdrew.

ROBERT MORRIS SWORN.

111. You are station agent at St. Fort? —Yes.

112. How far is that from the south end of the bridge? —Two miles.

113. To the place at which tickets are collected from passengers going on to Dundee? —By the stopping trains, by the slow trains.

114. You did not take tickets for persons going to Newport or Broughty Ferry? —No.

115. You remember last Sunday night the train from Edinburgh to Dundee coming up, do you not? —Yes.

116. What o'clock was it? —Five or six minutes past 7 o'clock.

117. She was up to about her turn? —Yes, she was up to time.

118. What did that train consist of? —Did you notice the number of carriages? —Two third-class on the engine, and one first-class behind them, then a third-class, then a second, and the guard's van.

119. You assisted, I believe, in taking the tickets? —Yes.

120. And Friend and Ingles also assisted in it? —Yes.

121. What part of the train did you go to for tickets? —I collected three compartments of a third-class between the second-class carriage and the first-class carriage.

122. That was the first-class carriage towards the end of the train? —Yes.

123. Can you remember how many tickets you took there? —Yes, four.

124. Were there any persons in any of those compartments that only showed you a ticket, but did not give it up? —One for Newport.

125. They were all adults, there were no children? —No.

126. Having collected the tickets from those three compartments, did you go anywhere else? —No.

127. I suppose the tickets you collected in that way you handed over to Friend, whose business it is to keep them? —He handed them over to me that night, and I told them up.

128. Have you any list made up of the tickets? —Yes.

129. Just hand it up to me, if you please. (A list of the tickets collected was handed in.)

130. This shows the number of tickets of both second and third-class passengers, whether they are single or returns? —Yes.

131. This also shows the station at which the ticket was issued, and does it show the place to which it was destined? —They are all for Dundee.

132. In short you took nothing but Dundee tickets? —No.

133. What is the total number? —36.

134. There were two half-tickets, so that there would be 57 persons represented by the tickets and others that you had seen, or some one else had seen, who did not give up their tickets? —Yes.

135. Besides the passengers, were there any in the train, railway servants, who had no tickets? —Two.

136. What were they? —Two guards.

137. Do you mean two guards besides the guard of the train? —Yes, two guards who were not on duty and one the mail guard.

138. On the engine there would be the driver? —Yes, the driver and the fireman.

139. And, so far as you know, that represents every living person who was in the train at the time it left St. Fort? —Yes, except five or six who were going to Broughty Ferry.

140. The 56 passengers who gave up their tickets and the persons whom you saw, and that Ingles, one of the previous witnesses, saw, who did not give up their tickets, with the Company's servants, represents every one in the train? —Yes.

141. The train was up to her time? —Yes.

142. Was there anything about the train or its management, when it came into St. Fort, different from usual? —Nothing.

143. There was nothing, I suppose, different from usual when the train left St. Fort? —No.

144. Was there anything different in the permanent way there or near St. Fort, so far as you know? —Nothing.

145. And you had no reason to anticipate that there would be any differences with that train from any other train that had passed since the bridge was built? —No.

146. (The Commissioner.) This list which you have handed in was made up yesterday, was it? —Yes.

147. From what was it made up? —From the tickets.

148. Is this the form that you usually send in? —No, we only send in the tickets.

149. They being in your possession at the time? —Yes.

150. As I understand, there were 72 people, including the Company's servants; or 73 is it? —(Mr. Traymer.) Taking it at the most you may call it 72 persons.

TAY BRIDGE DISASTER.

THOMAS BARCLAY SWORN.

151. How old are you? —29.

152. You are a signalman in the employ of the North British Railway Company? —Yes.

153. Where is your station? —At Tay Bridge; at the south end.

154. That is what we will call the south end cabin? —Yes.

155. What were your duties there? —Signalman.

156. What does that infer? what had you to do as signalman? —Signalling on the train and block telegraph.

157. That is to say, for trains that were coming in; signalling that the line was clear in the opposite direction? —Yes.

158. How long have you been in the Company's employment? —Ever since I joined the railway. I have been in their service three years and eight months.
159. You have been at the south side cabin since the bridge was open, is that so?—Yes.
160. Have you been on duty every day?—No.
161. You were on duty, I believe, on Sunday last, the 28th of December ?—Yes.
162. When did you go on duty that morning?—I was on duty all night on Saturday night till 7 o'clock in the morning. I was on duty on Saturday night, and I went up and down to pass the Sunday trains.
163. Was it your duty on Sunday, the 28th, to pass the trains from Dundee and from St. Fort respectively in the afternoon and evening?—Yes.
164. Was it your duty, in particular, to pass the train that was coming up from Edinburgh that day to St. Fort, at a few minutes past 7?—Yes.
165. I suppose you were in your cabin attending to your duty at the time the train was expected to arrive, were you, before she came up?
166. Can you tell me at what time in the night it was that you got the signal that the train was up?—It was 8 minutes past 7 when I got the signal.
167. It would be 8 minutes past 7 when the signal was sent on to you at St. Fort that it had arrived?—Yes, at 8 minutes past 7.
168. And that was the signal that it had started?—No, that was when it had started; when it left St. Fort; at 8 minutes past 7.
169. When did it pass your cabin?—7.13.
170. At what rate was the train going, according to your judgment, when it passed your cabin?—About three or four miles an hour.
171. Which I suppose, was the usual pace?—Yes, about the usual pace; about three miles.
172. Have you any copy of the regulations with regard to the speed of the trains on the bridge?—I have not with me.
173. Just look at that; is that a copy of the regulations relating to the bridge (the same being handed to the officers)?—That is a copy of the regulations relating to the rate of speed.
174. The speed that night, when this particular train went past, was as usual?—Yes.
175. There was nothing, so far as the speed was concerned, to attract your attention?—Nothing.
176. Were you alone in the cabin then?—No.
177. Who was with you?—John Watt, the foreman surface man.
178. Had he gone with you to the cabin that night?—He came up along with me.
179. From where?—Our dwelling-houses at the side of the bridge, at the end.
180. Was there any particular reason for Watt accompanying you that night?—None; he had been in the custom of coming up before.
181. When the train came to your cabin, I suppose you went out to it?—Yes.
182. You had to give the driver of it, I believe, the token so his warrant for going on?—The train staff, as we call it.
183. Did you carry the train staff as usual?—Yes.
184. And hand it to the stoker?—Yes.
185. Was there anything, either in the Company's servants or in the state of the train, to attract your attention to the condition of the train more than usual?—No.
186. Everything was as usual; as far as you could see.
187. When the train passed your cabin, I suppose your duty was to telegraph it to the north side?—Yes.
188. Did you do so?—Yes.
189. Was that done by a speaking instrument, or is it simply a signal?—A signal, a bell signal.
190. After the train had passed, you rang the signal bell to the north side to indicate that that train had passed your cabin?—Yes.
191. Before that time, I suppose, the line was clear?—Yes.
192. Before you signalled the train on?—Yes.
193. Did you send out any other message except to the north?—I gave the line "clear" to the station in the rear, at Wormit.
194. So that when this particular train passed your cabin you signalled on to the cabin ahead that the train was coming?—That it had entered the bridge.
195. And you signalled to the next station to yours southwards that the line was clear?—Yes.
196. And that station at Wormit?—Yes.
197. You have a book, I suppose, in which you enter the times at which you make the signals?—Yes, and from the train.
198. Have you that book with you?—Yes.
199. Will you just turn to it and tell me, in order to verify the hour, the time at which the train got on the line, the time at which it was signalled to you, the time at which it passed, and the time at which you signalled it on "clear." When did you get the signal that the train was on the line?—Eight minutes past 7.
200. And it passed your cabin at what time?—7.13.
201. And you immediately, I suppose, made the signals you have mentioned?—As soon as the train was wholly passed.
202. And these entries were made that night at the time?—Yes.
203. So that I may take it that these entries are exactly accurate?—Yes.
204. After you had made the entries in your book what occupied your attention next; had you to wait for any other train that night?—Yes.
205. After you had passed the train on to the bridge what were you doing?—I went and cleaned up my stove in the cabin, and prepared it to put on fresh fire.
206. You stirred it up and began to make up the fire?—Yes, and raked out the ashes after I had made my book and shut my points; that is, the points to let the train come on.
207. Then did anything happen to call your attention to something unusual?—This man Watt was standing looking at the cabin door; the door was shut, but Watt was looking watching the train across the bridge, and after I had done all that I have said, and just when I came up from the fire, he said that there was something wrong with the train, he was sure, that he had seen a great flash of fire and the tail lamps disappeared.
208. Was Watt put about at all; did he tell you with any degree of excitement?—No; he was not excited, but I did not believe him.
209. You were under a different impression?—I thought the train would be going down the incline towards the north side, and I said that to him at the same time.
210. Did you look out to see whether the tail lamps came into view again?—It was my impression that she was down the incline, and I said we would watch and see her rounding the curve going into Dundee.
211. Did you wait?—I waited a few seconds and then opened the door and went down for some coal and brought them up.
212. How long was it after Watt had said that he was afraid something was wrong, and the tail lights had disappeared before you did anything in consequence of the disappearance of the tail lights?—About two minutes and a half or three minutes.
213. The tail lights never appeared again?—No.
214. Not having seen them at the curve as you expected, what did you do?—I tried my signal. I tried to ring him to see whether he would answer me.
215. The signalman at the north cabin you mean?—Yes; I tried that and I got no answer.
216. Had you any other connection with the north cabin except the one you have spoken of?—I had two speaking instruments.
217. Did you try both of them?—Yes.
218. With what result?—I saw that the communication was cut; they were all disconnected.
219. You then, I suppose, suspected that something had gone wrong?—Yes.
220. What did you do then in order to ascertain whether your suspicions were right?—We were struck for a moment, but soon after we collected ourselves, and we went outside and tried to get along the bridge a little bit, but it was that rough that we retraced our steps back along the Northport line and got down on to the shore.
221. You went from your cabin on towards the west shore?—Towards the north end, but not far.
222. How far were you and Watt able to get?—20 or 30 yards.
223. You turned back to the Tayport part which branches off to the east?—Yes.
224. Is your cabin there?—Yes.
225. Before you did that, you say you turned back; why did you not go on, on the northward journey?—The wind was very strong, and we thought we should get a better view coming back from the shore, and come back on the water.
226. Had the wind been unusually boisterous that night?—It was very rough, but it never struck me that there would be anything wrong with the bridge.
227. Did anything go wrong with the cabin?—Nothing.
228. I suppose the cabin is a good deal sheltered by that point which juts out from Pitferry to the west of your cabin above on the rising ground?—It is a little sheltered, but then it is elevated by the bridge.
229. Nothing happened to your cabin at all that night?—Nothing at all.
230. Do not let me misunderstand you: you were sure that something had gone wrong with the bridge after the communication had become disconnected?—Yes.
231. I suppose you were anxious to find out whether that suspicion was well founded?—Yes.
232. And it was with the view of testing it that you went along the bridge so far?—Yes.
233. Is the night that you and Watt turned back from pursuing a northward course because you could not pursue it further in consequence of the wind?—We Might not have been able if we had persisted; we thought it best to go back.
234. Do you think you could have pressed forward on towards the north side if you had persisted?—We might have persisted, but we had a good bit to come up from the cabin to walk on the bridge.
235. In that distance you had experienced the extreme boisterousness of the wind, I suppose?—Yes, it was so.
236. Was it making much noise; was it whistling and howling?—Yes, it was whistling.
237. Did you hear any noise that night like the bridge breaking or the train going over into the water?—We heard nothing but the wind.
238. It must have been pretty loud that night to prevent you hearing the crash that must have accompanied the fall of the train?—Yes, the wind was blowing away from us.
239. You turned back on to the Tayport line with the view of getting a better view of the bridge?—Yes, back of it?—Yes, along the upper side.
240. How far along the Tayport line did you go from your cabin?—Only to the end of the bridge, and went down on to the shore.
241. On to that boarding that is there, do you mean?—No, just on to the ground.
242. Could you see whether the bridge was entire, or had been broken?—Not at first.
243. When you got down it was pretty dark?—Yes, it was dark; the moon was setting about.
244. Did you remain there sometime before you saw what had happened?—We went backwards and forwards to each side, east and west of the bridge, to see if we could discover anything.
245. Did you try and see if you could discover something?—Yes.
246. From which side of the bridge did you see anything first?—The east side.
247. The moon had come out, and you had a better view, I suppose?—Yes.
248. And then you saw that the bridge had given way?—Yes.
249. When you found that out, what did you do?—We were not sure whether the train had arrived at Dundee; that was the next thing.
250. Seeing that something had happened, of a serious kind to the bridge what did you arrange to do?—One Nicholl, and I arranged to go and see if we could get tidings at Newport.
251. You went to Newport?—Yes.
252. Did you see the agent there?—No, not at Newport.
253. Where is Tayport?—After we learnt at Newport that the train had not arrived, we went on to Tayport.
254. You saw the agent there and communicated to him what you had seen?—Yes.
255. You had heard at Newport that the train had not arrived?—Yes.
256. Did you notice what number of carriages there were in the train, or not pay any particular heed to that?—I did not pay any particular attention to that.

Examined by Mr. Balfour.

257. The wind was blowing from the south-west that night, was it not?—Yes, I think so.
258. That is partly down the river and partly from south to north?—Yes.
259. A south-west wind?—Yes.
260. Before you allowed the train to pass your cabin you telegraphed to the north end to know if it was clear?—Yes.
261. You knew that the weather was clear?—Yes.
262. Did you let me understand you had been at the cabin for a considerable time, how long?—I have been at the cabin ever since there was one, since the bridge was opened.

Mr. Balfour.) Which was on the 1st June 1878.

(T. Commissioner.) That would be about a year and a half.

263. (To the witness.) Have you observed the bridge at all in a high gale during that time?—I have seen the bridge in a pretty severe gale.
264. Have you crossed the bridge in a very high gale?—No.
265. Neither on foot nor in a train?—No.
266. Have you ever observed whether or not in a high gale the bridge seemed to oscillate from side to side?—No.
267. Have you ever had any opportunity of seeing that?—No.
268. You were always in your cabin?—Yes.
269. (Colonel Yolland.) Will you refer to your book and name the time when you telegraphed the train on the line to the north side—9 minutes past 7.
270. You telegraphed it on to the north side of the bridge at 9 minutes past 7?—Yes.
271. Was that signal acknowledged?—Yes.
272. What by, one beat of the bell?—First one beat, and then two, and then one.
273. Did you receive any other signal from the north side of the bridge after that?—Yes.
274. At what time?—At 13 minutes past 7.
275. What was that for?—A passing bell acknowledging that the train had entered on the bridge.
276. That was the last signal you received?—Yes.
277. At 13 minutes past 7?—Yes.

(Mr. Barlow.) I understood you to say that the speed of the train when passing you was three miles an hour?—Yes.
280. Are you aware that the regulations state that the speed across the bridge of a train is 25 miles an hour?—Yes.
...Is it the usual to pass over the bridge at a speed of 25 or three miles?—25 miles over the bridge and three miles passing the cabin.

(Mr. Balfour.) The Court will notice that the witness declares that the bell had rung, and then the train stops to get the staff or biton.

(Thomas Commissioner.) I suppose without actually stopping, the biton is handed to the proper person?—Yes; at three miles an hour he gets it.

When the train is on the bridge the usual pace?—Yes.

(Mr. Barlow.) Did you notice the passage of the previous train?—No.

You were not there?—Yes, I was.

Did you not have to signal the previous up-train?—Yes.

At what time did it pass your cabin?—4.18.

Had there been nothing to pass the bridge between 4.18 and the time that this train passed it?—Yes.

What train was that?—The 5.30 from Tayport, at 8 minutes past 6.

That was the last train which preceded this?—Yes.

Did you hear any observation made by the driver or the guard that day with regard to anything peculiar in passing the bridge?—No.

(Colonel Yolland.) Did you notice any increase in the speed after the train had passed you at from three to four miles an hour?—I did not observe her after she was passed. I did not look after her again.

(The Commissioner.) As a general rule it would increase its speed after taking the biton?—Yes.

But you did not see it?—No, I went to attend to my duties.

The witness withdrew.

Examined by Mr. Trayner.

295. You are a surface man in the employment of the North British Railway Company?—Yes.

296. How long have you been in the Company’s service?—12 years.

297. During the whole of that period have you been chiefly employed in this Dundee district?—No, I was for five years on the line between Ladybank and Perth.

298. For some time back you have been employed in the Dundee district?—Yes.

299. As a surface man had you anything to do with the Tay Bridge, or did your duties lie on the other side?—My duties lie on the south side.

300. It was no part of your duty to look after the bridge?—I examine the points on the bridge.

301. And the points at the other side?—Yes.

302. Do you remember last Sunday night going with the last witness into his cabin in the evening?—Yes.

303. At what time did you go there; do you remember?—I could not exactly say.

304. You cannot say when you were there?—No.

305. So far as your memory will carry back, how long were you there before this train came up and passed the cabin?—About 10 minutes or so.

306. You know that the last witness had gone up to his cabin to attend to his duty in signalling on the train; in passing the train?—Yes.

307. Did you go with him for any particular reason that night?—No.

308. You had done so frequently before, had you?—Yes.

309. When you got into his cabin, I suppose you were aware of the signal that had come up from St. Forth that the train was coming on?—Yes.

310. At what time did the train pass the cabin?—At 7.13 I think it passed.

311. You had no duty there; you were there just as a friend of Barclay’s?—Just so.

312. The train slowed in passing the cabin to get the railway staff?—Yes.

313. Did you see it handed out?—Yes.

314. Was there anything you heard said, or was there any observation made by the driver, or by the guard, or by anybody else in the train at the time they were passing?—No.

315. Did you look after the train after it had passed the cabin?—Yes.

316. Had you any particular reason for doing that?—Merely for curiosity, I suppose.

317. There was nothing at that time in your mind that induced you to look after the train?—No.

318. But you saw her pass on a certain distance?—Yes.

And while Barclay was attending to his other duties you saw something that startled you for the time?—Yes.

320. What was it?—I saw fire from the train.

321. Was that while she was still running along the permanent way?—Yes.

322. Where was the fire coming from?—It appeared to be coming from the wheels.

323. It was rathen in the shape of a shower of continuous sparks than a flame?—It was sparks of fire.

324. Were there many sparks?—Yes.

325. It attracted your attention, I suppose, and fixed your attention on the retiring train?—Yes.

326. Was that a thing that you had never seen before?—I never saw it before except the brake-cars were on; whether the brakes were on the wheels or not, I do not know.

327. Except when the brakes were on it was a thing you had never had any experience of before?—Never.

328. How far would the train be from you when you saw these sparks; how far had she passed the cabin?—Not exceeding 200 yards.

329. That was when you first saw the sparks?—Yes.

330. How long did you continue to see the sparks?—As far as the train went.

331. It comes to this, that from the time that she had passed the cabin, a distance of 200 yards, until the time she entirely disappeared from your view, you saw these continuous sparks coming from what you thought were the wheels?—Yes.

332. How long after your attention was first directed to the sparks was it before the train disappeared from your sight?—It would not have been more than three minutes, say.

333. What distance do you suppose the train had reached from the south cabin when it disappeared?—About three-quarters of a mile.

334. Had the train by that time got on to that part of the bridge which spanned the navigable channel?—Yes.

335. It had come upon the high arches which were left for the purpose of navigation?—Yes.

336. Did it disappear from your sight suddenly?—Yes, the tail lamps of the train disappeared just in a moment.

337. Up to that time you had had them fully in view?—Up to that time I had had them fully in view the whole way.

338. And they went out all at once?—Yes.

339. Both the tail lamps together?—The whole three.

340. Was there anything else to attract your attention except the sparks which you have told us about, and the sudden disappearance of the tail lamps?—Yes.

341. What was it?—There were great flashes of

JOHN WATT sworn.

342. How near would the train be from you when you saw these sparks; how far had she passed the cabin?—Not exceeding 200 yards.

343. That was when you first saw the sparks?—Yes.

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TAY BRIDGE DISASTER:

fire before the tail lamps went out, greater flashes than those I had seen previously.

342. Do you mean that there were intermittent flashes of light different from the spark stream that you had been observing?—Yes; a flash of light.

343. One flash?—One great flash of light. Was that great flash of light disappeared?—Yes.

344. Immediately afterwards?—Immediately afterwards; they all disappeared at one time, the tail lamps and the fire.

345. You say that the train had got about three-quarters of a mile from you on the bridge by that time?—Yes.

346. Having seen these things, what did you do; did you say anything to Barclay?—Yes, I said there must be something wrong with the train. I thought she was over the bridge.

347. What led you to think and say that you thought the train had gone over the bridge?—It was the peculiar fire, and the tail lamps disappearing so quick.

348. Barclay thought that the fire and the tail lamps disappearing so quickly was due to the train having gone on to the incline?—Yes, he did.

349. But that explanation did not satisfy you, I suppose?—No, it did not.

350. Did you do anything along with Barclay afterwards to ascertain whether anything had gone wrong?—Yes.

351. In the first place, what did Barclay do after you told him this; what did he do in order to ascertain whether things were right or not?—He stood and looked for a few seconds, then he tried the instruments again.

352. He expected to see the tail lights reappear at the train got round the curve, I believe?—Yes, he watched it.

353. ‘As the train did not come into view, he tried his instruments to see whether he could communicate with the north cabin?—Yes.

354. I believe he tried them all, and found that none of them would work?—Yes, he tried all three.

355. You were there, and you are aware of that fact?—Yes.

356. That taught you there was something wrong with the bridge?—Yes.

357. Did you and Barclay do anything then with the view of ascertaining what had actually occurred?—Yes.

358. What did you do?—We tried to walk out on the bridge to see whether the train had gone over.

359. How far did you go along the bridge afterwards?—I could not exactly say; we did not walk far.

360. Why did you not walk any further?—It was that stormy that I could not walk.

361. You deemed it not very safe to go further along the bridge in the state of the weather?—Yes.

362. Was it blowing very rough?—Yes, it was blowing very heavy at that time.

363. You had you ever before experienced the same or anything like the same heavy weather at the Tay Bridge?—No.

364. It blow a pretty high in the Tay sometimes?—Yes, but never so high as on that night that ever I experienced.

365. You turned back simply on account of it not being prudent or safe to go any further?—Yes.

366. Did you turn on the Newpost line?—Yes; we went down that way to see if we could see anything of the bridge from the cassehole.

367. You saw nothing when you got there?—No; at first the moon was clouded.

368. And you went back from east to west backwards, and forwards to see if you could discover anything wrong with the bridge, and if so what it was?—Yes.

369. And did you ultimately get a view of the bridge?—Yes, we got a view to ascertain that there was part of it gone.

370. How long was it after the train had passed, as near as you could recollect, when you were able to ascertain that something had gone wrong with the bridge?—I could not exactly say, about 8 o’clock I should say.

371. As near as you can remember it would be about 8 o’clock?—Yes.

372. And you saw then that a great part of the bridge had disappeared?—Yes.

373. Had you any idea before that time that the bridge was gone; you said a little time ago that you said to Barclay, that the train had gone over the bridge, but you any idea that the bridge had gone with the train?—No, I had no idea of that.

374. What did you think had happened to the train?—I thought that the train had been blown off the rails.

375. That it had taken the sole of the bridge with it and had gone over?—Yes.

376. But you did not expect to find that the whole structure had been carried away?—No, I never expected that.

377. When you found that there was a great part of the bridge gone, what did you do?—I went away to St. Fort to give Mr. Morris the information.

378. He is the station master there?—Yes.

379. You were watching the train as it retired, and you kept your eye upon it until it entirely disappeared; at the moment of its disappearance did you hear any noise?—No.

380. Any crushing of the bridge or crushing of the carriages or anything else?—No, nothing but the bowing of the wind.

381. Did you hear any splash in the water when the carriages reached it?—No.

382. The wind was too high to enable you to hear anything but itself?—Yes.

383. When you got to St. Fort did you see Mr. Morris?—No.

384. Did you see there?—I only saw Mrs. Morris: she told me that Mr. Morris was away.

385. Did you give the information to anyone else?—I went on to Leuchars.

386. Did you see there the station master?—Yes.

387. You told him that the bridge was down?—Yes.

388. In order that he might telegraph it to Edinburgh?—Yes.

389. You said that the wind was so high that you could not prosecute your journey on the bridge with any safety that night; had you felt the wind very much when you were in Barclay’s cabin?—Yes; it was blowing very hard against the cabin.

390. Did anything happen to the cabin while you were there in consequence of the wind?—No.

391. Is it more exposed or less exposed to a south-west wind than the centre of the bridge?—The centre of the bridge is more exposed than that.

392. The rising ground and projecting point a little to the west of Barclay’s cabin would yield some protection from a south-west wind?—Yes, I daresay it would.

393. While you were in the cabin there was nothing to indicate to you that it was at all unsafe from the wind?—No.

394. Was it shaking?—Yes, it was shaking, not much, just a sort of shaking like when the great gusts of wind came.

395. Was it a serious vibration that went through the cabin?—No.

396. You were sitting in Barclay’s cabin for some time, I understand, before this train passed?—Only about 10 minutes or so.

397. Was the wind coming down with continuous violence, or was it coming in gusts?—It was coming in gusts.

398. You did not notice sufficiently at what intervals?—No.

399. Were they coming frequently?—Yes.

400. Between each gust was there a perceptible lull?—Yes.
402. Did you connect the wind with the disappearance of the train at all, at the time that it did disappear?—Yes.

403. You thought that it had been blown over?—Yes.

404. What did you consider, if you thought of it at all, to be the cause of the sparks and the great flash that you saw, before the train disappeared?—It appeared to me the same as if the carriages were skirting alongside of the girders.

405. The friction producing the fire?—Yes.

406. On what side of the train, east or west, was it upon which you saw the flash and saw the sparks?—The east side.

407. (The Commissioner.) You said that those sparks appeared to you at first when you saw them to be as if the brakes had been applied?—Yes, it appeared to be that.

408. If the brakes were applied would you not see the sparks come from the wheels on both sides?—Yes.

409. Did you see them from both sides?—No.

410. How did you know at that distance that it was from the east side that you saw the sparks; could you see the train distinctly?—Yes, I saw the tail lamps of the train; I saw that it was the east side of the train.

411. You saw the lamps distinctly?—Yes.

412. It was to the east of the lamps, was it?—Yes, it was from the east wheels of the train that the fire came from first.

413. It came first from the wheels, did it?—Yes.

414. How long did that continue?—It continued as far as I saw the train.

415. It began, you say, when the train had passed the cabin about 200 yards?—Yes.

416. Do you know the distance between the cabin and the place where the bridge gave way?—Yes.

417. What's the distance, how many yards?—Nine hundred yards.

418. You saw these sparks only on one side of the train, and at the wheels?—Yes.

419. For how long was it after you had seen those sparks on the wheels that you saw the sparks only on the wheels and not the great flame or flash?—As nearly as I could calculate it was three minutes.

420. That you saw the sparks only?—Yes.

421. And then you saw a great flash?—Yes.

422. Was that immediately before it disappeared?—Just before it disappeared.

423. All that I understand you to say is this: you saw on the east side, or the right-hand side of the train, sparks, and then just as it disappeared you saw a flash?—Yes.

424. (Colonel Yolland.) Have you ever noticed by night a train travelling fast round a sharp curve?—Yes.

425. And on those occasions when it has been dark have you seen sparks coming from the wheels?—No.

426. Never?—No, never.

427. Did you make up your mind at the time whether these sparks were caused by the wheels coming in contact with the rail or with the check rail, or what opinion did you form at the time as to the cause of the sparks?—I formed the opinion that with the wind blowing towards the east side the wheel was hard upon the rail causing the fire.

428. I am speaking of the time when you saw it 200 yards off, did you form any idea of what caused the sparks at that time?—The wind pressing the train on to the east side.

429. Pressing the wheels against the rails on the east side?—I formed that opinion.

430. (Mr. Barlow.) Have you ever seen sparks produced by a brake?—Yes.

431. Do you think that you could see them for half a mile?—Yes.

432. Did you ever see the light produced by a broken spring when the carriage body comes down upon the top of the wheel?—Yes.

433. Is that a brighter light?—Yes, I never saw but one, that was a flame altogether.

434. It soon became a flame, did it?—Yes.

435. Was the position of this light that you saw at the level of the rails or at the top of the wheel where the carriage body would be?—On a level with the rails.

436. (Mr. Trauner.) I want to understand this you say that the train had gone on about 900 yards, when you saw the great flash, about three-quarters of a mile from you?—Yes.

437. And then it disappeared altogether?—Yes.

438. What I want to know is this, after the flash died out, did you see for an instant the red lights?—No.

439. Then the red lights would be extinguished, I suppose, by the bright flash, or did you see the red lights and the flash together?—My eyes were taken off the red lights on to the flash, and I never saw them again.

440. When the flash went out everything was dark, there was no red light or anything?—No.

441. I understood you to say, though I do not know whether it is down, that this flash was seen while the train was still on the level of the permanent way?—Yes.

442. Did you see, or were you able to tell, whether that flash had been occasioned by the train going off the line or over the side of the bridge at all?—I said it was the train skirting the side of the girders.

443. You thought it produced a flame in that way?—Yes.

444. Could that flash which you saw have been mistaken for the opening up of the engine for the purpose of supplying it with more fuel?—No.

445. You think it was a flame produced by the friction of the carriages against the side of the bridge?—Yes.

446. And you thought so then?—Yes.

447. (The Commissioner.) You thought so then, did you?—Yes.

448. That the flame or the flash was produced by the friction of the carriages against the side of the bridge?—Yes.

449. Did that flash last long?—No, it did not last long.

450. Only an instant?—Only just an instant.

The witness withdrew.

EXAMINED BY MR. TRAUNER.

Henry Somerville, Esq.,

451. You are a signalman in the service of the North British Railway Company?—Yes.

452. Stationed at the north end of the Tay Bridge?—Yes.

453. How long have you been stationed there?—A few months.

454. Have you been in the Company's service before?—Yes.

455. Where?—At Letchars.

456. As signalman?—Yes.

457. And you are, I suppose, well accustomed to the signals used on the North British system for the advance of trains to clear them to the other stations?—Yes.

458. Were you on duty on Sunday last, the 28th of December?—Yes.

459. When did you go on duty, in the morning?—On Saturday night.

460. On Sunday morning when were you first on duty?—9 o'clock.

461. Up to half-past 10?—Yes.

462. And then from quarter to 1 till half-past 2?—Yes.
I do not mean that the train had reached the south cabin—No.

502. And from 4 till 20 minutes to 11?—Yes.

499. Did you get a signal from south cabin?—Yes.

498. And you saw it—That they had got the train on.

497. When was it due at the south cabin?—7.11.

496. What time would it take to cross?—Five minutes is the booked time.

495. Therefore it was due at the north cabin at 7.16?—Yes.

494. Did you get a signal from south cabin?—Yes.

493. And you saw it—That they had got the train on.

492. That the train was on?—Yes.

491. What did that mean?—That the train was put on to the block telegraph instrument.

490. It did not mean that the train had reached the south cabin?—No.

503. When did you get that message that the train was on?—7.9.

502. You have your book with you?—Yes.

501. And it indicates that you got that message that the train was on at 9 minutes past 7?—Yes.

500. You made the entry at once?—Yes.

501. You always do?—Yes.

502. You enter the messages that you receive and the time at which you receive them, and the messages that you despatch and the time at which you despatch them?—Yes.

503. The message that you got at 7.9, I suppose, informed you that the train had reached St. Port, the last stopping place before it came on to the bridge?—Yes.

504. The purpose, I suppose, of that was to take care that the line up to your point was clear?—Yes.

505. Having got that message, when did you get the next?—The passing bell intimating that the train was on the bridge at 7.14.

506. That intimated to you that the train had entered upon the bridge and passed the south cabin?—Yes.

507. Did you reply to that?—Yes.

508. Then, I presume, you expected the train up within five minutes?—Yes.

509. How long did you wait for the coming train before you began to wonder at its non-appearance?—Nine minutes.

510. That was four minutes past its time?—Yes.

511. What did you do then?—I went to the top of the stairs.

512. That is the stair close to your cabin?—Yes.

513. To look out along the bridge to see whether you could see anything of it?—Yes.

514. At that time how was the wind?—Blowing very strong.

515. Had you observed that before?—No.

516. How far would it be before you went out?—5 minutes.

517. How far would it be before you went out?—5 minutes.

518. What did you do then?—I went to the north cabin.

519. The purpose, I suppose, of that was. to look out along the line you did not see them?—No.

520. Did you see the signal?—No.

521. Did it strike you as being something curious not to see the signal light?—Yes, I knew it was out.

522. How far is that from your box?—Twelve hundred yards.

523. You would have seen the train's lights at that distance if it had been on the line, I suppose?—Yes.

524. Therefore looking along the line you did not see them?—No.

525. Did you see the signal?—No.

526. Did it strike you as being something curious not to see the signal light?—Yes, I knew it was out.

527. How far could you see?—I could not see very far, about to the distance signal perhaps.

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563. How far is that from your box?—Twelve hundred yards.

564. You would have seen the train's lights at that distance if it had been on the line, I suppose?—Yes.

565. Therefore looking along the line you did not see them?—No.
542. (Mr. Trayner.) Yes. (To the witness.) You did not see the train? Had you heard any noise of the crash of the bridge giving way, or the train going over into the water before that time?—No.

543. You account for hearing none of these things, I suppose, which must certainly have happened with a considerable noise, by the violence of the wind which prevented you hearing anything?—Yes.

544. When you had looked for the coming train, and could see nothing of it, what was it you did?—I tried the speaking instrument.

545. That was to communicate with the cabin on the south side?—Yes.

546. What was the result?—I found that the communication was broken down.

547. The communication was disconnected?—Yes.

548. Did you try any other than the speaking instrument; did you try the bell?—Yes.

549. And you found that that would not work either?—Yes.

550. When you found that the communication was broken down what did you do?—I went out to the top of the stair again.

551. This would make you very anxious, I suppose?—Yes.

552. You knew that something very serious had happened; and there being no appearance of the train, and the communication being disconnected, you went out again to see if you could see the train?—Yes.

553. And you saw nothing?—Yes.

554. Two gentlemen on the esplanade spoke to you?—Yes.

555. They informed you that the bridge was down?—Yes.

556. Who were these gentlemen?—I do not know their names.

557. Would you know them if you heard them?—No.

558. Having got this information that the bridge was down, and knowing certainly that the train had not come up to time, and that the communication was broken, did you go to communicate with any of your superior officers?—Yes.

559. To whom did you go?—Mr. Roberts.

560. What is he?—The locomotive superintendent.

561. You found him, I suppose, at the station?—I found him at the engine shed.

562. Having told him how matters stood, you returned to your signal box?—Yes.

563. How long did you remain there?—Till 10.40.

564. Then you were entitled to be relieved, and were you relieved?—Yes.

565. I think you said that it never blew so hard in your recollection as it did on that night?—No.

566. Has it been blowing there more than once so as to make your cabin shake?—To give it a slight shake.

567. Have you ever felt the bridge oscillating from stress of weather?—No.

568. Your cabin is scarcely on the bridge proper?—No.

569. It is on what may be called one of the land arches?—Yes.

570. Will you explain to me about this stair that you mounted, is your cabin on a level with the permanent way?—Yes.

571. That from the north side, the level rises till it reaches the arches which are raised for the navigation?—Yes.

572. What stair was it?—The stair to go up; the box has two stories.

573. Is it a signal box of two stories?—Yes.

574. This stair is from the lower part to the upper?—Yes.

575. And it raises you how much above the level of the line to look out; how high was the stair that you went up? was it 10 or 15 feet?—About 10 or 15 feet.

576. It was, I suppose, a position from which on an ordinary clear night you could have seen a very long way across the bridge?—Yes.

577. Could you have seen on an ordinary night the signals at the south cabin from that stair head?—Yes.

578. But I understand you to say, that on this occasion you could not see anything further than the signals at 1,200 yards distance?—Yes.

579. You saw that light at that distance, but could you see any of its surroundings?—No.

580. I suppose if the light had not been there you would have seen a very much shorter distance indeed from your stair?—Yes.

581. How far do you think you could see any other object than a light that night from your stair head?—About 50 yards.

582. (The Commissioneer.) This distance signal light, is, as I understand, upon the portion of the bridge which is still standing?—Yes.

583. But you said that the signal light went out at some time or other, when was it that it went out?—I did not say that it blew out.

584. It was alright when you went out to look for the train the first time?—Yes.

585. Was it alright when you went the second time to look for it?—Yes.

586. Do you know when it was that you first saw that it was out?—No.

587. Was it some time afterwards when you saw that it was out?—I did not see it out at all.

588. It was always alright when you saw it?—Yes.

589. Is it an oil light or gas?—Paraffin oil.

590. (Mr. Harlow.) From your box could you on a clear day see a train coming through those high girders?—Yes.

591. Were you looking out for the train that night?—Yes, at 7.25.

592. You were looking out for it at its proper time for coming?—At 7.25.

593. Did you see anything of this flash of fire that has been spoken of?—No.

594. (The Commissioner.) It was 7.25 when you were looking for the train?—Yes.

595. That was when you had failed to see it arrive you then looked for it, you were not looking out for it at the time that it would be passing through the girders?—No.

596. (Mr. Balfour.) It was telegraphed on at 7.14?—Yes.

597. (Mr. Trayner.) You looked for it at 7.25, because it was ten minutes behind its time?—Yes.

598. (The Commissioner.) Can you tell us what direction the wind was that night?—(Mr. Trayner.) I am going to prove that from a better class of witnesses; by men who were observing, not only the kind of wind, but the direction of it.

The witness withdrew.

Adjourned to Monday next at 10 o'clock.
Further examined by Mr. Trayner.

598. Had you since your last examination, believe, searched for the remaining plans of the bridge which you had not before ?—I have.

599. You have them now, have you ?—I have brought all I can find.

600. All the plans in Sir Thomas Bouch's possession relative to this bridge which have not already been produced so far as they can be found you now produce ?—Yes (producing the same).

(Mr. Harlove.) Upon the sectional drawing which you put in on Saturday I observe, first of all, a black line which seems to represent the bed of the river as it used to be; but I observe, independently of that, some pencil lines and some dotted lines and some lines in red ink, all apparently relating to the bed of the river. Will you be good enough to state or mark on this plan what those several lines mean, whether or not they represent any scouring which afterwards took place in the bed of the river, or will you state what they actually do mean. I will hand the drawing back to enable you to put that extra information upon it.

The witness withdrew.

Examined by Mr. Trayner.

601. You are station-master at the West Station at Dundee ?—Yes ; Tay Bridge Station.

602. How long have you been in the service of the North British Railway Company ?—25 years.

603. Prior to your being required at the Tay Bridge Station, you held office in Burtnessland ?—Yes ; Burtnessland and Polmont.

604. As station-master at each place ?—Yes.

605. Does it form part of your duty as station-master at Dundee to be present at the station on Sunday at any time ?—Yes.

606. On Sunday, the 28th December, I believe you were at the station ?—I was.

607. At what time were you there ; in the afternoon or the evening ?—About half-past 6.

608. Was it your ordinary duty that called you there at that time ?—No.

609. What was it that took you to the station at that time on Sunday, the 28th of December ?—It was in consequence of the locomotive foreman coming to my house and telling me that it was blowing a terrible gale outside; so much so that it was driving loaded wagons from the back of the viaduct at this end of the bridge along to the middle of the goods yard.

610. In short, you were called for in consequence of the exceptional character of the weather that night ?—I was.

611. When you went to the station did you find the facts to be as your locomotive foreman had represented ?—I did.

612. The wagons had been displaced and had been driven by the violence of the storm, the loaded wagons particularly ?—Yes.

613. Will you please tell me what distance they had been driven ?—I should say from 300 to 400 yards.

614. What did those wagons each contain in weight ?—They were loaded with coals, and I think they would average with the wagons and coals together about 10 tons each.

615. How many had been so driven ?—Three wagons.

616. I suppose you replaced those wagons ?—No, we did not; we only stretched them up so that they did not go any further.

617. Did anything else happen at the station that night from the violence of the weather ?—Yes.

618. What happened ?—It was likely to blow the roof off the station altogether.

619. Was any part of the roof damaged ?—Many parts.

620. Is the roof made of glass ?—Yes.

621. Was a great part of it destroyed ?—Yes.

622. Finding that the storm was affecting your station in this way, what orders did you then give with regard to the station ?—I sent for my inspector, Robert Card, and asked him to shut the gate of the exit stairs at Union Street Bridge to keep the passengers from coming down, and also passengers whom we expected by train from getting out that way, as the roof was worst about that part.

623. You were afraid of their being injured by any part of the roof falling ?—Yes.

624. Did you give any direction about the starting of the Newport train that should leave at 7.15 ?—Not at that time; the Newport train was standing in one of our dock sidings at the west end of our station. I considered that it would be dangerous for passengers to go along where the train usually stands, and accordingly I instructed my inspector to bring it back to the foot of the middle stair, where the passengers would just get down the stair and into the carriages without any risk.

625. You made this arrangement with the view not only to the comfort, but, I understand, to the safety of your expected passengers ?—Yes.

626. About this time did you look to ascertain how the signal stood with reference to the train that you were then expecting shortly ?—After I got all these arrangements made for the safety of the passengers I then looked.

627. Tell me as nearly as you can what o'clock that was ?—I think it was about half-past 7 o'clock.

628. You have said that you saw the signal ?—Yes, I saw the signal drawn.

629. That is to say, that they were put so as to indicate that the line was open for the train coming in ?—Yes.

630. Did that indicate to you that the train had passed any particular point ?—It indicated to me that the train had passed the south end of the bridge.

631. I presume that the signal you saw at your station "clear" would not be cleared until the signalman at the north cabin had received his notice that
the train had passed the south side?—The signals I saw are never drawn until the train is signalled from the south end.

632. That led you to expect that the Edinburgh train that was due was at hand?—Yes.

633. You would be momentarily expecting its arrival, I presume?—Yes.

634. How long after you noticed the signals did it first strike your mind that it was a signal that the train 'had not' come up?—I think it was about 10 minutes after I noticed the signals that I felt uneasy about it.

635. Tell me, in consequence of that uneasiness produced, what you did?—I saw a number of my own men standing on the platform, and I called out, and asked them if any of them could work the telegraph, when Shand, a guard, said he could do so, and I sent a messenger for the key of the telegraph office, and on going in I asked Shand to put the question to the signalman at the south end, had the Edinburgh train passed over the bridge?

636. What did you find?—I found that none of the instruments would work, excepting the one from the post office.

637. Was any of the instruments work from this side to the other side of the bridge?—Quite so.

638. That I suppose led you to suspect that something very serious had happened?—I thought that the high wind might have blown down some walls, or something like that.

639. Finding that you could not communicate with the other side of the river you left the office, meeting, I believe, two gentlemen?—Yes.

640. Who were they?—Mr. Lawson, and I think there was another; I do not know his name, but I know the two gentlemen by sight, and they told me what they had seen at the other end of the bridge.

641. What was it?—That they saw fire, they saw the train start on the bridge and a short time after they saw some unusual fire falling as it were from the top of the bridge to the water.

642. Which they supposed was from the train?—Yes.

643. I believe you asked them not to state to that to anybody?—Yes, I said it was a very serious matter, and it appeared to them not to spread the report of the fire. They were satisfied that something was wrong, and Mr. Lawson said he would go to the harbour master and tell him.

644. Then I believe you ordered all the station gates to be shut?—I sent for Shand again, and told him the report that was gone abroad, and ordered all the station gates to be shut, as there was likely to be a crowd, and there might be a number coming down, and the glass was falling from the roof.

645. Was Robert, the locomotive foreman, with you then?—No, he was not there at once. After giving orders, to the inspector, I proceeded to the engine-sheds, where I expected to find the locomotive for the train on its return.

646. And you found him?—Yes.

647. And you went together on to the bridge?—On to the signal cabin at the north end.

648. Did you then see that the bridge had given way?—No.

649. How far did you proceed along the bridge at all?—We did not proceed along the bridge at all.

650. How far as far as we could see that there was any gap in the bridge?

651. You went far enough to see that the bridge was partly blown down?—Yes.

652. Then you returned and telegraphed this to Edinburgh, to the manager of the company?—I returned with Robert, and I arranged that he would go to the harbour master and get a steamer at once, and I went to the telegraph office and telegraphed to the general manager and the general superintendent.

653. How long have you been at the Dundee Station, the Tay Bridge Station?—Since the bridge was opened.

654. During that time have you experienced any weather similar to that which you experienced on the night of the disaster?—I have not.

655. Or anything approaching to it?—I do not think it.

656. It was exceedingly violent on this occasion?—It was.

657. Have you ever seen the bridge oscillating either under the wind or any other cause?—I never have.

658. Did any of the guards or divers of the trains at any time intimate to you that in their opinion the bridge was in any way unsafe?—No one ever expressed it to me.

659. Or that they ever felt the oscillation?—Never.

660. A statement has appeared that on one occasion, in a high wind, the passengers were requested to leave the windows on both sides of the carriages open, did you ever make such a request?—I never heard that till now.

661. You never made such a request, and never heard of any one doing so?—Never.

662. Did it not occur to you to make such a request to anybody?—No. Mr. Balfour stated that he had no questions to put to the witness.

663. (The Commissioner.) Those three waggons of which you have spoken were coupled, were they?—They were coupled.

664. Had you no wedges to prevent them from moving?—No.

665. You said that they had been blown down by the force of the wind for 300 or 400 yards?—They were.

666. In what direction was that?—In an easterly direction.

667. Then the line at that part where they were moved was lying about east and west?—Yes.

668. Or north-east and south-west?—About east and west.

669. They were driven from west to east?—Yes.

670. Would it require any very great force to drive those loaded waggons in that way?—I never saw the wind driving loaded waggons such a distance, seeing that there was an ascending gradient the way they were coming.

671. Was it quite clear?—Yes, quite clear.

672. However, they were driven from west to east?—Yes.

673. You said that you had never seen the bridge oscillating yourself?—I never have.

674. Have you ever been on it at any time when the wind has been blowing very strongly?—I have.

675. Were you walking along it, or were you in a train?—I have been both walking and on a train.

676. In a high wind?—Yes.

677. You did not observe anything like oscillation then?—Nothing.

678. When it was blowing very strongly?—I never observed anything.

679. (Mr. Barlow.) At what time, on the Sunday in question, did you consider the gale to be in its most violent state?—I think it was from a quarter-past 7 till half-past 7 o'clock.

680. At the time the gale blew these waggons along the line it was not in a violent state?—It was not so high at that time, I think, as it was afterwards.

The witness withdrew.
Examined by Mr. Traynor.

681. You are locomotive foreman of the Dundee section of the North British Railway.—Yes.

682. And stationed at Dundee?—Yes.

683. How long have you been in the company’s service?—Four years.

684. What is your particular duty?—To transmit all orders from the superintendent to the engine drivers, firemen, medicines, and all connected with the rolling stock department.

685. And to see that the rolling stock is kept in good order?—Yes.

686. On Sunday, the 26th of December last, were you at the Dundee engine shed?—Yes.

687. In the evening at 6 o’clock, I believe?—Yes.

688. Your purpose there what?—To see that the shifts were changed, the day shifts to the night shifts.

689. It was a very stormy night.—Very.

690. Did you find that anything had happened to the engine sheds in consequence of the weather?—No, nothing had happened.

691. Did you fear anything happening?—Yes, I feared the doors being blown off their hinges.

692. I believe you stayed near to help the men to barricade them and secure them?—Yes.

693. From the shed where you were at 6 o’clock could you see the Tay Bridge?—No.

694. You got notice that night that something had gone wrong with the bridge while you were still at the engine shed?—Yes, I was outside the engine shed at the time I got the notice.

695. Who sent for you?—One of the signalmen.

696. He told you that the station master wanted you?—No, he said he thought there was something wrong with the train, that it had been on the bridge 35 minutes.

697. I suppose you knew what train he referred to?—Yes.

698. The one that was then coming up from Edinburgh?—Yes.

699. Then a minute or two afterwards you saw Smith; the station master?—Yes.

700. Tell me what you and he did after that?—We went to the cabin at the north end of the bridge.

701. He would tell you then, I suppose, that he had reason to be anxious about the train that was then on the bridge?—Yes.

702. You went to the north end of the bridge in order to ascertain anything that you could about the train?—Yes.

703. What did you and he do when you got to the north end of the bridge?—We went to the cabin and spoke to the signalman, and then made up our minds to go along the bridge.

704. When you were there, did you test the instruments at the north end of the bridge?—The signalman tested them, and found that they would not work.

705. Then you resolved with Smith to go along the bridge?—Yes.

706. Did you go along?—Yes.

707. How far did you go?—I went within 8 or 9 rods of the side of the bridge.

708. And you saw then that great part of the bridge had been carried away?—Yes.

709. Was it dark at that time?—Yes, the moon was shaded now and then.

710. With clouds?—Yes, and light again.

711. Smith did not go quite so far as you, I think?—No.

712. Did you see the water rushing out of the service pipe that conveyed the water to Newport?—Yes.

713. Describe, if you please, the condition of that end of the bridge to which you got so near?—When I got within the distance I have mentioned I saw a part of it sloping down.

714. Part of the bridge?—Yes. It was the rails that took my attention.

715. (The Commissioner.) The rails or the girders?—The rails.

716. (Mr. Traynor.) The rails on which the train ran?—Yes.

717. Did you see anything else beyond the end of what was in a sloping attitude except the twisted rails?—The rails were not twisted, but quite straight, but they were bent downwards.

718. Did you see anything projecting at the end of the bridge in an unchangeable shape, or downward shape, except the two rails?—Nothing. I took no notice of anything but the rails.

719. Could you see the other end of the bridge?—It did not mean where the south cabin is, but the end of the bridge where it first gave way.

720. Did you see lights on the south side?—I saw a red light.

721. I believe you first thought it was the train brought up?—Yes, I thought it was the train brought up.

722. You came back from your position and joined Smith?—Yes.

723. And you both returned together to the station, I believe?—No, I did not go to the station.

724. You returned from the bridge and went to the harbour master, I believe?—Yes.

725. To get a tug, I suppose?—Yes.

726. Did you find the harbour master?—Yes.

727. At the esplanade looking at the bridge, I believe?—At the boating shed at the end of the esplanade.

728. Was the tug got out that you went to arrange with him about?—No.

729. Why?—Because we could not get out the tug for the wind.

730. I believe the provost had got the ferryoader ready?—Yes.

731. Did you go out in her?—I did.

732. And you then saw the full extent of the breakage?—Yes.

733. I suppose after that inspection your idea that the train had been brought up changed?—Yes.

734. Is the train brought across the bridge by the engine that brings it up from Leuchars or Burntisland?—From Burntisland.

735. It comes on with the same engine the whole way from Burntisland?—Yes.

736. When had you seen that engine last?—Saturday.

737. The day before?—Yes.

738. In what order was it then?—It was in good order.

739. And the tender also, I believe?—Yes.

740. What kind of engine was it, give us a description of it shortly?—It was a bogie engine, four wheel couple, 6 feet 6 inch driving wheels, 17 inch cylinders, and 24 inch stroke.

741. Built by the Company?—Yes, the engine was fitted with the Westinghouse brake and two hand brakes.

742. Can you tell me the weight of the engine?—34 tons.

743. (The Commissioner.) Is that the weight of the engine?—Yes, of the engine.

744. And the tender?—The tender 24 tons.

745. The tender was loaded, I suppose?—Yes.

746. (Mr. Traynor.) The engine you saw was built by the Company; when was it built?—In 1871.

747. You have attended, I suppose, to its necessary running repairs?—Yes.

748. And from your examination of it on the preceding Saturday are you in a position to speak positively as to its being in perfect order?—I did not examine the engine personally myself. We had a
skilled mechanic to examine the engines daily, and his report then was "engine correct."

749. Who was the man who made the actual examination of this engine?—James Moyes.

750. When you went out on the bridge that night, what was the state of the wind?—It was very high indeed.

751. Had you any difficulty in getting along the bridge on account of the wind?—Great difficulty.

752. I want to have an idea about its force, was it of such a character as would have prevented you proceeding on unless you had been under great anxiety to know what had happened?—Yes.

753. It was only that extreme anxiety that made you persist against the force of the wind?—Yes.

754. Did you feel the bridge shake at all while you were on it that night?—No, I could not.

Mr. Balfour stated that he had no question to put to the witness.

755. (The Commissioner.) In fact it was the force of the wind that made Smith turn back, I suppose?—It was giddiness in the head, I believe.

756. When you say you got to the end within 8 or 9 yards, I suppose you had been to the end of the bridge since then?—No.

757. Have you never been to the end of the bridge since?—No.

758. Then you cannot say whether it is now in the same state in which it was when you saw it?—It is not in the same state.

759. How do you know that?—I saw it on Sunday night when I was in the boat, and that girder that I saw clapping has gone down altogether.

760. It was a girder that you saw?—Yes.

761. And not merely a rail?—It was the rails that took my attention to the girder.

762. Did you observe the girder?—No, I cannot say that I observed the girder, I take it that the girder might have been there, or the rails could not have been there.

763. Will you just explain that, for I do not quite follow you; was what you saw a portion of the rail hanging over such as there is now at the south end?—No.

764. What was it?—It was two rail ends that I saw.

765. Then when you saw those two rail ends, you saw the girder, did you?—Yes.

766. Then by whom you think that the girder was there?—The fact of the rails being there they required some support to keep them in their position.

767. Was the rail straight on or was it hanging down?—It was a little bent abruptly rather than straight.

768. Bent abruptly, where, near the break?—At the end of the break as it were.

769. It was bent first a little abruptly and then quite straight standing out?—Yes.

(Mr. Balfour.) The witness could go now if the court pleases, and then come back and tell us the difference between what he saw at that time and what he sees now.

(The Commissioner.) Then we will adjourn your further examination on that point until then.

770. (Mr. Barlow.) You say you saw the rails sloping down near where you stood?—Yes.

771. Did you see any timber with them?—I cannot say.

772. You cannot say whether you saw the deck of the bridge?—No; I did not stay above many seconds. Directly I saw it I turned round and came back, and had no time to see anything.

773. (Colonel Yolland.) What head light do your trains carry, a red head light or a white one?—A red light.

774. A red head light coming towards the Dundee side?—Yes.

775. That is what you supposed was the light that you saw?—Yes, it was the light that I supposed the driver had got.

776. (Mr. Trayner.) You were asked if you saw any part of the deck of the bridge from where you were standing; could you see whether or not there was anything under the rails which you saw projecting?—I could not say.

The witness withdrew.

Mr. James Black

Lawson sworn.

777. You are a wine merchant in Dundee?—Yes.

778. And you reside at the east end of Magdalen Green, facing the river?—Yes.

779. On Sunday night, the 28th December, there was a heavy storm, was there not?—Very heavy.

780. I believe you came out of your house on that evening about 7 o'clock to see the storm and its effects?—Yes.

781. How was the wind affecting the water of the river?—It was blowing it into foam.

782. Was the river running very high?—It was running very high.

783. Did you see it going over any part of the north end of the bridge on the land?—At the north end of the bridge the spray was going right over.

784. In clouds, rushing over?—Yes.

785. In your house, to the east or the west of the bridge?—West of the bridge.

786. Did you come eastward?—We came eastward.

Mr. Smart was with me.

787. How far were you from the bridge when you stopped your eastward progress?—We were at Mills, the accountant's house.

788. How far is it from the bridge?—About 300 yards.

789. Were you looking towards the bridge?—Yes.

790. Was it with the view of seeing how the bridge stood the storm that you went out?—Yes.

791. That amongst other things?—Yes.

792. You left your house about 7 o'clock?—At 5 minutes past 7.

793. And walked eastward to within 300 yards of the bridge?—Yes.
806. Did you endeavour to do that?—Yes. I ran with another gentleman, Mr. Clark, to the signal box at the north end of the bridge.

807. And when you got there, were you able to make yourself on the ground heard by those in the cabin?—Yes; several seconds after.

808. After several efforts had been made?—Yes.

809. Did the signalman join you then?—I believe Mr. Clark went up a few steps and spoke to him, and I shouted to him to come down, and I asked him if there was a train on the bridge, and he told me that the Edinburgh train had been signalled as having entered on to the bridge 10 to 15 minutes before, and he had no idea where it was. I told him that I thought the train was in the river.

810. At the time you saw that something fell from the bridge into the river did you hear any noise?—Not the slightest.

811. I mean any noise that would probably be caused by the fall of the train?—The noise of the wind, but no noise of the train.

812. I suppose there was nothing else but the noise of the water to prevent you hearing the noise that this catastrophe must necessarily have occasioned?—Nothing at all.

813. Then, after speaking to the signalman, do you believe you went with some others along the esplanade?—Yes.

814. Was it a difficult journey?—Yes, very difficult.

815. On account of the wind?—Yes.

816. You saw the station-master, and he told you what you have told us?—Yes.

817. (The Commissioner.) It was to the west that you walked, was it not?

(Mr. Trayner.) To the east. (To the witness.) You were still following on eastward?—Yes, to the station.

818. (The Commissioner.) From the signal box?—Yes; from the signal box to the North British Station.

819. (Mr. Trayner.) After you had delivered your message to the station-master you turned westward and went back to your own house in Magdalen Green?

820. I unengaged with Mr. Clark that he was to go to the harbour master’s office, and I went to the “Advertiser” office.

821. You went back that evening to your house in Magdalen Green, did you?—Yes.

822. How long after you had been to the station-master would that be?—I think it must have been about a quarter of an hour.

823. Was the wind still as high as before?—It was not quite so high.

824. Was the weather brighter and clearer?—Yes.

825. Had you a full view of the bridge on your way home?—When I got there.

826. Then you saw that all the big girders were away, did you not?—Yes.

827. Have you lived at Magdalen Green for some time?—Yes.

828. It is much exposed, I fancy, to gales from the south and south-west?—West-south-west.

829. Did you notice whether it was from that quarter that the wind was coming that night?—It seemed to me to be pretty much westerly.

830. Have you in your experience at Magdalen Green ever encountered a storm equal to what it was that night?—I never saw a worse one.

831. Did you ever see one as bad?—I cannot say.

832. You cannot say that you ever have or have not, or is it that you do not remember?—From memory I cannot speak.

833. To the best of your memory that was the worst storm you have ever known since you went to Magdalen Green?—I never saw a worse storm on.

834. Since you have been living here?—I have stayed at the west end of Magdalen Green for 30 years.

835. During that time may you have seen as bad a storm, but you never saw a worse?—No.

836. When you saw this mass of fire fall from the bridge, could you see the line of the bridge?—We only saw as we thought nearly to the north end of the big girders.

837. You did see to the north end of the big girders?—We did see very near that distance.

838. And this mass of fire was between you and the north end of the big girders?—We thought so.

839. On which side do you think it was?—On this side of the big girders, near the north side of the big girders, about where they joined the other ones, the low girders.

840. That is where you thought it was?—Yes, I thought it was there.

841. Not at the south end of the big girders?—No.

842. Could you distinguish the girders from the lower ones?—No. I could not see the big girders.

843. It was a more guess on your part that it was towards the north end of the high girders that you could make it out at all?—Yes.

844. Had you seen any fire before you saw this mass of fire falling down?—Nothing.

845. You were to leeward of the bridge, and any noise on the bridge would be coming towards you?—No.

846. You were to the westward of it?—Yes, a little. In a line with the north end of the bridge, pretty much so.

847. Therefore the place was it gave way would be very nearly in a south-west direction from you?—Yes, a little that way.

848. Were you on the west side of the bridge or on the east side of it?—I was pretty much in a line with the straight portion of the bridge.

849. Therefore, of course, you could not see anything like a fissure that there is, and this breaking away of the high girders?—No.

850. I thought you said you were to the eastward of the signal box?—That was after we went down to the post.

851. (Mr. Barlow.) When you saw that mass of fire coming down, did it fall rapidly, as a stone would fall?—No.

852. It fell slowly, did it?—Gently.

853. Did it come down in a straight line, or in an arc?—A little to the east.

854. With a sweep to the east?—A little to the east.

The witness withdrew.

Mr. George Clark sworn.

855. You resided at Magdalen Point?—Right opposite the point; right opposite the cabin.

856. That is nearly as possible opposite to the north end of the bridge?—140 yards north of the north signal cabin.

857. I did not ask you what your business was?—I have been out to Australia; I have been there some years as a merchant.

858. You are not in business now?—Not in Dundee, not since last year.

859. You have been to sea?—I have been to sea.

860. You said you had been to Australia?—To Australia and to China.

861. You have been through the Indian Sea?—Yes.

862. On Sunday the 28th of December last in the evening there was a very violent storm here?—A hurricane.
863. Is that, how you would describe it?—That is the way I should describe it. It was so unusual that you were looking out of your own windows to see its effect upon the train?—Yes, upon the train; I was looking for the train.

865. Did your window that you were looking from look straight down upon the bridge?—The bridge would be upon your right hand and a little.

866. If your house it would be a little to the west?—This is the signal box; the bridge would be there, about 10° to the right.

867. From your point of view that was to the west?—Yes.

868. What o'clock was it when you took up your position in the window to look at the train?—A little after 7, about 10 minutes past 7.

869. Did you see the train enter the bridge on the south side?—I saw the train at the bridge.

870. And could you mark its light advancing?—I marked its light advancing very distinctly.

871. Up to what point on the bridge had it reached as long as your attention was kept fixed upon it?—I thought that it had just got into the high girders, because when it gets into the high girders you cannot see the lights so distinctly, and then I turned round.

872. You followed it with your eye till the light became indistinct, as you thought, from its entering the high girders?—Yes.

873. And then you turned from the window?—I turned round.

874. Your brother was with you?—He was in the other room.

875. Did he call out anything to you?—He called out, "Look at the line, the train is over the bridge," or something of that sort; it was "Look at the line," I think.

876. You looked out?—Immediately; my head was only turned away from the window, and then I turned round again.

877. When your brother called out to you you turned back instantly?—Yes.

878. Could you see any lights when you turned round to the window?—No, it was all dark.

879. You waited, however, at your window to see if the train would pass, I believe?—Yes, about a minute.

880. And as it did not come in sight again you were afraid that something had gone wrong?—I ran up to the observatory at the top of our house; we can look right down upon the bridge from it.

881. What did you see when you went up to the observatory?—I saw nothing; it was too dark.

882. There were a great many clouds drifting, were there?—It was very dark, you could not see the point at all.

883. You went up for the purpose of seeing if anything was wrong with the bridge?—To look for the train. I thought the train was in the curve; we could not see the curve from the window.

884. You did not see the train?—No, I saw nothing.

885. What do you call the observatory?—It is on the top of the house.

886. You have no instruments there, I suppose?—Yes, there is a large telescope, but it was no use: we could not open the windows that night for the gale.

887. When you found that you could see nothing from your observatory what course did you follow?—I took a pair of field glasses and ran down to Magdalen Point with them to the bowstring girder at Magdalen Point.

888. What do you call the bowstring girder of the Tay Bridge?—Yes.

889. At Magdalen Point?—Yes.

890. Where you found Mr. Lawson, the last witness, and another gentleman?—Yes, two.

891. Did you try your glasses there towards the bridge?—Yes; there was too much spray to use the glasses, the spray was blowing over the plenum, the glasses all got wet.

892. Did you do anything with regard to the signalsman at the north cabin?—Yes, we entered into the North British ground behind the fence and shouted Mr. G. Clark to him.

893. Did that attract his attention?—No, we went up the ladder and called out, and then he heard us.

894. The wind, I suppose, was too loud for him to hear you?—You could not hear a man more than 2 feet from you.

895. Did you go up the stairs?—We went up the ladder and shouted, and he came out; he saw us on the latter.

896. You asked him something?—We tried to speak to him but we could not make him hear, and we came down the ladder.

897. And got into shelter?—We got him under the arch.

898. When you got him under the arch what did you say to him?—We said to him, "Where is the train?"

899. Did he give any reply?—He said that it had been on the bridge some time.

900. Was that the whole of the conversation between you and the signalman?—I did not want there, I ran as hard as I could.

901. You ran eastward?—To the station.

902. Mr. Lawson being with you?—Yes, and another gentleman.

903. And you there saw the station master and told him what you had seen?—Yes, Mr. Lawson told him what he had seen; I had seen nothing.

904. What had been seen, and what was feared?—Yes, I did not stop 10 seconds in the station; when I saw they were speaking to him I ran.

905. You went to Captain Metivin of the ferry boats and told him?—Yes.

906. Did you go to the harbour master?—I went to the harbour master's home, at the Custom House.

907. And told him?—He was not there.

908. Did you see him afterwards?—I saw him afterwards in the dock.

909. Your purpose was to get out a boat as fast as possible?—To tell them so that they would be able to get a boat out when the wind went down; it was impossible then to get out in any steamers.

910. When you got down to the dock office was the light any better than before?—Yes, the moon came out.

911. Were you able to use your glasses then?—We used the large telescope then.

912. The telecope in the office?—Yes, a very fine glass.

913. And you saw then that the bridge was down?—Yes.

914. Had the wind moderated at all then?—Yes, it was still blowing very bad through.

915. You are accustomed, obviously, to observe the characters of the wind?—Yes.

916. Did you notice that night whether the storm was a continuous blow or whether it came in periodical gusts, squalls?—Very heavy squalls about every 7, 8, or 10 minutes.

917. And between those squalls a periodical quiet?—No, a very heavy gale between the squalls; the squall was only heavier than the gale; there was no lull.

918. You would describe it as a constant gale, with periodical heavy squalls?—Yes, but not what you call squalls and a lull between them.

919. But the force of the squall would be more concentrated than the force of the continuous gale?—Yes.

920. How long have you lived at Magdalen Point?—Thirty years. I have been away five or six of seven years.

921. I suppose the point is exposed to any severe wind that blows?—Especially from the south-west, but this wind was west.

922. Had you ever experienced a storm like this, since you went to Magdalen Green?—No, not so bad; the heaviest storm that I remember was in September 1869; there was more sea then, but not so much wind.
TAY BRIDGE DISASTER

Mr. G. Clerk. 

923. You would regard the weather on the night of the 28th of December last as something very exceptional?—It was the heaviest storm that I have ever seen here.

924. (The Commissioner.) You have been in the Tropics?—I have seen a typhoon in China that was not any worse than this, just about the same.

925. Have you ever seen a tornado in the West Indies?—I never saw a tornado.

926. You said; if I understood you rightly, that you watched the light until it got between the high girders, or what you believed to be the high girders?—What I believed to be the high girders.

927. Then it became indistinct?—I turned round then.

928. You were standing at the window, and your brother was standing at another window, looking out in the same direction?—Yes.

929. You turned round?—I turned round.

930. And as you turned round or after you turned round, your brother asked you whether or not you saw the fire?—Yes.

931. Did you turn round to the window immediately?—Yes.

932. Did you see any of the fire?—No.

933. Therefore the fire must have been instantaneous almost?—Not so quick as that, because he was in one room and I was in the other. I should say from the time I turned round to the time I looked back it might have been 10 seconds.

934. You did not leave the window?—I did not leave the window.

935. You merely turned round?—It could not have been longer than 10 seconds; it might not have been more than five.

936. When you turned round again it was perfectly dark, was it?—It was quite dark; my brother described the fire as three fires.

937. So far as you yourself were concerned there was only an interval, as far as you believe, of 10 seconds between the time that you were looking out on the bridge and saw the light of the train, get dim, and your turning round again and seeing nothing?—It was not longer than 10 seconds.

938. (Mr. Balfour.) Have you in your observatory any instrument for registering the force of the wind?—No.

939. At what time did you consider the storm at its highest?—After I went out, the heaviest of it.

940. At what time during the evening do you consider the storm was its highest?—I was in the house until 7 o'clock.

941. You could not tell till after you went out?—Not so well of course.

The witness withdrew.

Mr. Alexander Maxwell, juni., sworn.

Examined by Mr. Trayner.

942. You are an engineer?—Yes.

943. You live with your father, who is an ex bailiff of this town at Magdalene Green, do you not?—I do.

944. I believe it is immediately to the north of the bowstring girder?—Yes.

945. On Sunday evening, the 28th of December, do you remember that there was a great storm?—Yes.

946. Did anything happen to your house or about your house that alarmed you?—Yes, in the first place I noticed the chandeliers of the room shake; I noticed them move, and about 10 minutes past the chimney cauris came down from the top of the house, about five of them.

947. There were some friends at your house that night, I believe?—There were.

948. And there was a suggestion made that you should look out and see the bridge, and what effect the gale would have upon it?—Yes.

949. Who made that suggestion, do you remember?—I think it was a Mr. Miller.

950. Did you act upon that suggestion; did you go to the window?—Yes.

951. You turned down the lights in your house and locked them up?—We did.

952. Did you look out yourself?—Yes.

953. Tell me what you saw?—The first thing that caught my attention was the signal light, a little to the north of the big girder, it was flickering. I thought that the lamp of the signal was on fire. Then almost at that moment, or shortly afterwards, I saw two lights of the engine coming on to the bridge on the west side, and I followed it on closely to the big girders, where I saw the flashing of the lights, the light would be flashes as it were passing the spars.

954. You followed the light of the advancing engine from the south side till it reached the high girders?—I did.

955. Before the train reached that point, did you see any lights near or about the train, except the head lights of the engine itself?—No; I saw the danger signal on the south side.

956. I am not asking you about that; you saw no fire or sparks about the engine except the head lights of the engine?—No.

957. When it got to the big girders tell us what you saw?—At that time I thought I saw the lights shaken, but I suppose it would not be the case. Before it came to the big girders I thought I saw the lights shaken, but when it came to the big girders I saw, as it were, flashes passing as it would be the spars of the big girders between me and the train.

958. You saw it coming on, but it was occasionally observed as it came past a high girder or spar?—Yes; then it suddenly disappeared about the third or fourth girder from the south side.

959. At the time of the disappearance did you see any fire or light?—At the time, but about a second or two seconds afterwards there was a flash about two girders in advance of the train; then after that there was another light at about another two girders, all coming towards the north; then there was a third flash. Taking it roughly, it would be two girders from the north side.

960. (The Commissioner.) Will you say, that over again; about two seconds after you had seen the light disappear what did you see?—There was a flash from about two girders in advance of the train.

961. (Mr. Trayner.) That is to say, in advance of the place where you had last observed the lights of the train?—Yes.

962. (The Commissioner.) When you say "two girders" you mean two lengths between two piers?—I mean between two piers.

963. (The Commissioner.) Go on if you please?—Then there was another flash; a second flash which was about another two girders in advance of the first flash, then a third and last flash, which was the largest of the whole of them, about the second pier from the north side.

964. (Mr. Balfour.) Do you say that that was the greatest flash of the whole?—Yes; the largest.

965. (Mr. Trayner.) Of course when you say about two piers from the north end of the higher girders, you are giving us as near a guess at the thing as you can, you cannot speak with any certainty?—I have a photograph which was taken from our window to give an idea of the angle at which I would see it.

966. You are giving us your opinion formed at the time?—It certainly was near this end.

967. The last flash?—Yes.

968. Did you see at any time a stream of light or a flash as if a lighted body had been precipitated from the bridge towards the east?—No.

969. And those flashes which you did see, I suppose, were not flashes starting from the bridge downwards, were they?—Yes, they were.

970. All of them?—Yes.
971. On which side of the bridge did the flashes go?—They went towards the east.

972. Did you see anything like a dark body falling from the bridge into the river?—No.

973. Was it too dark to see anything but the flashes of light at that distance?—About that period a cloud came over the moon.

974. Shortly after that did you use the telescope you had?—Yes.

975. Is it a powerful one?—Yes.

976. And you discovered that there was a gap in the bridge?—Yes, we noticed it with our eyes, before using the telescope, but not believing it we took to the telescope.

977. You saw what you believed to be a break in the bridge before you used the glass, but having used the glass afterwards you saw that that was so?—Yes.

978. And you saw the water escaping from the bridge?—Yes.

979. At the time of these flashes that you have described, was there anything peculiar about the condition of the wind?—It seemed to be about its highest point then.

980. What I was really porting at was this; the wind came in occasionally heavy gusts?—Yes.

981. And any of these gusts at a point of time with the flashes that you saw?—No. I could not say that there was one immediately afterwards.

982. Immediately after the flashes?—Yes.

983. Could not you say whether there was a sudden gust at the time the flash struck your eye?—I could not exactly say that.

984. (Mr. Commissioner.) You have told us that the first flash that you saw was about two seconds after you had lost sight of the head lights of the train?—Yes.

985. How long after that was it when you saw the second flash?—I think the whole thing was divided into four spaces; the whole thing occupied about 15 seconds altogether. I should say from the time that the light of the train went out till the time of the last flash at this side would be about 15 seconds or thereabouts.

986. And they were at distinct intervals, were they?—Yes, quite distinct intervals.

987. Did you say about equal intervals?—No, the last one was the brightest of the whole.

988. But did they occur at about the same interval the one from the other?—Yes, about.

989. They were in succession, moving forward towards the north end of the bridge?—Yes.

990. You could see that very distinctly, could you?—Yes.

991. What is that that you have in your hand?—This is a photograph from the window, showing how I look on to the bridge; it was taken in 1877 when the bridge was built.

992. Will you mark "1," "2," "3" the places where you supposed the flashes were?—I could put them nearly.

993. You are an engineer?—Yes.

994. (Mr. Trayner.) A practical engineer?—A practical engineer.

995. (Mr. Balfour.) A mechanical engineer?—Yes. (The witness marked the photograph.)

996. (Mr. Beresford.) To what circumstances do you attribute those flashes of light?—They were rather too red for friction sparks; I should think they were too coloured, too red. I never saw friction sparks so darkly coloured, but I thought it might be that those flashes or sparks would light the gas on the main pipe of the bridge and cause them to be a little darker in colour than they otherwise would be without the gas.

997. Did you attribute those flashes to gas?—Partly, not at the time. I afterwards thought that they were too dark coloured to be sparks only from the breaking of the girders; but I thought then that the sparks from the broken girders would light the gas from the broken gas pipe and probably cause the light to be a little coloured.

The witness withdrew.

Mr. W. A. CLARK.

Examined by Mr. Trayner.

998. You are the brother of a previous witness, Mr. George Clark?—Yes.

999. On Sunday night, the 28th of December, were you in your brother's house at Magdalen Point?—Yes.

1000. You were both looking out of the window to see the train coming from Edinburgh across the bridge?—Yes.

1001. You were not at the same window?—No.

1002. Did you see the train come on the bridge at the south end?—Yes.

1003. Could you follow its light advancing?—Yes; I traced its light till it entered the large girders.

1004. Follow the train from that moment till you lost sight of it altogether, what happened after you saw the train come on the bridge at the south end?—I followed the train after it came on the bridge till I supposed it was at the third large girder.

1005. (Mr. Commissioner.) You mean the third large pier?—Yes, then it suddenly disappeared; five seconds after that I saw three sudden flashes.

1006. You saw you followed it till it came to about the third-pier from the south of the high girders?—Yes; then it suddenly lost sight of it.

1007. (Mr. Trayner.) An interval of five seconds elapsed before you saw anything else?—Yes.

1008. At the end of that five seconds what did you see?—Three sudden flashes from I should imagine the extreme north end of the large girders.

1009. Were those three flashes quite distinct?—Yes.

1010. Then what did you see?—I saw no more, but I noticed that the signal lights at the south cabin which had previously been quite visible were obscured for a space of probably 10 seconds after I saw the flashes.

1011. To what did you attribute the obscuring of the light at the south cabin?—I could not tell at the time; now I imagine it must have been the spray caused by the falling girders.

1012. Were you able to see whether anything fell from the bridge towards the river?—Nothing.

1013. Were those flashes of light that you did see flashes as if departing from the bridge towards the river?—Yes, in an oblique direction.

1014. Downwards?—Yes.

1015. I suppose there was scarcely any appreciable period between the flashes?—No, just an instant.

1016. Just enough to mark that the flashes were not one light, but three distinct flashes?—Yes.

1017. Did you call out to your brother?—I did.

1018. What was it you said?—I said, "Look at the fire; the train must be over the bridge," or something to that effect.

1019. Did you keep your position at the window after you saw the flashes?—For about three minutes.

1020. To see if the train came on?—Yes.

1021. But it did not?—No.

1022. Did you do anything then? did you go out with your brother?—Not till about five minutes after my brother.

1023. You were not with him?—I was not with him.

1024. You went out five minutes or so after your brother, I suppose, to ascertain if you could see what had happened?—Yes.

1025. Did you discover that the bridge was down?—Not for some time afterwards.

1026. Was there any light or fire on the bridge from the time you saw the advancing lights of the train till you saw these three flashes?—Not that I observed.
1027. Or lines of sparks along the deck of the bridge?—No, nothing.

1028. Did those flashes that you saw appear to you to be the result of friction, or did you form any opinion as to what had occasioned them?—At the moment I formed the opinion that it was burning coal; but upon second consideration I knew the train had not time to get so far on the bridge as where I saw the flashes.

1029. The train could not have got into a position in which you could have seen the burning cool of the train or the reflection of its light at that point?—No.

1030. I understand from your point of view the train, where you saw the flashes, must have been dead on to you, and therefore you could not see the furnace?—Not exactly dead on, our house is a little to the east.

1031. Was it nearly head on?—I should imagine about 50 yards to the east.

1032. You know the position in which you thought at the time the train was where you saw the lights?—Yes.

1033. You have looked many times since from your window at the same spot?—Yes.

1034. Do you think now it was possible that those flashes could have been the reflection of light coming from the open furnace door?—No.

1035. (The Commissioner.) Is not your brother's house nearly in a line with the high girders?—About 50 yards, or a little more probably, to the east.

1036. At that time could you see at what part of the high girders this flash would be, whether it would be in the fore part or in the after part?—Yes, I could see that perfectly.

1037. You are on the east side of it a little?—Yes.

1038. It would be a little out of the straight line?—Yes.

1039. You would be below the line of the rails?—Yes.

1040. Therefore any sparks upon the rails from the brake being put on would hardly be visible to you, would they?—Probably not, but I think I could see them.

1041. Had you ever seen anything of the kind before?—Not on that portion of the bridge.

1042. You would be about 50 yards, you say, to the east of the straight line?—Yes.

The witness withdrawn.

Mr. A. Kennedy.

Examined by Mr. Trayner.

1058. You are an engine driver in the service of the North British Railway Company?—Yes.

1059. How long have you been in their service?—Six years.

1060. An engine driver?—Yes.

1061. What part of the company's system is it that you drive over?—The northern section.

1062. Between what points?—Between Dundee and Burntisland.

1063. That is a train that comes up from Burntisland on a circle round by St. Fort, Tayport, and Tay Bridge into Dundee?—Yes.

1064. Where were you driving your engine on Sunday, the 25th December last?—Yes.

1065. From Tayport to Dundee?—Yes.

1066. When did you leave Tayport?—At 5.50 p.m.

1067. Was it a passenger train?—Yes.

1068. How many carriages were there?—Five carriages and two brake vans.

1069. When did you get to Tay Bridge with that train?—About 3 minutes past 6.

1070. You note the time exactly in a book that you keep?—Not every place that I stop at on every part of the road.

1071. Can you tell me from your book when you entered the Tay Bridge that night?—Not exactly.

1072. It was about that time, 3 minutes past 6?—Possibly 5 minutes past.

1073. Your train passed over the bridge in safety?—Yes.

1074. Was there anything unusual about the passage that afternoon?—Nothing.

1075. Did you feel the train vibrate, or the bridge oscillate, more than usual?—No, not at all.

1076. Was the wind high when you passed?—Yes, it was blowing a strong gale.

1077. Have you crossed the bridge in a stronger?—I certainly have in as strong.

1078. You are certain that you have crossed the bridge in a gale as strong as it was blowing at that time?—Yes.

1079. Did you notice in your passage across the bridge whether everything seemed in good order, or was there anything out of order?—Nothing out of order.

1080. Was the brake put on your train at all in going across the bridge?—Yes, coming towards the north end.

1081. That is where the incline is?—Yes.

1082. Did you notice whether putting on the brake occasioned any sparks from the wheels?—No.

1083. Have you ever seen sparks emitted from the wheels by the putting on of the brake upon the Tay Bridge?—Yes.
1084. Have you seen it often, or is it a rare thing?
—It is a common thing.

1085. The brake is only put on, I suppose, after you have reached the top of the incline as you come down to the south end?—Yes.

1086. And you have often seen sparks coming from the wheels in consequence of the appliance of the brake?—Yes.

1087. That Sunday night, the 28th of December, you did not see any sparks?—No.

1088. Can you say that there were none, or is it simply that you were not taking heed, and did not see any?—I cannot say that there were none, for I stood on the wind side.

1089. You were on the westward?—Yes.

1090. (Mr. Balfour.) You spoke about sparks coming when you apply the brake on the Tay Bridge; sparks fly, I suppose, sometimes when the brake is applied at any place?—Yes.

1091. You did not mean to say that there was any peculiarity in the sparks on the Tay Bridge?—No.

The witness withdrew.

Mr. Robert Shand sworn.

Examined by Mr. Trayner.

1101. You are a guard in the service of the North British Railway Company? —Yes.

1102. Were you the guard on the train that left Tayport for Dundee at 5.50 p.m. on the 28th December last?—Yes.

1103. That is the train of which the last witness was the driver?—Yes.

1104. What did it consist of, how many carriages?—Five carriages and two brake vans.

1105. At what time did you pass on to the bridge with that train?—I could not exactly say to a minute, but a few minutes past 6.

1106. And you reached Dundee in safety?—Yes.

1107. Was there any wind that night?—Yes.

1108. Was it blowing very hard?—Yes, blowing very hard.

1109. Had you ever noticed it blowing as hard on any other occasion when you were crossing the bridge?—I could scarcely say.

1110. It was a very strong gale?—Yes, it was blowing very hard.

1111. Did you feel any unusual oscillation in passing over the bridge?—No, none.

1112. Before you came to the place where the high girders commence on the south side, was there anything that attracted your attention?—No.

1113. What was it?—Sparks from the wheels of a carriage.

1114. Before you reached the high girders from the south you noticed sparks coming from the wheels of a carriage?—Yes.

1115. One of the carriages in the train?—Yes.

1116. What position in the train did it stand in, was it about the middle or in the front?—The third carriage from the rear.

1117. That would be the one immediately in front of the brake van, would it?—No, there was the brake van, a third-class carriage, and then that carriage.

1118. This carriage was in front of that third-class carriage?—Yes, it was a composite carriage.

1119. Did you see from that the sparks were coming?—Yes.

1120. Before you saw these sparks, had you on the brake?—No.

1121. Seeing these sparks what did you do?—Immediately put on my brake.

1122. Did you put on the brake before you reached the top of the incline?—Yes.

1123. What effect had that upon the sparks?—None.

1124. They still continued?—Yes.

1125. Did the putting on of the brake increase the sparks?—The sparks came from the van then.

1126. From the brake van?—Yes.

1127. But the sparks from the composite carriage in front still continued?—Yes, they still continued.

1128. How long did they continue?—Till we reached the curve on the north end.

1129. Did you take off the brake when you were in the high girders?—Yes.

1130. Was that before or after you had entered on the incline?—It would be about the middle of the high girders when I took off my brake.

1131. Before or after you entered upon the incline?—Just about the time that we entered upon the incline.

1132. It was unusual to take off your brake at the place where you usually put it on?—The application of the brake depends on the speed we are going.

1133. You were coming down hill then?—Yes.

1134. Do you not put on your brake there generally?—It depends upon the speed we are running at.

1135. Running at the regulation speed upon the bridge, do you usually put the break on at that point or not?—No, not at that point.

1136. Usually you do not?—No.

1137. What is the incline there?—I could not say.

1138. You took off the brake in the high girders?—Yes.

1139. Why did you do that?—Because I was certain there was nothing wrong with the train then.

1140. Was there anything so far as you could see out of order in the bridge that night?—No.

1141. Have you any idea what was occasioning those sparks from the wheel of the composite carriage?—At first I thought that the axle had broken.

1142. And you put on the brake to stop the train until it was found out whether that was so or not?—Yes.

1143. Did you hang out any signal?—Yes, I held out a red lamp.

1144. At the side of your own carriage?—Yes.

1145. But that had not been seen by the driver?—No.

1146. It was not answered or responded to in any way?—No.

1147. I understand that soon after that you were of opinion that there was nothing wrong with the train?—Yes, I began to see sparks coming from the rear of the carriages, and only sparks.

1148. Did you see any sparks coming from any of the carriages except the composite one before you entered the high girders?—Yes.

1149. Were the sparks numerous?—Occasionally.

1150. What in your opinion occasioned the sparks from the other carriages, indeed from them all except the brake van?—I believe it was the wind.

1151. I do not know whether you are able to explain that; how would the wind produce sparks.
from the wheels of the carriages—It was our idea at the time that it was the wind pressing the carriages upon the rail.

1152. (The Commissioner.) He means forcing the wheel against the rail, I suppose.

1153. (Mr. Thayrer.) Against the rail or against the guard rail—Against the rail.

1154. Did these sparks continue from the time you first saw them until you reached the north cabin?—No, they ceased by the time we got to the distance signal.

1155. Did you apprehend any danger to yourself or to your train that night in coming across?—At the time I thought the axle was broken I did; but after- wards I did not.

1156. You apprehended danger from the breaking of the axle, not from the wind on the bridge?—From the breaking of the axle only.

1157. Apart from that, you apprehended no danger to yourself or to your train from the condition of the bridge or the state of the weather?—No, none.

1158. Did you apprehend danger in crossing that bridge?—No.

1159. It has been said, I have noticed, that you stated that you would not go over the bridge in a storm for 500.; did you ever say that?—Never.

1160. Did you ever give any one reason to suppose that you apprehended danger in going over the bridge?—No, never.

1161. Whether you said it or not, was there anything in the bridge or the management of the bridge that led you to apprehend danger to yourself or your train at any time?—No, nothing.

1162. Did you ever hear of an idea being given, on a request made, that passengers should open the windows of the carriages in going across the bridge in a high wind?—No, never.

1163. I suppose you were at the station when Mr. Smith, the station master, asked someone if he could work the telegraph at the north cabin?—Yes.

1164. And you said that you could do it?—Yes.

1165. And you went to the north cabin and tried?—No, we went to the telegraph office at the station.

1166. Did you try the instruments there?—Yes.

1167. The instruments communicating with the south side?—Yes.

1168. Was it for the purpose of communicating with the south side that you were using the instruments?—Yes.

1169. And you found that they were disconnected?—Yes.

1170. (The Commissioner.) When you get to the distance signal the railway takes a curve to the east, does it?—Yes.

1171. And according to your opinion the stress would be then taken off the wheel and it would not press against the rail; is that what you mean?—Yes.

1172. And then the sparks ceased?—The sparks ceased then.

1173. I did not quite understand you to say when it was that you first saw these sparks, was it as soon as you got on to the bridge?—No, it was a small bit on the bridge before I saw the sparks.

1174. Before you got to the high guarders?—A good bit before we got to the high guarders.

1175. Did they increase as you went on?—They were just about the same from that carriage.

1176. Did you examine the wheels of that carriage afterwards when you arrived at the station?—Yes.

1177. Was there anything in the wheels at all that would lead you to suppose that anything was wrong?—Not that I saw.

1178. The sparks continued till you got to the distance signal?—Yes.

1179. Where the railroad turns?—Yes.

1180. (Colonel Yealand.) Which side of you were you looking out, so as to see the sparks?—The side next Newport.

1181. On the east side, the right-hand side as you were approaching Dundee?—Yes, the right-hand side.

1182. It was from that side that you saw them all the way?—Yes.

1183. (Mr. Barlow.) Did you in crossing the bridge before on other occasions ever see sparks?—Not in the straight of the bridge.

1184. Have you ever seen them in other parts of the line?—I have seen them from the brakes in coming round a curve.

1185. You say here that you saw them in this case from the carriages, not from the brakes, you have not seen them upon other parts of the line from the carriages?—No.

1186. Had you ever before seen them from the carriages on the bridge?—Not in the straight of the bridge.

1187. And you saw them before you arrived at the high guarders?—Yes.

The witness withdrew.

Mr. George Murray said.

Examined by Mr. Thayrer.

1188. You are an inspector of permanent way in the service of the North British Railway Company?—Yes.

1189. And stationed at Dunfer?—Yes.

1190. Your district, I believe, extends from the Dundee Station to Leuchars?—Yes, to Leuchars.

1191. A distance of 6 miles south of Tay Bridge?—Yes.

1192. Of course that includes the whole of the bridge itself?—Yes.

1193. If you were the person to inspect the permanent way of the bridge?—Yes.

1194. How often did you fulfill that duty?—Every other day.

1195. How did you do it?—By walking along and seeing that every nail and key was tight on the rail.

1196. And the points?—And seeing that the points at wards were in proper working order.

1197. You sounded them occasionally?—Every other day I walked along.

1198. It was your duty to keep the permanent way in perfect order, or if you found it out of order to have it put into order at once?—Yes.

1199. Were the signals under your inspection too?—Not entirely, under mine; there is a signalman placed for that purpose.

1200. Apart from the duty of the signalman at the north and south ends, did you pay any attention to the signals?—No; only if anything was wrong when I was passing I would report it to the signalman to go at once.

1201. When did you last inspect the permanent way of the Tay Bridge?—On Friday the 26th.

1202. You said you inspected it every other day, that would have led you to inspect it on Sunday, but I think you were not on duty on Sunday?—No, but I had a man on duty on Sunday.

1203. Did you inspect the bridge on Friday with care?—Yes, I walked along it.

1204. At what time of the day?—It would be about 11 o'clock, between 11 and 12.

1205. In the forenoon?—Yes.

1206. Did you go from north to south, or did you come from the south northwards?—I came from the south to the north.

1207. Did you make a careful inspection of the bridge on that day?—Yes.

1208. In what condition did you find it?—I found everything correct.

1209. Frost is apt to put your way a little out of order, is it not?—Oh! nothing; I saw nothing of that kind in the bridge at all.

1210. A severe frost is apt to put your way out of order?—Yes, when there has been a severe frost, and then there is a fresh we get a slack a bit.
MINUTES OF EVIDENCE.

1211. It was in December; was there any frost to affect the way for some time before your inspection?—Nothing whatever.
1212. It had been fresh weather?—Yes.
1213. Open weather for some time before?—Yes.
1214. Are you able to say from your inspection on Friday the 26th, whether the bridge from end to end was in perfect-working order, or was there anything wanted to be done with it?—Nothing; the bridge was in good order from end to end.
1215. There was nothing to report on and nothing to repair?—Nothing.
1216. If you had seen anything out of order, what would it have been your duty to do?—To call my staff of men and get it repaired at once.
1217. You have been the inspector of that bridge since it was opened?—Yes.
1218. Have you passed over the bridge when there was a high wind?—Well, I have.
1219. I suppose more than once?—Yes, more than once.
1220. Have you often high winds on the Tay? We have on different occasions.
1221. Did you ever find the bridge swinging or shaking with the wind?—Never.
1222. Not to any extent?—No, nothing.
1223. You have never felt anything, so far as you could judge, by walking over it, between the stability of the bridge where it ran on the top of the girders and that part of the bridge where it ran within the girders?—Nothing; all the same.
1224. Did you ever apprehend any danger to yourself or others from the use of the bridge?—Nothing.
1225. (The Commissioner.) Have you ever been between the high girders when a train has been passing?—Yes, often.
1226. Of course the bridge would vibrate when a train was passing?—Nothing scarcely.
1227. Not at all?—Not at all.
1228. You did not feel it?—I never felt anything.
1229. Have you been there when there has been a high wind and a train passing too?—I have.
1230. And you have never felt anything like vibration or oscillation?—No.
1231. You know what I mean by oscillation?—Yes, perfectly well.
1232. (Mr. Barlow.) Have you noticed as between hot weather in summer and cold weather in winter much movement in the expansion joints?—Nothing.
1233. Do they move at all?—No.
1234. Is there no movement whatever?—Nothing that I could notice.
1235. Is it your business to inspect the rollers under the bridge?—No, but the permanent way.
1236. Who inspects the rollers under the bridge?—Mr. Noble.

The witness withdrew.

JAMES ROBERTS recalled.

Further examined by Mr. Trayner
1237. You have been to see the bridge?—Yes.
1238. Is it in the same state at the north end as it was when you saw it immediately after the high girders had gone?—Yes; the rails appear to be in the same condition, but I am of opinion that they were longer at that time; the same shape, but longer.

The witness withdrew.

Captain Scott sworn.

Examined by Mr. Trayner.
1243. You are a commander in the Royal Navy?—Staff commander.
1244. And a superintendent of the training ship “Mars” stationed on the Tay?—Yes.
1245. The “Mars” is anchored in the Tay, how far to the east of the bridge?—About three-quarters of a mile.
1246. I suppose on board the “Mars” you note the direction from which the wind blows, and the state of the barometer, with considerable precision and care?—We note the winds and the weather, not the barometer.
1247. Who keeps the log of the state of the weather and the winds?—The officer of the watch keeps a rough log.
1248. Is that transcribed?—Yes, by the chief officer in a fair log.
1249. Were you on board the “Mars” on Sunday evening the 28th of December?—Yes.
1250. Did you individually notice the barometer that day?—I did.
1251. What was observable about the barometer?—I observed a rapid fall from noon.
1252. Until when?—Until 7 o’clock.
1253. Did it reach its lowest then?—It reached its lowest at 7 o’clock.
1254. So that the pressure was greatest then?—I presume so.
1255. Have you any notes of the readings of the barometer that day?—I have private notes that I jotted down in my diary; that is the only thing.
1256. Is it also noted down in the ship’s log?—I believe not.
1257. Can you give me the readings of the barometer?—Yes, I can give you the readings at noon and the readings at 7.
1258. Give me first the reading at noon?—At noon it is 29 and 6-10ths.
1259. And at 7 o’clock?—Twenty-nine.
1260. It was about half-an-inch more at noon?—Yes, 6-10ths.
1261. That would be a little more than half-an-inch in the course of that period?—Yes, in the course of seven hours.
1262. Have you been here for some time, have you not?—For 10 years.
1263. From your knowledge of the coast a falling barometer would indicate, would it not, a rising and coming storm?—Yes, a coming storm.
1264. I suppose you would take precautions on board to have everything tight and taut there?—Just so.
1265. What did you do?—We put additional lashings on the booms and made everything snug.
1266. I suppose those precautions you found were very necessary on this occasion?—Just so, they were quite necessary.
1267. Was it an unusually strong gale?—Yes.
1268. Will you describe it, how would you describe it?—We describe storms in the navy by numbers, from 1 to 10, 12 would be the maximum, 1 to 12.
1269. Twelve represents the maximum strength of the wind pressure or disturbance?—Just so.
1270. On this occasion how would you describe the
gale on the 'Tay' by figures?—From 10 to 11 in a
squad.

1271. The whole gale made so by a continuous
gale, what figures would describe that?—I should call
it 1, a whole gale.

1272. In popular language, it was just about as
severe a storm as you could have experienced, is that
so?—I have experienced more severe storms.

1273. In this country?—I believe so.

1274. If it was represented during the squall by
the figures from 10 to 11, and the maximum was 12, there
could not be anything worse than there was on
the Tay that night?—It is very difficult to compare
one storm with another unless they occur about the
same time. I think from my remembrance of the
storms upon the Tay previously to the bridge being
put up, we have had one or two storms quite equal in
force in the last two or three years.

1275. As near as you can give me the years in
which those previous storms as bad as this occurred;
how many storms before this one do you think were
equal to it in violence?—I should think three at
least.

1276. Can you distribute them over 10 years with
anything like neatness of time?—I cannot give you
the dates of the storms, but some few years since
a large merchant ship was lost on the north coast
of Scotland, and I think on that occasion the storm was
about as violent.

1277. That is one, when did the other two occur?
—Probably six years since.

1278. Is it six years since the last occasion on
which there was a storm equal in violence to this
one?—The 'Ma've' was lost since. I suppose
four years since, or four or five, as near as I can
recollect.

1279. Is it four years since the last storm equal to
the one on the 28th of December occurred?—Probably
it would have been about the same in force as near as
I remember.

1280. But the long interval between these two
extremely violent storms was about four years?—I
think so.

1281. The other two had been prior to four years
ago or within the 10 years you speak of?—Yes, just so.

1282. You say that the figure which represents the
maximum force in the navy is 12?—Yes.

1283. Did you ever register the wind at the max-
imum force?—Not in this country.

1284. Where did you find the wind in such violence
so as to warrant the using of the figure 12?—In the
River Plate. I experienced it there and in China and
the West Indies.

1285. You said that the officer of the watch kept
the log of the wind and weather, where is that kept,
the rough one?—It is kept on the upper deck under
shelter, in the companion.

1286. And is there open room ready for the purpose
of having the observations noted upon it at the time by
the officer of the watch?—Yes.

1287. So far as you have observed, does the officer
attend to that duty by noting down all the observa-
tions at the time they are made?—He does.

1288. Is there any particular number of times in
each watch during which the officer must make his
observation and consequently his record?—Every
hour.

1289. The wind on that night you said was of a
force that would indicate the figures 10 to 11, when
the squall was on?—Yes.

1290. Did you observe what interval of time elapsed
between the gusts or squalls that came down?—They
appeared to me to be about every ten minutes, from
the violence of the storm.

1291. I suppose those gusts came in circles and
struck periodically in that way?—The wind was very
steady. I noticed that the wind was very steady.

1292. There was a continuous gale blowing?—
Yes.

1293. Every 10 minutes there was a sudden gust
or squall which would have a greater and more con-
centrated force than a steady gale?—Yes.

1294. Is your log here?—It is.

1295. Who is your mate who will speak to it, Bau-
worth?—The man on the watch is here; there are
two here, Baustworth and McMahon, who will speak
to the log.

1296. (The Commissioner.) Do you recollect on the
board the 'Mars' or on shore?—On board the 'Mars.'

1297. You were on board the 'Mars' that after-
noon?—Yes.

1298. Can you tell me from your own observation
what the direction of the wind was at noon, when it
began to blow?—South-south-west, as near as my
memory will help me.

1299. It gradually got to the west?—It shifted, so
far as I recollect, about sunset from 4 to 5 o'clock,
half round to west.

1300. At the height of the storm somewhere about
west?—At the height of the storm west.

1301. Assuming it to follow the course of the
usual tornadoes of the West Indies it would at that
time be directly south of the centre of the storm?—
At right angles.

1302. You would be gradually approaching it, and
passing to the south of the centre?—Probably the
centre of the storm would be near us.

1303. Passing a little to the north of you?—Yes.

1304. Wherefore its greatest intensity would lie at
the time when the wind was to the west?—I think
so.

1305. According to all usual experience?—Yes; I
have had a great deal of experience.

1306. Have you ever registered abroad even in
tornadoes as much as 12?—From 11 to 12 frequently
during my career.

1307. In the West Indies?—Yes, and in China.

1308. Then you would say certainly that from 10
to 11 was an intensely strong storm in this country,
would you not?—There is a marked difference
between the registering, the higher you go in figures
the more marked is the difference. There is a vastly
greater difference between the figures 11 to 12 than
there is between the figures 9 and 10.

1309. After all, that depends, does it not, very
much upon the person who registers it?—Yes, just so.
If you have no instrument for measuring it, it is
only guess work.

1310. At the same time, from your long experience,
you would say that any gale that came to us high as
11 would represent a severe gale?—From 10 to 11,
certainly, if I should say.

1311. At that time the wind was from the west?—
Almost due west.

1312. Directly at right angles to the high-girders
crossing the bridge?—Yes.

1313. (Mr. Barlow.) When you speak of the wind
boiling west, is it with reference to the true north;
or the compass north?—Magnetic north.

1314. (Mr. Trayner.) There is no official observa-
tory at Dundee?—I believe not.

1315. So far as you know there is there any anemo-
meter at Dundee to measure the wind's pressure?—I
believe not. There is certainly not any public one.

The witness withdrew.
Examined by Mr. Traylor.

1316. What is your position on board the "Mars"? — Gunner's instructor.
1317. You were on the "Mars" on the 28th of December last? — I was.
1318. What was your watch? — I was on watch, not the deck watch.
1319. Did you see the log that is kept on deck that day, and the weather observations on the weather and wind? — No, the other man marked it up.
1320. Who is that? — McMahan.
1321. Have you got the log here? — Yes.
1322. Let us see it. (The log was handed on.)
1323. It was on deck a great part of the time.
1324. Not part of the watch? — No.
1325. What part of the day were you on deck? — The whole of the evening, and at intervals.
1326. Beginning at what time? — Beginning from 5 o'clock up to about 9.
1327. Tell me what kind of evening was it after 5 o'clock? — It came on, to blow very hard by degrees, but it was not so strong at 5 o'clock as from 7 to 8.
1328. But even at 5 o'clock it was blowing pretty stiffly? — Yes.
1329. Was it a continuous gale? — Yes.
1330. Or was it coming down in squalls? — It was coming down in squalls at intervals.
1331. It was a constant gale, with the addition of those periodical squalls or gusts? — Yes.
1332. How long have you been stationed in the Tay? — Two years and five months.
1333. Have you ever experienced wind of that violence in the Tay since you came? — No.
1334. Look at the log and tell me first how the wind was blowing according to the log at 12 o'clock on the 28th December. You have no doubt, I suppose, that the log is kept accurately? — No.
1335. How was the wind blowing on the 28th December at 12 o'clock, or did McMahan keep it at 12 o'clock? — No; from 4 to 8.

Mr. Hugh McMahon sworn.

1336. It stands at what figure, 10 to 11? — Yes.
1337. How long have you been in the Tay? — About two years and eight months.
1338. Has you ever recorded 10 to 11, or 10 to 12? — Yes.
1339. I suppose 10 to 11 means the force of the gale? — A very strong gale.
1340. Were there also gusts or squalls coming down? — Yes.
1342. I suppose they made a great noise when they came? — Yes, they made a great noise.
1343. Was your ship that afternoon, the boats and the other appurtenances of the ship, specially lashed to prevent danger of loss or being washed away? — Yes; there was no extra lashing put on, but they were secured better.
1344. More than usually is the case? — Yes.
1345. In anticipation of this storm that you saw coming? — Yes.
1346. The barometer was falling, did you notice that? — I did not notice that.
1347. You, I suppose, acted under the orders of Captain Scott in making things all secure? — Yes.
1348. (The Commissioner.) What is your rank in the navy? — I was never in the service.
1349. You are in the merchant service? — Yes.
1350. What rank did you hold there? — Bostawan and able seaman.
TAY BRIDGE DISASTER.

Examinied by Mr. Trayner.

Admiral WILLIAM HERIOT

Y. H.

M. DOWALL. DOUGALL.

Admiral W. H. Mlrandt Dowall.

1834. You have never been a commissioned officer, neither mate nor master?—Yes.

1832. (Mr. Barlow.) Have you a compass on board ship at the hurricane?—Yes.

1833. You know your ship lies east and west by the compass?—Yes.

1834. And that is how you form your opinion of the direction of the wind?—Yes.

The witness withdrew.

TAY BRIDGE DISASTER.

Admiral W. H. Mlrandt Dowall.

1835. You live at Scotscaig at the month of the Tay?—I do.

1836. And have lived there how long?—I have lived there continually for 29 years.

1837. It is on the south side of the river, is it not?—Yes, in Fife.

1838. How long were you in the navy about?—I went to sea in 1832, and I got wounded and was put ashore and put on the shelf as a young captain after May 25th, since that I have been ashore.

1839. In the course of your service, do you suppose you have not come to deal of the navigable parts of the world?—Yes: I have been all over the world pretty much.

1840. And made yourself acquainted with the storms that prevail in the Indian and Southern Seas?—The Chinese and the American too.

1841. Your mansion house at Scotscaig is how far from the river?—It is about, as the crow flies, a mile and a quarter. About 3 miles and a half from the most part of the Tay Bridge, about 3 miles from the nearest part of the bridge, and a mile and a quarter from the river mouth.

1842. You lie something like east and by south of the bridge?—I think perhaps a little more to the southward, I think about south-east and by east.

1843. You remember the night of the 28th December?—I do.

1844. Just describe what happened?—I remarked when I came from church in the afternoon that there had been a very rapid fall in the barometer; I hardly believed that the barometer had not been touched by some one, but I compared it with the auroral close to it, and I found that they corresponded. I found that it had fallen between 11 o'clock and 4 o'clock 6-10ths. My house is nearly 200 feet above the sea, and it had fallen from 29 40 to about 29 80.

1845. What is the altitude of your house?—Nearly 200 feet. That rapid fall led me to believe that there was mischief coming, it showed me that the gradients of the atmospheric pressure were very steep. About 4 o'clock there was not much wind, but there was heavy rain, and we walked from church with umbrellas without difficulty. About 5 o'clock, the wind changed more to the westward, and we entered into a heavy gale, and it changed upon three points more to the westward, to about west-south-west, and strengthened very much. About 7 o'clock there was a squall of very great fury, and I happened to be reading alone, I stopped reading, and I went to the door to see what was happening, and how the wind had changed, and it had changed. As I have said, it was blowing very hard, and I came in again and began to read. About 7.15 to 7.20 there was another very serious squall, and I made the remark that if this sort of thing was often to happen in this country we should require typhoon shutters in this country. There was a peculiarity in this gale. I remarked the extreme difference between the fury of the squalls, and the lulls, and the sensation between the squalls, and the remark I made was this, "What a trying gale for the poor sailors of those ships which had not strength to make continual sail in a roll; when they roll heavily to windward, and get stuck " and swept by coming seas." That will give an indication of the strength of the gale.

1846. Did you anticipate any danger to Scotscaig House?—I thought the windows might come in.

1847. If they had been blown in the roof would have been blown out?—Sure to.

1848. Did the fury of the gale suggest to you that it was like a typhoon in violence?—Yes.

1849. You have been out the Tay for 29 years; I want to know from you if you have experienced on the Tay a gale or squall equal to this in severity during that time?—Never during these squalls. May after this, if there are any. I was never during these squalls. On 2 previous occasions I have known very heavy gales, the heaviest one was on the 3rd of October, and there was a very heavy gale from north-west to north, which uprooted a great many trees on my property. There was another gale about the year 1860, I think on the 3rd of October, and the next heaviest gale I remember was one about from south and by east, which made sweep through my property and uprooted trees. Those two directions are unusual directions for heavy gales; the trees are not so well prepared to resist the pressure from those two directions as from the south-west or west. The roots of the trees shoot out in the direction of the prevailing winds, where the greatest pressure comes, and the trees are better prepared to withstand a heavy gale from west-south-west than from south by east, or to the north-west of the wind. That rapid fall led me to believe that there was mischief coming, it showed me that the gradients of the atmospheric pressure were very steep. About 4 o'clock there was not much wind, but there was heavy rain, and we walked from church with umbrellas without difficulty. About 5 o'clock, the wind changed more to the westward, and we entered into a heavy gale, and it changed upon three points more to the westward, to about west-south-west, and strengthened very much. About 7 o'clock there was a squall of very great fury, and I happened to be reading alone, I stopped reading, and I went to the door to see what was happening, and how the wind had changed, and it had changed. As I have said, it was blowing very hard, and I came in again and began to read. About 7.15 to 7.20 there was another very serious squall, and I made the remark that if this sort of thing was often to happen in this country we should require typhoon shutters in this country. There was a peculiarity in this gale. I remarked the extreme difference between the fury of the squalls, and the lulls, and the sensation between the squalls, and the remark I made was this, "What a trying gale for the poor sailors of those ships which had not strength to make continual sail in a roll; when they roll heavily to windward, and get stuck

The witness withdrew.
Mr. Charles Clark sworn.

1424. Six is the maximum?—I never marked it, and I never marked 5.

1425. This was about the most severe storm you ever encountered?—About as heavy a one as I ever knew.

1426. I mean in the course of those observations you have been making?—Yes.

1427. Did you notice where it was marked as gale, whether it was not a powerful gale accompanied with squalls?—The fall of rain will tell you, and if it is a gale marked with no fall it is wind; and if it is a gale marked "heavy fall of rain," "a little wind," it is still marked "gale," but the wind column is not marked.

1428. You cannot tell me from your record whether it was accompanied with squalls or not?—Decidedly.

1429. Was it or was it not?—There is 22 of rainfall that date.

1430. Does that mean squalls?—No.

1431. There were no squalls that night.—No. If the wind blows strong I understand they call it a gale; it may be a squall or not.

1432. Have you not noticed whether it was a gale accompanied by squalls or not?—No.

1433. It was a gale of such an order as you never saw exceeded?—Two or three times, possibly, in the last 14 years, not exceeded, but equaled.

1434. I understand you to say equaled here on the Tay; I believe these observations have been made by you since you have resided at Magdalen Green?—Yes.

1435. Over how many years has that been?—Fifty-two years in the same house.

1436. (Mr. Commissioner.) You have recorded, you said, at Magdalen Green for 52 years.—Not on the Green.

1437. But here at Dundee?—Yes.

1438. But you have registered only for about 14 years?—Yes.

1439. During those 14 years you have seen it on at least four or five occasions blowing as strong as it blew on that night?—I say so from memory, not more than four occasions at any rate.

1440. (Mr. Barlow.) You spoke of the gale as if the gale had one continuous force of the same character; was it a gale that blew stronger at one moment than at another?—I do not think it.

1441. You think it was a steady blowing gale, without variation?—I may say that I never go out after dark, and the consequence is that I cannot tell you that.

1442. (Mr. Commissioner.) It was dark that day between 4 and 5 o'clock?—Before that, at 4 o'clock.

1443. But you did not go out after 4 o'clock?—No.

The witness withdrawn.

Mr. W. Ross McKelvie sworn.

1444. You are a civil engineer and architect in Dundee?—Yes. I superintend the cemetery works in Dundee. I am now known as a civil engineer and cemetery architect.

1445. You reside here?—Yes.

1446. Since 1862, I believe, you have kept a record of the weather for the Scottish Meteorological Society?—Yes.

1447. You have kept that record of the weather at Dundee for the last 12 years, I believe?—Yes.

1448. You make the barometric and the thermometric readings twice a day?—Yes.

1449. At 9 a.m. and at 9 p.m.?—Yes.

1450. I believe you have no instrument to test the wind pressure?—No.

1451. And do not know of any in Dundee?—None in operation.

1452. You communicate your observations, I believe, to the Scottish Meteorological Society from time to time?—Monthly.

1453. Have you a book with you?—Yes, I have.

1454. Will you kindly turn to the 28th of December last?—Yes.

1455. Are the entries made in your book under that date made in your usual way?—Yes, I mean, that in the usual way, twice a day, at the hours which you book represents, namely, 9 a.m. and 9 p.m.?

1456. (Mr. Commissioner.) In your own handwriting?—In the handwriting of my assistant, who resides on the ground.

1457. (Mr. Trayner.) They are made under your supervision and direction, and you know that they are correct?—I examine the list and sign it.

1458. On Sunday the 28th of December what was the reading of the barometer at 9 a.m.?—29·540.

1459. And at 9 p.m. what was it?—29·990.

1460. At what height above the level of the sea were those observations made?—107 feet above the mean sea level.

1461. Your book also contains a general record, or
TAY BRIDGE DISASTER:

Mr. W. Ross
McEwen.
5 Jan. 1860.

What is the general statement, of the condition of the weather?—Yes.

1462. What is the general statement your book contains applicable to the Sunday that I have referred to?—At 9 o'clock in the morning the wind is reported as "south-west" blowing what we call "1." The strength of the wind is measured from 1 to 6; 6 we call our highest.

1463. At 9 o'clock in the morning on Sunday the 28th of December it was blowing at about its lowest point.—Yes.

1464. What is the next entry?—At 9 o'clock at night.

1465. How was it blowing then?—At 6, our highest point.

1466. Is it so recorded there?—Yes.

1467. Now then, in the morning just give me again the direction of the wind at 9 o'clock?—South-west.

1468. And at 9 p.m.?—At night, west.

1469. In short, you noted all the observations during that day with reference to the condition of the weather and the direction of the wind?—Yes.

1470. Did you notice the gradual rising of the wind?—Yes; later, a second gale; an ordinary blast was still from a point pretty nearly west, but another spread up from a different quarter.

1471. What quarter?—It commenced one point east, perhaps south-east, and gradually wore round to south-west, and at 9 o'clock at night it was due west.

1472. At what o'clock in the day did the second gale rise, or begin to rise?—During a portion of the day I was so occupied that I could not notice it; but at 4 o'clock I noticed that there was a considerable increase in the force, and at 5 o'clock I noticed that it was very much increased in force and velocity.

1475. Did you notice that it was not only much increased at 5 o'clock, but that it was still increasing, or tending to moderate?—It had the appearance of increasing.

1474. You said both in force and velocity?—Yes.

1475. When, according to your own observation, did this gale begin to moderate?—As far as I noticed it came out and looked at it a little before six, and it was blowing very hard then. I had occasion then to walk a distance, and during that walk I was impressed with the peculiarity of the wind.

1476. Were you on your way to church?—Yes.

1477. Kindly explain what was the peculiarity which struck you on your way to church after 6 o'clock?—It came on on one occasion in gusts, or rather like a whirlwind, very strong.

1478. With a concentrated force?—Yes, very much so.

1479. Can you tell me when it appeared to you to commence its diminution or decrease?—I think about half past 6, or some time past 7; about half past 8 I was sensible that it had diminished both in force and velocity; the distance of time between the swifts was increased from 5 to 7 minutes.

1480. What is the interval between the gusts strengthened?—Yes.

1481. Did the gusts themselves lengthen when they came down?—They were not so strong.

1482. You were in church at half past 6, I presume?—Yes.

1483. How long did you remain there?—Till 8 o'clock.

1484. These observations that you have just been telling us of about half past 7, and so on, must have taken place while you were in church?—Yes.

1485. How were you able to observe while in church; what struck your attention while you were in church?—On account of my taking note on my way going, I heard the wind less or more while in church; one particular thing was the ventilator in the roof; which at one particular time made a tremendous noise, and I turned round to look to see what had been wrong. I was afraid something had happened, and on looking round I feared it was the ventilator of the church that had blown up; I noticed the office bearer going to fix it down, and looking round I noticed that the time was 15 minutes past 7 by the church clock.

1486. Did that gust which struck the church produce any effect upon the building otherwise?—I did not make further inquiry.

1487. I do not mean from inquiries that you afterwards made, but from your feeling or sensations while you were there?—I felt some insecurity at the time; I felt somewhat unsafe at the time; but I did not make any further inquiry.

1488. How many of those distinct gusts or squalls do you think struck the church in the course of your stay there from half past 6 till 8?—I confess I could not say that on my way going.

1489. Distinct gusts?—Yes.

1490. After you left church at 8 o'clock, how was the wind?—I found that the wind had subsided considerably, and that the interval between the gusts had lengthened out, perhaps 2 minutes more; there were about 7 minutes between the gusts.

1491. When you left the church you went home; on your way did you encounter in the streets any signs of violence from the results of the weather?—Yes; broken chimney cairns, slates, and zinc from the tops of houses, and in one case a large door.

1492. Blown off its hinges?—It had that appearance; it was a door with a latch on it, at any rate. I confess it alarmed me somewhat.

1493. It really was sufficient to produce alarm in your mind for the safety of yourself and others passing along the streets, as I understand?—Yes.

1494. Had the bridge passed through your mind that evening in connexion with the gale?—About this period I was overtaken by some gentlemen who were in the same church, and one of them warned me, and said I should have something to report about that night's gale, that is, to the Society; and some other ings were mentioned along with this, and one of them said he should not like to go over the bridge; that was about the extent of it.

1495. That brought the bridge prominently before your mind with reference to the gale?—Yes.

1496. When you got home I suppose it was still in your mind?—Yes, it was.

1497. Did the suggestion made by that gentleman whom you have mentioned excite in your mind a fear of the safety of the bridge?—Not for the safety of the bridge.

1498. A fear for the stability or safety of anything in connexion with it?—No, nothing.

1499. You got home; what did you do?—At the foot of the street I met a gentleman who said to me that he had heard from a gentleman going to Invergowrie that the bridge was down. I said I did not hear it, and he said, "I am going up the road to see." I did not go up the road, but went into my house.

1500. Where did you go then?—I went upstairs and went to the window to see if I could see the bridge.

1501. Did you see the bridge?—I saw the near end of it, the middle of it was under a sort of mist at the time; the moon was shining bright with some clouds, and I saw the north end of it.

1502. But the clouds must have prejudiced you from seeing what the condition of the centre of the bridge was?—For a short time.

1503. Very shortly after that you continued to look at the bridge, did you ascertain the condition of the bridge from your window?—I noticed that a portion of it was down.

1504. You went to an upper window to look at the bridge?—Yes.

1505. I understand you to say that that was on account of what a gentleman had said to you before that you entered your own house?—I have no doubt that that was so.

1506. Was your state of mind with reference to the bridge, looking at the weather, such as would have induced you to go and look at the bridge if this gentleman had not spoken to you on the subject, or was it simply in consequence of his mentioning what
he had heard?—That is a question that I do not know very well what to say to. I passed the bridge on going out at a place where I could see the bridge, but I did not happen to look at it.

1509. After leaving church at 8 o'clock, did the question of the stability or instability of the bridge occur to your mind, at all until someone had remarked upon it to the effect that it was a bad night for it?—No.

1508. That observation was made to you soon after leaving church?—Yes.

1507. Did you resolve then to go home and ascertain for yourself the effects of the gale upon the bridge, or did you not think of looking for the effects of the gale upon the bridge until the man told you that he had heard that the bridge was down?—I rather think that the man telling me that the bridge was down was the primary cause of my examining it.

1510. I suppose that the direction from which the wind was coming was a direction which you knew quite clearly would test the bridge as severely as any other could?—Yes.

1511. You have been observing the weather for 12 years, more or less, have you known during that period of any such wind before?—We have had storms before approaching it in velocity but not in force, or that sort of swirly nature in it like the whirlwind slope, yes.

1512. Do not all these gusts and squalls come more or less in swirls?—That is the general law.

1513. You have had squalls and gusts on a day before this during the 12 years that you have been observing the weather?—Yes.

1514. And you say that they have come in the same way and have been of the same character?—Yes; but not with the same force.

1515. Are there any other times that the same velocity?—I think so.

1516. But not with the same pressure?—No, not so much pressure concentrated upon one point.

1517. How do you account for having the same character of wind, with the same velocity and yet less pressure?—The force was more.

1518. No, no; how do you account for having had on previous occasions wind of the same velocity and the same character, and yet with less pressure than on the night of the 28th?—I cannot account for it.

1519. But that is your opinion?—That is my opinion.

1520. The testing of the pressure is merely a matter of opinion, is it not; you have no instrument to test them by which you have formed?—Quite so.

1521. Are there a great many large chimney stalks in Dundee?—Yes.

1522. Are any of those chimney stalks in such a position as to be operated upon with considerable force by wind coming from the south-west and hauling round to the west, many of them ranging from below Lochee downwards on the coast, would they all be within the circular range of this wind's operation?—It would depend upon the centre of the storm, if it was across the town or behind it or in front of it.

1523. Did any of those chimney stalks come down that night?—I don't know; not to my knowledge.

1524. In matters which would have been notorious in Dundee and within your knowledge if it had happened, is it not?—Yes, I think so.

1525. Everybody would have heard of it through the newspapers; but there was no such thing, so far as you know?—No.

1526. Can you account for the fact that if the force of the wind brought down the bridge, it did not bring down some of the chimneys?—I cannot answer that.

1527. You have said that the wind on that evening reached, according to your judgment, its maximum force?—Yes.

1528. Have you ever remarked the wind at its maximum force within the last 12 years?—Yes.

1529. Tell me how often you have done that within the last 12 years?—It would take me some little time to tell you that, but I will undertake to furnish you with an answer to that question.

1530. And the dates during the last 12 years on which the wind had in your opinion attained the maximum force and was so registered by you?—Yes.

1531. Now, although there were none of these large chimney stalks blown down, as far as we know, what was the effect of the night's storm on the Balgay Cemetery, which is under your superintendence?—Several monuments were blown down.

1532. How many?—Eight or nine, eight were blown down, and the ninth partly.

1533. And in the Eastern Cemetery?—Thirteen. I am speaking from memory just now.

1534. What was the size or height of those monuments above the ground?—Perhaps 8 feet; 7 feet or 8 feet.

1535. Were those monumental stones placed towards the south so as to be seen from the river?—I might say that they are in different directions.

1536. Take the Balgay Cemetery, is it on the level or on a slope?—It is rather on the corner of the hill; the two sides are on the crown of the hill.

1537. Were there any of these monuments blown down on the slope furthest from the river?—On the north slope, yes.

1538. Has it then affected the Cemetery on both slopes?—On the summit of the north slope, the south-west slope, we have not so many monuments on that.

1539. None were blown down on the south-west slope?—No, on the summit.

1540. Is the Eastern Cemetery on the level or on a slope?—It slopes nearly from north to south.

1541. Then that was all facing the gale?—Yes; rather sideways to the gale; it slopes from north to south, and the gale came from west to east.

1542. If it so slopes, it would be exposed to the wind hauling round from south-west to west?—Yes.

1543. There you said there were some 13 blown down?—Yes.

1544. Is any of your previous gales have you had experience of a similar disaster in the cemeteries?—Not to the same extent, to some extent.

1545. You did not go down to the esplanade at all that night, did you?—No, I did not.

1546. Did you make an attempt?—No. I did not go out after I returned home.

1547. (The Commissioner.) I see you distinguish between force and velocity, what do you quite mean by that. I suppose that the force of the wind depends upon its velocity, does it not?—A storm may go very quick and go regular with a regular force, that is an even force, and an ordinary anemometer records that; it records the velocity. Another storm may go very quick at one time and very hard at other times, and go very gently at others; an anemometer takes no note of that.

1548. You have no anemometer, have you?—None.

1549. All you mean is this, that this storm had a sudden gust in it?—Yes.

1550. Not that you distinguish between force and velocity, because the force of a storm depends upon the velocity of the wind which might be blowing at the time?—I referred to it with regard to measuring the force of it. The anemometer may be deceiving in that way; one thing would record the force of the storm, and the other would simply record the velocity.

1551. Did you register the force of the storm as from zero to 6?—Yes.

1552. Not as they do in the navy and other meteorological offices, from 0 to 12?—No, from 1 to 6.

1553. That gives you a less range?—Yes, quite so.

1554. You say you have often registered a force of 6?—Yes; I make a distinction. I do not from memory remember.
TAY BRIDGE DISASTER:

Mr. John Jack sworn.

1555. You have often done so, have you?—Yes, from 1 to 6.

1556. Have you often registered the force at 6?—Yes.

1557. About once a year?—I think once in the last year.

1558. Have you often made a register at 6?—Yes.

1559. (Mr. Barlow.) How do you determine in your own mind what is the maximum force of the wind; what is No. 6 upon your register; by what sort of calculation do you decide that the storm is a

storm in that form?—That requires a little training.

Mr. Buchan, of Edinburgh, gave me some lessons on that, as to how I should determine what is a gale.

1660. Can you tell us how it is done?—If we were under a storm I could tell you, but it is difficult to explain it here.

1661. (The Commissioner.) Is it a mere question of guess?—Yes, it depends very much upon experience.

1662. It comes to a guess at last?—Yes.

The witness withdrew.

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Mr. John Jack sworn.

1563. What is your age?—I shall be 86 come the 22nd day of February.

1564. You were a long time, I believe, at sea?—I was.

1565. You were in command of a merchant ship for some time, were you not?—22 years.

1566. After that you were dock and harbour master at Dundee for 36 years?—Yes.

1567. And from that position you retired 6 years ago?—Thereabout.

1568. In the course of your life, I suppose, you have been in many parts of the world?—I have never travelled very far, but I have been a good deal on the sea.

1569. Where did your ships generally trade to?—between the Canary Islands and London.

1570. Did you ever go to the South Seas?—Not to the South Seas.

1571. You have been chiefly trading in Europe and about the coast?—To Russia generally, and Frussia, and up the Baltic.

1572. You have been chiefly occupied in the European-trade?—Yes.

1573. Where do you live?—At Tayport.

1574. How far is your house from the river?—Two cables' lengths, I suppose, or three cables' lengths.

1575. How many fathoms are there in a cable?—It is two cables' lengths, it is not above 200 or 300 yards.

1576. On Sunday the 28th of December last there was a great storm here?—There was.

1577. Will you describe in your own way what you thought of it?—I may say, in the first place, that I was never out of doors, but I had a fine view of the river upstairs, and I was there, I may say, most of the time.

1578. Was the river running high?—Very; it was a sheet of foam.

1579. The river was running high, and there was a great deal of spray blown about?—Yes.

1580. The 'whole' river, you say, was a sheet of

foam?—We had some little craft lying there, and I had my glass occupied all the time seeing it drifting down. We had the moon bright at times, and at other times it was so dark that we could see nothing.

1581. Tell me what you thought of the night as regards the storm that was blowing?—I must say that as far back as I could recollect I never saw such a storm of wind.

1582. Was it very loud?—Very loud.

1583. Was it continuous?—I considered that every three or 10 minutes there would be a gust; the gale was boisterous, but when a gust came it was what I never heard before.

1584. You never heard anything like this?—It was like artillery going.

1585. There came between these gusts quieter times?—Yes, but still a heavy gale.

1586. But when a gust came it was even more marked than the gale?—Yes.

1587. Did your house suffer?—Yes; but I was afraid to go out.

1588. The next day did you find that your house had suffered?—We had one of the family that had come in between 11 and 12 o'clock, and when he came he came across a piece of lead about 13 feet long and 14 inches broad.

1589. Did you find the next day that it had been blown off your own house?—He told me when he came in it was there, and I went and saw it, but it was moderate then.

1590. At what o'clock was that?—About 11 o'clock; past 11.

1591. When you found this piece of lead did you afterwards discover that it had been blown off your house?—No question of it.

1592. Was there anything observable at the eaves of your roof?—Yes; my impression is strongly that it continued for half-an-hour longer there would not have remained any of the roof on my house.

1593. Were the eaves beginning to open?—The eaves were beginning to open up.

1594. Did you attribute that to the gale that night?—To the wind.

The witness withdrew.

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Captain Charles Wright sworn.

1595. What is your age?—Forty-nine.

1596. What is your occupation?—I am the captain of a Tay ferry steamer.

1597. What steamer?—The "Dundee."

1598. How long have you been a captain of a Tay ferry steamer?—Five years.

1599. Going constantly on Sunday and Saturday, I suppose?—Yes.

1600. Do you remember Sunday the 28th of December?—Yes.

1601. Were you plying across the ferry on that day?—Yes.

1602. Was it your steamer that left Dundee at a quarter past 1 that day?—Yes.

1603. What kind of weather was it when you went across to Newport at a quarter past 1 p.m.?—It was pretty good weather at that time; a light wind.

1604. After you reached Newport, when did you return from there to Dundee?—At a quarter to 2.

1605. You brought over some passengers then, I suppose?—Yes.

1606. What kind of wind had you then?—The breeze was beginning to increase at that time.

1607. And how was the river?—It was pretty smooth at that time.

1608. After you got over to Dundee about 2 o'clock, I suppose, when did you sail next for Newport?—At a quarter past 4.

1609. What was the state of the wind then?—Much the same as it was at a quarter past 1.

1610. It was only blowing fresh?—Yes.

1611. Nothing more?—No.
1612. What state was the river in?—The water was pretty smooth at that time.

1618. Pretty much in every way as it had been when you came over at 2 o'clock?—Yes.

1619. When did you reach Newport about half-past 4, I suppose?—Yes.

1620. How long did you lie there?—We left at a quarter to 6 there.

1621. And returned to Dundee?—Yes.

1622. Was the state of the wind and the state of the river—pretty much the same on your return passage as it had been going across?—The wind was freshening always.

1623. Was there any very observable difference in the wind or the water on your passage home at half-past 4 or a quarter to 5 from what it had been on your way over to Newport?—Much the same.

1624. That brings us up to near 6 o'clock; when did you go back to Newport again?—We left Dundee at 5 o'clock again; at a quarter past 5.

1625. And came back from Newport to Dundee at what time?—At a quarter before 6.

1626. Either of those passages was the water or the wind observably different from what they had been on the previous passages?—From a quarter past 5 to 6 it was a great deal worse.

1627. In your passage from here to Newport at a quarter past 5 it was a great deal worse than it had been on the previous passages?—Yes.

1628. Do you mean that the wind was stronger?—Yes, with heavy showers of sleet.

1629. Was the river rising?—Yes; fast; it was rising very fast.

1630. But you brought passengers with you again from Newport to Dundee about 6 o'clock; about 6 o'clock you reached Dundee with some passengers?—Yes.

1631. What was your next passage; when should you have gone next?—At a quarter past 8.

1632. Did you go?—No, I got inside at 6 o'clock.

1633. I did not require to go away till a quarter past 8.

1634. At a quarter past 8 did you go?—No.

1635. When did you go again that night, or did you go again?—At a quarter past 9.

1636. Why did not you go at a quarter past 8?—It was blowing a gale of wind.

1637. Owning to the state of the wind you did not go out?—No.

1638. Were you the solo judge of whether you should go or not?—No.

1639. Under whose orders were you acting?—Captain Methven's.

1640. Is he the superintendent?—Yes, he is the superintendent.

1641. It was under instructions that you did not go out at a quarter past 8?—Yes.

1642. Had there been a gradual increase of the storm from 6 o'clock till a quarter past 8?—Yes.

1643. I rather infer that it had got better at a quarter past 9, if you went then?—Yes.

1644. I was about what time in your opinion, the storm reached its height, between 6 o'clock, when you reached Dundee, and a quarter past 9, when you went out again?—About 10 minutes or a quarter past 7, was the worst time of it all.

1645. Were you at the water side all that evening waiting about the steamer?—Yes.

1646. And watching the state of the weather, I suppose, and the river?—Yes.

1647. You can see the ludge, I suppose, from the place where your steamer lay?—Yes, we can see it.

1648. Did you notice this train coming across it?—No.

1649. What time did night it was between 6 and 8?—I cannot tell you, regards wind, but as regards light it was not dark generally; there were clouds passing over the moon.

1650. When the clouds did pass away the moon was pretty clear?—Yes.

1651. And you had got light then?—Yes.

1652. What kind of weather did you experience going across at a quarter past 9?—There was a strong breeze, but we made the passage very well.

1653. How long did you take?—About 40 minutes.

1654. What is your usual passage across from point to point?—In a good day about 10 minutes.

1655. You do not mean to say you took 40 minutes to go across?—No, to go across and come back again.

1656. How long did you take to go from here across, 20 minutes?—Yes.

1657. And 20 minutes to return?—Yes.

1658. So that the state of the wind and the river, though it had moderated, was such as to make your passage cross the usual length?—Yes.

1659. Have you had any experience in the merchant services sailing to foreign seas?—Yes, I have.

1660. How long were you at sea?—Between 20 and 30 years.

1661. Were you in command at any time?—No.

1662. Have you been in the China Seas?—The same time I was there.

1663. How would you describe this gale on Sunday the 28th; have you ever seen anything like it in this country?—No, it was so equally and so gusty.

1664. But you have equally weather in the Tay, have not you?—I never saw it so equally as on Sunday the 28th.

1665. You have seen it very bad on the Tay with squalls and gusts?—Yes.

1666. This was very much worse than anything you had seen in the Tay?—I never saw the like of it before.

1667. In the Tay you are accustomed to gales of wind accompanied with squalls and gusts, though not so strong?—Yes.

1668. Are you often exposed to such weather as prevents you making the passage in less than 20 minutes?—Sometimes.

1669. That is not a very unusual thing, is it?—In westerly weather, no.

1670. I suppose, on the other hand, you do not often see weather that keeps you from going out at all?—Not very often.

1671. But it does happen?—Yes.

1672. If you can tell me, do; how long ago in it since you were last compelled to give up the passage by the weather before December last?—About a twelvemonth ago.

Examined by Mr. HALFPENNY.

1673. Where was the wind blowing from when you were prevented crossing a twelvemonth ago?—I do not recollect.

1674. It sometimes comes in storms from the east in the mouth of the Tay?—Yes.

1675. And that sometimes prevents you crossing?—Yes.

1676. When there is a heavy sea on outside and the waves are rolling in, are you prevented crossing?—Sometimes.

1677. But not very often with a west wind?—No; sometimes with a north-west wind it prevents us crossing.

1678. But very seldom with a south-west wind?—No, not very often.

1679. You told us that the wind that night was coming in squalls or gusts, have you any notion how long there would be between the squalls or gusts?—About 10 minutes.

1680. There would be 10 minutes tolerably quiet, the gale blowing in a steady way, and then a very heavy gust?—Yes.

1681. Was that the character of the weather when the gale was at its worst at 10 minutes or a quarter past 7?—Yes.

1682. The gusts coming at intervals of about 10 minutes?—Yes.

1683. And you had never seen anything, as I understand you, so heavy as that before?—No.

1684. All the terms that you have been on the Tay ferries?—Yes.
1679. How many trips a day do you make on an average on the Tay ferries?—Seven times.

1680. So that you have had very great opportunities of observing the state of the water, and the wind on these ferries?—Yes.

1681. You are not able to say apparently how long it is since you were ever stopped by a west wind or south-west wind before; can you say whether you have ever been stopped by a wind of that kind?—We have been stopped at different times.

1682. But never by a gale so bad as this?—No.

1683. (The Commissioner) You said that on the occasion of your crossing at a quarter after 9 o'clock to Newport, you took about 40 minutes to go there and back?—Yes.

1684. So that you got back again at about five minutes to 10?—Thereabouts.

1685. But I suppose you stopped a short time at Newport to land your passengers and take in others?—Yes.

1686. How long did you stop there?—About three minutes, I believe.

1687. You also told us that you thought that you had been stopped from crossing, not unfrequently, by a north-west gale?—Yes.

1688. Have you ever been stopped by a west gale?—Yes, we have been stopped by a west gale too.

1689. I suppose a west gale would be quite as bad as a north-west gale, would it not?—Yes.

1690. (Mr. Barlow.) Have you ever seen any ships go under the bridge?—Yes.

1691. Large ones?—Pretty large vessels.

1692. Have you ever seen a ship foul the bridge?—No.

1693. Has it never been fouled since it has been put up?—Not to my knowledge.

1694. You have seen ships pass through it?—Yes. The witness withdrew.

EXAMINED BY MR. TRAYNER.

1695. You are superintendent of the lights at Tayport?—I am principal keeper of the south lights at Tayport.

1696. Your age is what?—65.

1697. How long have you been there?—20 years.

1698. Were you on duty on Sunday the 28th of December last?—Yes, on shore duty, on duty on the land.

1699. When you were on shore duty, where did that take you to in connexion with the lighthouse?—To the west tower.

1700. How many lights are there?—Two.

1701. And you were at the west tower?—Yes, the lighthouse, the other one stands in the river.

1702. How far back is the west tower from the river?—It is close to the river.

1703. How high is it?—67 feet, I think.

1704. You were, I suppose, on the ground at this west tower?—Yes.

1705. At what time did you go on duty?—There is only one of us to attend to the lights all the night, and we have to clean down during the day, so that we may go on duty at lighting time, at 4 o'clock in the afternoon.

1706. Apart from the general necessity of your presence during the day, it was your duty to be there at lighting time at 4 o'clock?—Yes.

1707. And you were there?—Yes.

1708. And you remained there for how long?—Till 5 o'clock; we lit them at 5 o'clock.

1709. After that you were at the tower?—Yes.

1710. Did you remain at the tower after 5 o'clock, or did you go away and return?—I went away and returned.

1711. When did you return?—At 7 o'clock.

1712. How long did you remain after you came there at 7 o'clock?—About 26 minutes.

1713. Were you in that tower at a little after 7 o'clock?—Yes.

1714. When you came back at 7 o'clock you went into the tower?—Yes, I went up to the light room.

1715. At what o'clock was that?—At 7.

1716. And you remained in the light room how long?—25 minutes.

1717. How was the wind at that time?—About west-south-west, or west by south.

1718. How was it in strength?—Blowing very hard.

1719. Was it a steady gale, or was it equally?—So.

1720. Did you experience in the light room of the tower any effect from the wind?—Yes.

1721. What?—I felt a tremulous motion.

1722. Is the tower?—In the tower.
1743. Was that a gale from the westward?—From the westward.
1744. Is that a tumultuous motion in the lantern?—The lantern.
1745. Not in the tower?—By the time I had got downstairs I could not say that I felt it, it was only in the light room.
1746. I understood you to say that the lamps themselves were in a tumultuous state?—Yes, in the light room.
1747. The whole fabric was shaking?—Yes; you felt it distinctly under your feet shaking.
1748. (The Commissioner.) When was that?—That was in 1859.
1749. Since that you have never felt anything like it?—No, only that time on Sunday night.

The witness withdrew.

Examined by Mr. Tnatner.

1750. You are an Episcopal clergyman in Dundee?—Yes.
1751. One of the clergy of St. Paul's, I think?—Yes.
1752. I understand you travelled on Sunday evening the 28th of December last from Newport to Dundee?—I did.
1753. Leaving Newport at 5.50, I think?—About that time.
1754. And reaching Dundee by means of the Tay Bridge?—Yes.
1755. Have you often travelled by this bridge since it was opened?—Very frequently.
1756. Have you travelled over it when the wind was pretty high?—Yes, I have.
1757. How did the wind strike you on the night of the 29th?—I mean, in comparison with the state of the wind on previous occasions when you have passed over the bridge?—I was surprised that we did not feel greater effects in crossing the bridge.
1758. In the first place the wind was higher than you had previously experienced?—Yes, it was higher.
1759. You expected therefore to feel it more than you had ever previously done?—I did.
1760. Now you say, the result of your experience of that evening was to surprise you that you did not feel it more?—Yes.
1761. After you had entered upon the bridge on the south side, did anything happen to direct your attention particularly to the state of the wind or the state of the bridge?—One of my fellow passengers opened the window facing the west.
1762. Why did he do that, was it matter of conversation between you as to opening the window?—It was in the course of conversation, he remarked on the curious effects that were sometimes felt in crossing over bridges in a high wind.
1763. And you both agreed to try the effects by opening the window?—He opened the window, I did not say anything about it.
1764. When he opened the window there anything peculiar?—There was an effect something similar to shocks of electricity felt in the ears, first one ear and then the other.
1765. Was that across the whole line of the bridge, or at any particular part of it?—In crossing through the higher girders especially.
1766. You had there lattice work between you and the wind?—Yes.
1767. Which you had not in the other parts?—No.
1768. You experienced these peculiar slight shocks that you have likened to electric shocks?—Yes.
1769. At that time were both windows open, or only one?—Only one.
1770. The one to windward?—Yes.
1771. Did you open the other one?—No, the other window was never opened.
1772. What carriage were you travelling in?—A first-class carriage.
1773. Do you recollect what part of the train it occupied relatively to the others?—I fancy about the middle.
1774. Did you feel any movement or oscillation while passing over the bridge, or any part of it?—Not the slightest.
1775. Did you feel any movement or vibration or oscillation in the carriage which you attributed to the strong wind?—No.
1776. The only thing you experienced was the effect of this kind of experiment which was tried at the suggestion of a fellow passenger?—That was all.
1777. Did you observe the state of the river whilst you were passing over it?—Yes.
1778. What was it?—Very rough.
1779. When did you arrive at Dundee?—Exactly at a quarter past 6 by the clock in the station.
1780. What was the wind like?— Exactly at a quarter past 6 by the clock in the station.
1781. (The Commissioner.) It was only those, what you call, electrical effects to which you attention was called by your fellow passenger, was it?—Yes.
1782. Not any effect upon the bridge itself?—No.
1783. Only he said there was a peculiar effect in the ears?—Yes.
1784. And that you felt?—Yes.
1785. (Mr. Barlow,) I presume in referring to that as an electrical effect you hardly, perhaps, mean electricity, do you, but something similar to an electric shock?—No, only similar to an electric shock.
1786. Something in the nature of a percussive effect?—Yes.

The witness withdrew.

(Mr. Ralston.) I am not quite sure about what Captain Greig said as to the comparison between the last gale and the gale of 1859; some of the gentlemen here are under the apprehension that he thought the last gale was stronger, but a question might clear up the matter.

(The Commissioner.) I understood him to say that on the 28th of December he found the gale equally strong with the one in 1859.

Examined by the Commissioner.

1787. You told us that to the best of your recollection it was a last gale on which you had ever experienced a gale of this sort. As this was in 1859, you thought?—It was in 1859, and the one on Sunday night was about similar, only the gusts on Sunday were more severe.
1788. That is to say, the gusts which came every five or 10 minutes were more severe on Sunday the 28th?—Yes.

The witness withdrew.
Examined by Mr. Trathan.

1789. You are the harbour master of Dundee?—Yes.
1790. How long have you occupied that position?—Eight years past.
1791. Do you remember Sunday the 28th of December?—Yes.
1792. When was it high water that day, in the afternoon tide?—At 2 30.
1793. At 2 30 what kind of weather was it?—Moderate weather then.
1794. Were you down at your office at the dock about that time?—Yes.
1795. How long did you stay?—A very short time.
1796. When were you back again at your office?—About a quarter to 6.
1797. At that time, what was the weather in comparison with what it had been at half past 2?—It was blowing fresh then.
1798. You were going to church in the evening, I think?—Yes.
1799. And went, did you?—Yes.
1800. While you were in church were you able to observe whether the wind was moderator or increasing?—Yes. We could see very much through the short time I was there. I was there about 10 or 15 minutes. I left about five minutes past 6, I think, the wind had commenced blowing, in gusts then. I had some little difficulty in turning the corner at the tidal basin; it is rather an exposed place, and after I got to the west end of the Custom House we got the full force of the gale again elsewhere. It was very strong then, and would be about ten minutes past 6. When I got upstairs I told my wife she should not go out, it was not safe, she was going to church too; but I went by myself. I had some struggle to get to church; it was blowing very hard in squalls.
1801. Was it beginning to be equally at that time, 6 o'clock?—Yes, by 6 o'clock the wind was blowing in gusts.
1802. You went to church?—Yes; while in church the squalls were very heavy at times; a little after 7 o'clock there was something very strange took place, like as if the side of the building, or some of the masts of something had given way.
1803. A great crash was it?—Most like something rolling along the roof, like as if something had been torn off or rolled along the roof just for a moment.
1804. Was there anything torn off the roof?—I do not think it.
1805. Was this the wind?—It was a very furious gust of wind just at that time.
1806. Did it produce any terror in your mind?—I knew it was blowing hard before, but when that gust came, I thought it was very bad indeed, and for a time it stopped the minister's voice; we could not hear the voice for a time. I thought it was damage to the building.
1807. Was the noise in church was that, noise repeated at any time?—Not that noise, but still it blew very hard at times.
1808. You knew the gusts were beating upon the church at intervals?—Yes.
1809. And I suppose you could hear the noise of it very well?—Yes.
1810. When did you leave the church?—Immediately the service was over.
1811. When was that?—I suppose about 8 o'clock.
1812. When you left the church some one told you that a train had gone over the bridge?—Yes.
1813. And you went down to your office?—I went to the railway station.
1814. What happened when you got there?—I found a number of gentlemen standing there waiting to go to Newport, but we could get no information from any one as to any accident.

1815. The talk at that time was only a rumour that this thing had happened?—I do not think it was known at the railway station.
1816. Had you not heard before you got there that the bridge was down, and the train was over it?—No; no one knew that the bridge was down then, but a gentleman ran in to tell this party that the Edinburgh train was over the bridge. It had just reached him when I came to him, and him and immediately went down to the railway station. I do not think any of these gentlemen at the railway station knew anything about it.
1817. Thus gentleman told them that the train was over the bridge, not that the bridge itself was down?—Yes.
1818. Being unable to get information at the station, you went to your own observatory?—Yes.
1819. What instruments have you in this observatory?—We have two very large telescopes.
1820. Anything else?—No, we have a weather glass.
1821. You have no instrument for testing the wind pressure?—None.
1822. When you got into your observatory did you use the instruments that you have, that is to say, the telescopes?—Yes. We shut the lower deck to prevent any damage being done to the observatory, and opened the west window. Our glass is generally placed looking down the river, not up the river. We turned the glass round to the west window, and I commenced at the north end of the bridge, and traced it out to a vessel's foremost that was lying there. I was looking at it to-day, and the same thing was observed with the steamer's foremost. I traced the bridge to her foremost, and her foremost interrupted the bridge. I moved the glass past her foremost, and there was no bridge. I told this gentleman, "There is no bridge now." I went to the south side with the glass, and traced the bridge to where it is left standing now, and I said, "There is no bridge; the bridge is gone."
1823. So you discovered that that part of the bridge which had been made high for purposes of navigation was down?—Yes, but to make sure I sent a man to my house for my night glasses, and we went along to the Tay ferries, to the superintendent's office, thinking that we could get a look at it there, but we could not see it there, and we went to the esplanade. Of course from the esplanade the thing was very plain, with the night glass we could see all the stumps standing.
1824. When you found that the bridge was down, what did you do?—I went away and ordered the steam tug to be got ready to go up to this station.
1825. Do you suppose there was no time lost in getting it ready?—Unfortunately, we could not get her afloat, it being low water, we would have to wait to get her afloat, so I went back to the ferries to get the superintendent to go out with the ferry steamer.
1826. Did you get him to go out with it?—He had gone with the ferry steamer to Newport, and left word that if it kept moderate he would go up when he came back.
1827. When he came back you went up?—When he came back I went up.
1828. What time was it when you left the Dundee side to go to the scene of the disaster?—About 10 o'clock. I really do not know the time exactly.
1829. You went out in the ferry steamer?—We went out in the ferry steamer and got round the middle bank, and got up to as near as it was prudent to go to the bridge.
1830. And there you put out a boat, I believe?—Yes.
1831. Did you go in the boat yourself?—Yes, I was the first man in the boat.
1832. And the captain of the ferry boat and some of the crew went in the boat?—One of the captains and two of the crew, and a master-rigger.
1833. Did you get with this boat close to the bridge?—Yes, we pulled up pretty much to the centre of where it had broken down; then we pulled away to the north till we got underneath the first standing girder, and then we came back south.

1834. You got to where the north end of the bridge was standing?—Did you observe in what condition that end of the bridge was?—Just as it is now.

1835. With the rails hanging over, slightly depressed?—We could see something hanging down; it was night time, though it was clear.

1836. Your opinion is that the end of the north part of the bridge is in the same position now as it was that night?—Yes.

1837. You left that, and pulled away where?—We pulled along the piers.

1838. On the east side or the west?—On the west side.

1839. And kept away south?—It was on the danger side of the piers, the wind being from that side, but we could not pull on the east side for fear of getting foul of the debris.

1840. From any stoppage that you observed, or any current, was there any indication that the debris of the bridge was lying to the east of the piers?—You could see the water breaking over it.

1841. That of course warned you to keep on the other side of the piers?—Yes.

1842. You went through the north piers?—We went through the north piers, and then came to the south.

1843. Did you keep as near as possible all along the piers?—Yes, as near as we could for the sea; the sea was very heavy at times.

1844. Was the sea running very heavy?—Yes.

1845. You saw no body floating about?—No.

1846. There was nothing you saw to pick up?—Pieces of wood.

1847. No luggage, or clothing, or anything of that kind?—No.

1848. Having seen that you were practically of no use to anybody or anything, you returned?—Yes.

1849. But I take it that you were there sufficiently in time, and were sufficiently on the look out, to have rendered any assistance if assistance had been of any use to anybody at that time?—Yes.

1850. And you made sure that you could not be of any assistance before you returned?—Yes.

1851. You came back then and had an interview with Provost Brownlee and Mr. Cox, the ex-Provost, who was acting on behalf of the railway company?—Yes.

1852. And you arranged to have divers ready for the next morning?—Yes.

1853. And have they been working at intervals since then?—Yes, at every opportunity since then.

1854. I do not want anything that you have merely been told, but can you give us from your own observation what has been the course of action on the part of the divers, and what the results have been?

1855. (Mr. Treverner.) You have been out a good deal with the divers?—Yes, always.

1856. Have you been in some measure superintending the diving operations, I mean directing the places at which the barges are to be moored, and the places where the men are to go down?—Yes.

1857. I may take this from you generally, have the diving operations been conducted in accordance with your orders as given?—Yes.

1858. And up to this point to your satisfaction?—Yes, quite so.

1859. Have you seen anything recovered by the divers?—Yes.

1860. What?—The first trace that we got of the train was on Wednesday afternoon, the divers came up, or one of the divers belonging to the harbour trustees came up, and he said when he got on the barges, "we have got something now."

1861. Do I care so much what he said unless he brought something with him?—He pointed to his line for us to haul upon it, and we hauled upon it; I was afraid that the men would break the line, and I told them to stop as the tide had commenced to run flood pretty strong, and I told the diver to go down and cut a piece off whatever it was; he said it was something like tarpaulin or cloth; I said to him, "Cut a bit off, go down and bring a bit of it up, let us see what it may be," he said he thought there was a line in it, and he went down, and when he came up there was fast to the line a piece of lining with the stuffing of a first-class carriage.

1862. Cloth lining?—Yes, blue cloth lining and hemp stuffing, and also he cut off a piece of waxed floor-cloth, and brought it up with him, it was not possible for the divers to go home with the melancholy satisfaction that we had at last found a trace of the train.

1863. That was on Wednesday?—On Wednesday afternoon; perhaps those gentlemen here will remember what day it was.

1864. Wednesday was the 31st, was it Wednesday that the man brought this up?—It was Tuesday. I was wrong.

1865. Tuesday the 30th?—Yes.

1866. Nothing else was done that day?—No.

1867. Was anything got or done of any moment, that you saw, on the 31st, the Wednesday?—That day we made fast a rope to the spot where the man cut this stuff out, and when we went back the next day we sent him down by this line, and when he came up he told us that he had been into the first-class carriage, but there was not anything in it.

1868. He brought up nothing?—He brought up something. I forget what they were, but the other diver went down immediately close to this one.

1869. What is the name of the first diver that you have been speaking of?—John Fox.

1870. What is the second diver's name?—Simpson.

1871. Simpson went down afterwards?—He went down at the same time out of the Tay Bridge steamer; he went into a third-class carriage when he went down, he came up and told us that he had been into a third-class carriage; he went down again and said, "I have been into another third-class carriage;" he went down again and he says, "I have been now on the engine," so we came away then, but very much disheartened.

1872. What I am anxious to get is opinions but results. On that day you got nothing?—Only the satisfaction of finding the carriages.

1873. The divers discovered two carriages and the engine?—Yes.

1874. Were you there on the 1st of January at all?—Yes, we were there on Thursday too.

1875. On the 1st of January was anything recovered?—There were some sort of foot-pads and lamps, but they were looking again more for the latter portion of the train.

1876. Nothing in point of fact except these lamps and foot-pads was brought away on the 1st of January?—Nothing.

1877. Then on the 2nd what was done?—We started, but it came on to blow a gale of wind before we could get to the spot, and we came back.

1878. On Saturday you had a good day; what was got on Saturday?—We did not get very much, only some lamps and things; we supposed that the remainder of the train was behind, but all to pieces.

1879. Did you have anything brought up yesterday?—We were there yesterday; we went over from where we started first; we did not start exactly at the southernmost pier first, we started about the second pier, and yesterday we went from the second pier to the south, where the bridge is standing, and found no trace of any carriages.
1897. \( \text{Mr. Balfour.} \) For how long during each tide, or at the slack of each tide, can the divers work?—They have been working with a pretty strong ebb tide, and also till the tide got pretty hot flood tide; they have been working two and a half hours.

1898. \( \text{Mr. Balfour.} \) That is part of the ebb and part of the flow and the slack?—Yes.

1899. \( \text{Mr. Balfour.} \) That is about the maximum time that you can work?—Yes.

1900. \( \text{Mr. Balfour.} \) Is it possible for the divers to work at the slack which occurs at low water, and also at the slack which occurs at high water?—We did so when it was daylight.

1901. \( \text{Mr. Balfour.} \) Can the divers work except in daylight?—Perhaps some divers can. I would not like to put a man amongst such debris as that in a widow at night time.

1902. \( \text{Mr. Balfour.} \) It would not, in your judgment, be safe?—I would not do it.

1903. \( \text{Mr. Balfour.} \) So that, practically, they are limited to the slack water, either at the top or the bottom of the tide during daylight?—Yes.

1904. \( \text{The Commissioner.} \) That is to say, about 24 hours every day, on the average?—Some days we have two tides.

1905. \( \text{Mr. Balfour.} \) The tail light you say was about 40 feet astern of the first-class carriage?—Yes.

1906. \( \text{Mr. Balfour.} \) In that interval of 40 feet you suppose there was the guard's van, two third-class carriages, and a second-class carriage?—Yes, two thirds and a second, but they have been knocked all to pieces; there is not a vestige of the workman.

1907. \( \text{Mr. Balfour.} \) That tail light was 40 feet astern of the first-class carriage?—40 to 50 feet.

1908. \( \text{Mr. Balfour.} \) When you first began your operations did you go at once to this particular place, or did you search all along beginning from the north end?—When we went up with the steamier that night I saw a portion of the girders above water.

1909. \( \text{Mr. Balfour.} \) That is where you began, is it?—I thought to myself, surely there was some cause for it, being above water, and none of the rest, so we commenced operations there, working north.

1910. \( \text{Mr. Balfour.} \) And you found nothing working north of that?—We found nothing north of that till we came to the first-class carriage.

1911. \( \text{Mr. Balfour.} \) Does the first-class carriage lie north of where that girder stands up?—Yes; perhaps 500 or 600 feet.

1912. \( \text{Mr. Balfour.} \) 500 or 600 feet north of where that stands up?—Of where we commenced.

1913. \( \text{Mr. Balfour.} \) The tail light stood north of that too, did it?—North of where we commenced, but south of where we found the first-class carriage.

1914. \( \text{Mr. Balfour.} \) But north of where you commenced?—Yes.

1915. \( \text{Colonel Yolland.} \) Can you tell where about the engine was, in which opening, between the first and second piers, the second and third, the third and fourth, or the fourth and fifth, reckoning from the south?—The engine is lying nearly up to the fifth broken pier.

1916. \( \text{Mr. Balfour.} \) The engine lies south of that pier, does it?—A little south.

1917. \( \text{Mr. Balfour.} \) And on the eastern side of the bridge?—Quite so.

1918. \( \text{Mr. Balfour.} \) Have you any idea how far it is away from the bridge east of the piers?—I do not think it is over 40 or 50 feet at the outside.

1919. \( \text{Mr. Balfour.} \) How far south from the fifth pier?—Just immediately south of it; very little to the south of it; very nearly in the east line of it.

1920. \( \text{Mr. Balfour.} \) Can you say whether any portion of these remains that you have been alluding to were found south of and on the eastern side of the fourth pier?—What we found belonging to the missing carriages was to the south of the fourth pier.

1921. \( \text{The Commissioner.} \) That is to say the lamps?—Yes.

1922. \( \text{The Commissioner.} \) Were those lamps far from the brick and stone work of the piers?—The lamps were just outside of the fallen girders, where the girders have tumbled down; the lamps were immediately just outside them on the ground on the east side of the girders; just immediately on the east side.

1923. \( \text{The Commissioner.} \) Can you distinguish between the top of the girders and the bottom of the girders?—Yes, the divers go underneath the girders; the girders are lying on their east side.
1924. Was the engine found between the girders?—Inside of the girders.

1925. Were the lamps found inside, or further east?—They were immediately on the east. The girder is lying to the eastward, and the lamps were immediately down there.

1926. Has anything been found so far south as the third girder from the south end?—Nothing.

1927. At what distance do you suppose the tail lamp that you allude to was south of the fourth pier?—20 feet, or 40, or 60 feet?—The tail lamp would be perhaps 50 feet south of the fourth pier, and these other lamps betwixt that and the end of the first-class carriage.

1928. (Mr. Truener.) When you say the fourth pier, you mean counting from the south?—Yes.

1929. (The Commissioner.) You say that the engine is a little to the south of the fifth of the broken piers, that is counting from the south, and that the tail lamp was 40 to 50 feet south of the fourth pier?—Yes; say 60 feet.

1930. (Colonel Yolland.) I have not heard nor seen any allusion to the tender, is it supposed to have been separated from the engine?—That I do not know; I intended to have had a thorough examination of the engine to-day, but after we got there I thought it was still more important to persevere and try to find the remains of the missing carriages. There has been one diver at the engine to-day, but I have not heard his report, but I may get more particulars about the engine to-night.

1931. (Mr. Barlow.) At what time was it low water on the night of the accident?—About half-past 8.

1932. The tide continued to fall after the accident?—Yes, the stream of the tide will run down an hour after low water nearly; with such a wind it would continue to run down for an hour.

1933. You spoke of one part of the girders being visible above the water, what is it lying on to render it visible?—It is bent up; the ground is rather shallow there, and the girder is bent up.

1934. Can the men get underneath the girder there?—Yes.

1935. It is not resting upon any bed of gravel, or anything of that sort?—No, what was the top of the lower girder which is now lying broadside the farthest east portion of it is all above the ground about a man's height, it seems to be lying on the edge of the bottom, and lying with a little cant to the westward.

1936. Not resting upon gravel or stones?—The divers get right underneath it.

1937. At about the level of a man's breast?—Yes; and in some parts where it is bent upwards they cannot touch it at all.

1938. (Colonel Yolland.) You are speaking now of the right girder?—Yes.

1939. (The Commissioner.) All the evidence that you have been giving with respect to the position of these girders and so forth is derived from the reports of the divers to you?—As to what is under water; at that part that is highest above the water the girder is broken at the strongest part.

1940. (Colonel Yolland.) At the second pier?—About the second pier, a little to the north of the second pier, that girder is broken there at the upper side of it.

The witness withdrew.

Examin'd by Mr. Truener.

1941. You are in the employment of the North British Railway Company?—Yes.

1942. Under Mr. Roberts, the locomotive foreman?—Yes.

1943. And you inspect, I understand, the engines and tenders from time to time to see that they are in proper working order?—Yes.

1944. And you also take care that any repairs that are necessary are done?—Yes.

1945. You know the engine that was lost on Sunday the 28th of December?—Yes.

1946. When had you last inspected that engine before that Sunday?—On Saturday night.

1947. Saturday night, the 27th?—Yes.

1948. What condition was it in?—Good order.

1949. Did you examine both engine and tender?—Yes.

1950. Both were in good order?—Yes.

1951. Were they needing any repair?—No, they were in good order.

1952. They were in such order as you felt it right to let them go out?—Yes.

1953. If the engine or the tender had not been in good order, what would it have been your duty to do?—If it was in my power to do so, to make the repairs, and if not, to stop the engine from going out.

1954. To repair at once, if any repair was needed, that you could do yourself, and if not, to prevent it going out?—Yes.

1955. Were you quite satisfied that the engine and tender were fit for work and should go out?—Quite satisfied.

1956. And so you passed them?—Yes.

1957. That was on the night of Saturday, the 27th?—Yes.

The witness withdrew.

Adjournd to-morrow at 11 o'clock.
THIRD DAY.

Tuesday, 6th January 1880.

James Young sworn.

Examined by Mr. Traynell.

1888. You are, I believe, a carriage and wagggon inspector in the employment of the North British Railway Company?—Yes.
1889. You are stationed at Burntisland?—Yes.
1890. How long have you been stationed there?—Four years past August.
1891. You are a track-lifter in their employment before that time?—Yes.
1892. Were you at Burntisland on the 28th of December last when the train that was lost came in from Dundee in the morning?—Yes.
1893. I believe it was then put in to the platform to stand until it returns in the evening?—Yes.
1894. Was that done with it then?—Yes.
1895. After it was placed in its position, did you examine the carriages?—Yes.
1896. How did you examine them? what did you do?—Tapped the wheels and examined the axle boxes and springs and underneath the couplings.
1897. I suppose you did that in order to satisfy yourself that everything was in order?—Yes.
1898. Did you also examine the couplings?—Yes.

1899. In 1958, had the engine a brake?—Yes.
1900. Was there any defect?—No.
1901. Was the engine new?—Yes.
1902. Did you find anything wrong, or did you find anything right?—I found all things correct.
1903. There was none of the gear wearing?—No, everything was complete.
1904. Did you count the number of carriages?—No.
1905. Did you ever know a carriage blown over by the wind during the whole of your experience?—No, not in my time.

The witness withdrew.

William Robertson sworn.

Examined by Mr. Traynell.

1906. You are a carriage and wagggon inspector at Leuchars Junction, and in the employment of the North British Railway Company?—Yes.
1907. 1884. How long have you been an inspector in their employment?—I entered their employ in the year 1848.
1908. 1885. How long have you been an inspector?—I think 28 years.
1909. 1886. Did you examine the carriages that composed the train, that was lost on the night of the 28th of December when it came to Leuchars Junction?—Yes.
1910. 1887. It breaks off from Leuchars Junction and goes round to St. Fort to take the bridge?—Yes.
1911. 1888. How did you examine them?—I tapped the wheels and examined the axle boxes.
1912. 1889. Did you find anything wrong, or did you find everything right?—I found all things correct.
1913. 1890. There was none of the gear wearing?—No, everything was complete.
1914. 1891. Did you count the number of carriages?—No.
1915. 1892. Did you ever know a carriage blown over by the wind during the whole of your experience?—No, not in my time.

The witness withdrew.

Edward Simpson sworn.

Examined by Mr. Traynell.

1916. Where do you live?—At 33, Crofts Lane, in Dundee.
1917. 1893. You are a diver?—Yes.
1918. 1894. You were employed by the North British Company to dive at the Tay Bridge after the accident?—Yes.
1919. 1895. When were you employed?—I was employed on Monday afternoon.
1920. 1896. That would be the 29th?—Yes.
1921. 1897. What were your instructions?—To go on Tuesday morning to the scene of the wreck, and go down and see what I could discover.
1922. 1898. How long have you been a diver?—Between four and five years altogether.
1923. 1999. On Tuesday, the 30th did you go to the scene of the wreck?—Yes.
1924. 2000. One: How many dips did you make on that day?—One.
1925. 2001. How many dips did you make on that day?—Yes.
1926. 2002. What did you go down from?—On a small steam launch at Tay Bridge.
1927. 2003. At what part of the broken bridge?—I went down at No. 7 pier.
1929. 2005. Do you count from the pier that is standing, or from the first pier that is down?—I count from the pier that is standing.
1930. 2006. You went down off the sixth pier that is broken from the south?—Yes.
1931. 2007. How long were you down?—I could not say.
1932. 2008. Did you find anything?—Nothing but a girdar that day.
1933. 2009. Did you find anything?—Nothing but a girdar that day I came across that.
1934. 2009. Could you see it so as to make any inspection of it?—No, I could only feel it.
1935. 2010. Was your examination then a long one?—No.
2011. Did you get any information on the first occasion of your going down on the condition of the girders?—No; other than that the girders were lying, upon its broad side, the head of the girders lying towards the east, and the foot towards the west, in the remainder lying, as it were, north and south.

2012. On Wednesday, the 31st of December, you returned?—Yes.

2013. How many dips did you make on that occasion?—I could not exactly say, three or four dips.

2014. When did you make your first descent on Wednesday, and at what time of the day?—I cannot tell.

2015. Was it in the forenoon?—Yes.

2016. You can only work at a certain state of the tide?—Yes.

2017. Did you occupy on each of the dips as much time and give as much attention to the inquiry as you could?—I gave as much time and attention to the inquiry as I could.

2018. On Wednesday when you made your first dip, where did you go down?—I went down at the scene of the wreck, and fell in with a third-class carriage.

2019. At what pier was that?—Between No. 4 and No. 5 piers.

2020. (The Commissioner.) Counting which way?

2021. (Mr. Trayer.) You always count, I suppose, from the south?—Yes.

2022. And that No. 1 pier is the first pier on the south that is broken?—Yes.

2023. That is your basis of calculation all through?

2024. What did you find?—I found a third-class carriage.

2025. How was it lying?—Partly on its side; it was then casting towards the eastward, lying hard up against the girders.

2026. Its head was lying towards the eastward rather?—Partly.

2027. Was its head up against the girders?—Yes, the head was completely off, the roof was.

2028. In what position was the part of the carriage that was existing?—Up against the top part of the girders.

2029. (Mr. Barlow.) The top of the carriage was touching the top of the girders; was it?—The parts that were left of it were touching the top of the girders.

2030. (Mr. Trayer.) The part of the carriage still remaining was close up to the top part of the girders?—Yes; I got underneath; I went into it.

2031. Was the floor out of it?—No.

2032. You got in at one of the sides?—Yes, I got in at one of the doors.

2033. Except a break of the head of it, which was gone off, was the carriage otherwise entire?—No, parts of the sides were away.

2034. Was any part of the roof gone?—There was no part of the roof, that I could see there remaining; parts of seats were away, and some whole seats were away.

2035. The carriage was a complete wreck?—Yes.

2036. Did you find anything in the carriage?—No, nothing, only gravel.

2037. You brought up nothing from it?—No.

2038. After you had discovered what you have described, did you go?—I was called up, and we shifted a little further towards the fifth pier, and went down there and discovered the engine.

2039. How was the engine lying?—It was lying on its side.

2040. What was the position of its head?—The funnel towards the east, with its head towards the north.

2041. Was it pretty straight towards the north?—Yes.

2042. Did you discover the tender?—A part of it only. I could not get along to examine any more of it.

2043. As far as you could get you found that the tender was attached to, or behind it?—Yes.

2044. Was it attached to it?—I could not see that.

2045. Is there a good deal of sand silted up now, and gravel?—Yes, a great deal of sand; the girders is quite clear, almost.

2046. What do you say about the carriages or the engine?—The boiler is a little immersed among the sand.

2047. Having got as far as you could towards the tender, can you tell me how the tender is lying?—It is lying on its side, the same as the engine.

2048. You say you went down on this occasion a little nearer No. 5 pier?—Yes.

2049. How far from No. 5 pier is the engine lying, do you think?—I should think about 50 feet. I cannot say exactly.

2050. In what direction is it lying?—Toward the south.

2051. And the tender still further to the south?—Yes.

2052. As far as you can judge, it was in a continuous line with the engine?—Yes, in a continuous line with the engine.

2053. How is the girders there with reference to the engine and tender?—The girders is partly broken where the engine is lying.

2054. Above?—No, below it; the lattice work.

2055. Is the whole of the engine and the tender inside the girders?—Yes.

2056. Then there is part of the iron work of the bridge below and part above the engine and tender?—Yes.

2057. And the part below is broken?—Yes; the part above, I fancy, it was.

2058. But you cannot tell?—No.

2059. You brought up nothing from the engine or the tender?—Yes, I brought up the carriage lamp.

2060. Anything else?—Nothing else.

2061. That was your second descent that day; did you go down again?—Not till the afternoon.

2062. In the afternoon did you go down a third time on that day?—Yes.

2063. Where did you go down?—I went down, and dropped on the first-class carriage.

2064. From the pier?—It was close upon No. 4 pier, between No. 4 and No. 5 still.

2065. A little to the north of No. 4?—Yes.

2066. There you dropped down upon the carriage?—Yes.

2067. Did you get into it?—Yes.

2068. Is it entire, or was that also wrecked?—That is also wrecked.

2069. When you got into it did you feel anything?—I felt the cushions and things.

2070. Did you bring up anything?—Nothing.

2071. But did you examine the carriage so as to ascertain whether there was luggage or a body in it?—Yes.

2072. And you found nothing?—I found nothing.

2073. I think that exhausts your visits to the wreck on Wednesday?—Yes.

2074. How does the girders lie with reference to the first-class carriage?—Just the same, it is in continuation all along.

2075. Then it lies inside the girders, part of the girders being below, and the other side of it above?—Yes.

2076. Then on Thursday, the 1st of January, did you go down?—Yes.

2077. How many times did you go down?—I went down twice that day.

2078. Then where did you go down first?—Between No. 3 and No. 4.

2079. South of No. 4 pier?—Yes.

2080. How far south of No. 4, or how far north of No. 3, was it that you went down?—I was close to No. 3 than to No. 4.

2081. You cannot give me the feet?—No, I cannot.
2089. When you went down on the first occasion did you find anything there?—Nothing. Nothing but the girder in the same position.

2089. And that you thought was in the same continuous line with that which you had discovered at a point further north?—Yes.

2090. You found no carriages?—No.

2091. Nor any sign of the train?—No.

2092. On the second descent on the 1st of January did you go down just about the same place?—Yes.

2093. With the same result?—Yes.

2094. On Friday, the 2nd of January, you were not down were you?—No, it was stormy.

2095. On Saturday, the 3rd, did you go out?—I was not down that day.

2096. On Sunday last, the 4th, you were down, I believe?—Yes.

2097. How often were you down?—Three times.

2098. The first time you went down where?—I went down between No. 3 and No. 4 piers, about I would say, 60 or 70 yards from No. 4, south of it.

2099. (Colonel Yolland.) That would be close to No. 8?—It was not far from No. 3.

2100. (Mr. Travers.) Having got down there what was your course of procedure?—I searched along No. 4.

2101. Northward to No. 4?—Yes, towards No. 4.

2102. What did you find first?—When I came within about 60 feet of No. 4 I got a carriage lamp, the side lamp of the brake van.

2103. In what condition was it when you brought it up?—It was whole, all but the red glass; that was cracked a little.

2104. Where did you find it?—Close beside the boom.

2105. The boom of what?—The boom of the girder underneath it.

2106. (Mr. Barlow.) The upper or lower boom?—The lower boom, but belonging to the top of the girder.

2107. (Mr. Travers.) The girder, then, there is broken?—Not just there.

2108. I mean where you found the lamp?—Where I found the lamp it was not broken.

2109. You thought this belonged to the brake?—Yes.

2110. Did you find anything there?—Yes, I got two plates there.

2111. They were part of what?—I thought they were part of the bridge; some of the flooring of it.

2112. It was what you found first on your progress northwards?—Yes, on my progress northwards.

2113. After finding this did you come up?—No.

2114. You went on?—Yes, I went on and discovered a girder broken.

2115. How far was that north of that place where you found the lamp?—About 20 feet, I think; I cannot say exactly.

2116. (Mr. Barlow.) It would be about 40 feet from the pier, I think?—Yes.

2117. (Mr. Travers.) You found there that the girder was broken?—Yes.

2118. Did you find anything else on that occasion?

2119. That was your first descent on Sunday; did you go down again?—That was my three descents altogether.

2120. You have described the result of the three descents?—Yes, that was all in one tide.

2121. On each occasion you went down at the same place and pursued the same line?—Yes.

2122. Then you brought up these things as you got them?—Yes.

2123. Then were you down yesterday?—No.

2124. Then you examined in that way from a little north of pier No. 3 to just above pier No. 5?—Yes.

2125. Do you say that you found the girders lying, so far as you can judge, almost in a continuous line between those points?—Yes.

2126. Broken near to the north of No. 3 pier, where you found the lamp broken; did you find the girders broken in any other place?—At the engine; the place where the lamp was found, near the engine.

2127. The whole length of that girder, so far as you can judge, is lying on its side?—Yes.

2128. Is it lying north and south, or pointing eastward at all?—I think it is lying north and south, but I could not see in the dark.

2129. But your impression, from grogging along, is that it is lying north and south?—Yes.

2130. And the engine and tender and carriages that you have been in are all inside the girders?—Yes, they are all inside the girders.

Examined by Mr. Balfour.

2131. Am I right in understanding that all the carriages that you have found are part of a third-class carriage and part of a first-class carriage?—Two-thirds.

2132. But nothing else except the engine and the tender?—No, and the lamp.

2133. You told us that you found part of the girder broken, and you described clearly where the engine and tender were?—Yes.

2134. Was the latter work that you found part of a broken girder?—Yes.

2135. Did you find any part of the boom of the girder broken?—Not there.

2136. Where did you find any part of the boom of the girder broken?—To the south; the last thing I saw there was a broken girder.

2137. Did you find anything else on that occasion?

2138. Which of the two parts were separate from each other?—They were about that (describing) separate.

2139. Eighteen inches?—Yes, I could go between them.

2140. Which of the booms is that?—The top east boom as the girder was standing in its proper position.

2141. When it was standing as it is now, it would be the lower boom, as it lies now?—Yes, as it lies now.

2142. Because the side of the girder that is lying on the ground was what was the east side when it was standing up?—Yes.

2143. Did you discover any of the beams of the girder broken in any other place than what you have described?—No.

2144. As far as you have been able to discover?—No.

2145. Then is there anything else in regard to the position of the girders that you found?—No; I have told you everything.

2146. (The Commissioner.) I understood you to say that the lamp of the brake was found, so far as you can judge, 60 feet south of No. 4 pier;—Yes; but that is diagonally from the pier.

2147. But in a straight line from the line of the pier?—I understand you to say that the girder was found somewhere like 50 feet out from the line of the pier?—One part of the girder I should reckon was 20 feet, and the couplings together 27 feet 2 inches.

2148. Twenty feet is what you would have called the bottom of the girder?—Yes.

2149. The bottom would be 20 feet from the line of the pier, and the part lying eastward was 27 feet more, making 47?—Yes.

2150. Then you think that this lamp was found in a straight line from No. 4 pier, about 60 feet?—Between 50 and 60 feet, as nearly as I can recollect.

2151. The lamp was close to the top of the girder?—Yes.

2152. And outside of it?—Underneath it.

2153. You observed at something like 40 feet to
the north of it the boom of the girder was broken?—Yes.

2149. Was that the upper boom of the girder, as I understand you?—The original upper boom of it.

2150. On the east side?—Yes.

2151. Did you examine the lower boom of the girder on the east side?—No.

2152. Not at all?—No.

2153. You do not know in what state that is?—No.

2154. (Colonel Yolland.) Is the upper boom on the eastern side or the right side, or on the western side?—On the eastern side, the boom is on the eastern side, too right side.

2155. When you say it was the upper boom on the girder, do you mean the upper boom on the right hand side looking north, or the upper boom on the left hand side looking north?—The upper boom on the right hand side looking north.

2156. (The Commissioner.) Which is now lying in the bed of the river?—Yes.

2157. (Mr. Barlow.) You mentioned that the third-class carriage which you found there was lying near what was the top of the girder, which is now lying to the eastward; how did you find the engine?—It is far nearer the bottom of the girder; that is to say, to the westward. (The Commissioner.) The Court would suggest to the gentlemen representing the Board of Trade that it would be very desirable to have photographs taken of the different piers of the bridge.

(Mr. Munro.) Certainly. A photographer is present, I understand.

(Mr. Barlow to the Photographer.) I would suggest that you should place your instrument upon No. 3; and from that position take photographs of the south-side of No. 4, and the north-side of No. 2, could you do that?

(The Photographer.) Yes.

(Mr. Trayner.) And so on over the whole of the piers?

(The Photographer.) Yes.

(Mr. Trayner.) Would the Court also desire to have a separate photograph of each individual pier?

(The Commissioner.) Yes.

(Colonel Yolland.) And a general view from the north end and from the south end?

2158. You mentioned that the lattice work of the girder, underneath the engine, as it now lies, is broken?—Yes.

2159. Could you get under that lattice work?

2160. How did you get to find that it was broken?

2161. Was the lattice work actually separated?

2162. It was not simply buckled?—It is actually broken.

2163. As regards the past of the girder that is broken, is it that part which is lying at the lowest side on the right hand side looking north?—Yes.

2164. You looked at all the other parts, and you say that they are not broken?—I did not look at all the other parts; that is only what I discovered in my search.

2165. Therefore you do not know that the rest were not broken?—No.

2166. Do you know that the one immediately over the one that is broken is still unbroken?—I cannot say that.

2167. (Colonel Yolland.) Can you say whether you saw the bottom boom on the other side broken?—Only the one boom I have described, that is the upper boom.

The witness withdrew.

Examin'd by Mr. TRAYNER.

2168. You are a diver?—Yes.

2169. Do you reside in Dundee?—Yes.

2170. By whom were you employed to go to the scene of the wreck of the bridge?—The Harbour Master, Captain Robertson; I am employed by the Harbour Trustees.

2171. When did you go out first?—On Monday morning.

2172. The 29th of December?—Yes.

2173. How many dips did you take on Monday?—One.

2174. Where did you go down?—South of No. 3 pier.

2175. That is the third broken pier counting from the south?—Yes.

2176. How far south of No. 3?—South of No. 3, 30 feet, I think.

2177. What did you find?—I found a girder.

2178. How were the girders lying?—They were lying on their sides.

2179. Did you travel north or south from the point where you descended then?—I travelled both ways along.

2180. Did you find girders both north and south from the point where you descened?—Yes.

2181. Keeping a continuous line?—Yes.

2182. Did you find any part, or examine at any time to see if any part, of a girder was broken?—I found none of it broken.

2183. On that first occasion did you discover anything else?—No.

2184. That was all you found on the first dip on Monday?—Yes.

2185. On Tuesday the 30th how many dips did you take?—Two, the first one in the forenoon and the next one in the afternoon; and I got on the north mile of No. 3 girder.

2186. How far north?—I travelled for the most part between two piers on the Tuesday.

2187. You went down near No. 3, but to the north of No. 3, and travelled from there, how?—Northwards.

2188. To No. 4?—Yes.

2189. What did you find between No. 3 and No. 4?—I found nothing on Tuesday in the forenoon but just the girders.

2190. Much the same as on your previous visit between No. 2 and No. 3?—The same.

2191. Lying in the same position as nearly as you could judge, in the same line?—Yes.

2192. How far east of the pier is the girder lying?—I reckon about 30 feet.

2193. What part of the girder?—The bottom floor of the girder.

JOHN COX sworn.

2194. Did you find any broken part of the pier?—Yes.
2194. That was your morning dip on Tuesday; what did you do in the afternoon?—I went down to the north of No. 4 pier.
2195. Did you go much to the north of No. 4 pier, or close to No. 4 pier?—I went between 20 and 30 feet north of No. 4 pier.
2196. Did you find girders there?—I found a girder, and the first-class carriage.
2197. You found girders there?—Yes.
2198. Lying on their sides, in the same line as before?—Lying on their sides, in the same line as before.
2199. Did you find any part of the girders broken?—Not to the northward of the pier.
2200. You found the first-class carriage, you say?—Yes.
2201. Was it entire, or was it wrecked?—It was wrecked. The roof was completely off and the windows and doors broken.
2202. Was there any part of the door hanging to it?—There was one door; the southernmost door of the carriage was hanging to it.
2203. Had it been shattered?—No, not at all.
2204. Was it on its hinges?—Yes, the door swung on its hinges.
2205. I suppose in that first-class carriage there were at least three doorways?—There were three doorways and three windows.
2206. But there was only one door, the southernmost one, that remained?—Yes.
2207. Did you go through the carriage to see if anything was in it?—I examined it thoroughly.
2208. And you found nothing?—No further than cushions and some broken pieces of wood.
2209. Did you bring anything up?—Yes, I brought some cushions up and some of the oil cloth belonging to the floor of the carriage.
2210. If that all that you discovered on your two dips on Tuesday the 30th?—Yes, that was all.
2211. On Wednesday the 31st, how many times did you go down?—Twice on Wednesday.
2212. Where did you go down the first dip on Wednesday?—At the first-class carriage. I did not examine it on the Tuesday, because the tide was too strong to examine it.
2213. The tide was too strong, you say?—Yes.
2214. And your time was up?—Yes.
2215. On Wednesday, the first time you went down you went to the first-class carriage, did you not, and made a careful examination of it?—Yes.
2216. And found all the doors?—Yes, and went inside the carriage.
2217. It was on Wednesday that you brought up the cushions?—Yes, and some oilcloth. On Tuesday night it was hanging out of the carriage, jammed between the carriage and the top part of the girder.
2218. It was on the Wednesday that you brought up the cushions?—Yes.
2219. How did you find the girder in connexion with the carriage?—The carriage was lying hard upon the east side of the girder, that is the top part of the girder.
2220. The side nearest the ground now?—Yes. (The Commissioner.) No, that is the top part of the girder. (pointing.)
2221. Mr. Trauger) Ho means the top part of the east girder. (To the Witness.) Both tops of the girders are now looking to the east?—Yes.
2222. And you found the first-class carriage hard against which of those girders?—Against the top of the girder looking to the eastward.
2223. Inside of the girder?—Yes.
2224. Did you find the girder broken there?—No, I did not find anything broken.
2225. Did you find anything else on that first dip on Wednesday?—No.
2226. Where did you go down on your second dip on Wednesday?—To the south of No. 4.
2227. When you got down, how did you travel, north or south?—Southwards.
2228. Did you find anything south of No. 4?—Nothing but the girders.
2229. In the line and in the condition you have described before?—Yes.
2230. Was that the whole result of Wednesday?—Yes.
2231. On Thursday, the 1st day of January, I believe you went down once?—Yes.
2232. On that occasion I believe you went to the first-class carriage, which you have before described, to make a thorough examination of it?—Yes.
2233. Did you make a thorough examination of it?—Yes.
2234. You found, I suppose, that the doors and windows, except one door, were gone?—All.
2235. How was the roof?—It was completely off.
2236. And the floor, how was that?—I believe it was all whole so far as I could find.
2237. How was the carriage standing?—It was standing upright on its wheels.
2238. Did you make a careful examination of it on that occasion?—Yes.
2239. I believe you did nothing else on Thursday?—No.
2240. Is there anything about the state of the carriages that you can tell us; how was it, bowing northward?—Yes, north and south.
2241. The two ends of the carriage?—I did not find the north end of the carriage, but the south end of the carriage was all whole.
2242. Are the three compartments of the carriage distinct?—On the inside, indeed, I could find nothing but the shell of the carriage.
2243. Then is it a carriage in which you could pass from one end to the other now?—Yes.
2244. The inside has been completely shattered?—Yes, there is nothing, only the cushioning and padding through it.
2245. On Friday, the 2nd of January, you were not down, I believe; it was too stormy?—Yes.
2246. On Saturday the 3rd, did you go down?—Yes.
2247. How often?—Once.
2248. Where did you go on Saturday?—The south side of No. 4, to look for the hindermost part of the train.
2249. South of No. 4, did you find anything?—Nothing but a girder and some lamps.
2250. You found some girders as before?—Yes.
2251. Did you find some lamps?—Yes.
2252. How many?—About eight or nine of them altogether. I found eight.
2253. Are those side lamps or lights that are put into the tops of the carriages?—They are the roof lamps.
2254. Did you find them in any hue, or were they scattered about?—They were scattered. I found one of them inside the girder.
2255. And others outside?—Yes.
2256. Were they to the east of the girders or to the west of them?—East of the girders.
2257. All to the east?—Yes, all to the east.
2258. How far to the east of the pier?—About 30 feet.
2259. Did you find any trace of a carriage or wall at that place?—Nothing further than some of the door railings belonging to a third-class carriage.
2260. What railings do you mean?—Horizontal, I think they are.
2261. You mean the handle or iron rod that runs along?—The iron rod.
2262. Those have all been brought up?—Yes.
2263. You found no trace of any van?—No.
2264. Or of a carriage to the south of the first-class carriage that you have described?—No.
2265. I need not ask you if your examinations on all these occasions were very carefully made?—They were as careful as I could make them.
2266. Then the getting up of this handle or iron rod that you have mentioned was the only result of Saturday's work?—That was all.
Examined by Mr. BALFOUR.

2290. Did you find the water thick and muddy on these different occasions when you have been down?—Yes.

2291. Were you able to see in it?—Not much.

2292. Is what you have described to us what you ascertained by feeling?—All by feeling.

2293. You told us that on the first occasion, which I think was Monday, you went along a part of the girder; what length of the girder did you feel along?—Between 40 and 50 feet.

2294. The different lengths at different times, as far as you could easily get?—Yes.

2295. In speaking of the state of the girder you have spoken only of the piece which is now lying lowest, being the part that was eastward?—Yes.

2296. Have you been able to find the condition of what is the upper part that lies now in those places before it came down?—Some part of it.

2297. Not so much as of the other?—No.

2298. (The Commissioner.) You have said that the only portion of the boom that you did find broken is that piece which is now furthest to the east, which is the lowest part?—Yes.

2299. That was, as you have said, the upper east-right-hand boom?—Yes.

2300. Now, have you at all examined the lower right-hand boom, which would now be to the west?—No, I have not examined that.

2301. Now, have you examined any portion of the permanent way which, I suppose, would be to the west now?—No, I have examined no portion of it.

2302. You have not told us exactly what was the position of the first-class carriage that you examined carefully relatively to the fourth pier; is it to the north or south of it?—To the north of the fourth pier.

2303. How far to the north of it?—About 40 feet, as far as I can judge.

2304. (Mr. BARLOW.) Did you find the fractured end of the girder that you spoke of resting upon the gravel on the bed of the river?—Resting upon the girder, not upon the bed of the river, resting on the facing of the girder.

2305. What was the facing resting upon?—It was clear of the ground, clear of the bed of the river about three feet.

2306. And resting upon the facing of the girder?—The girder was not resting solid on the bed of the river.

2307. (Mr. BALFOUR.) What is the facing of the girder?—That is the lattice work, the cross work of the girder when it was standing.

2308. (Mr. TRAYNER.) It must be resting upon something; what is it?—I cannot tell you that.

The witness withdrew.

Examined by Mr. TRAYNER.

2309. You are a diver?—Yes.

2310. Where do you reside?—At North Shields.

2311. Have you had a good deal of experience as a diver?—Yes.

2312. How many years?—About seven years.

2313. You were employed to come up here to dive at the scene of the Tay Bridge wreck?—I came up here to get employment, and I got employed here.

2314. For whom?—For Mr. Drummond; I am not sure.

2315. You the railway company?—Yes.

2316. When did you first come?—At 1 o'clock on Wednesday morning.

2317. And you began work on Thursday the 1st of January?—Yes.

2318. On Thursday how often did you go down?—I could not say.

2319. Several times?—Yes.

2320. Did you obtain your examination on each of your dips to pretty much the same place?—Pretty much the same place.

2321. You kept going down and coming up at the same place?—No, going along the girder.

2322. How far did you travel in the course of the day from north to south?—About 60 or 60 feet.

2323. You went down between what piers?—I think it was between the third and fourth piers; I could not say exactly.

2324. You are counting from the south?—From the south.

2325. How far north of the third pier?—That I could not say.

2326. Can you give us any idea; were you near the middle of the two piers?—It would not be the middle: it would be more to the north of the middle.

2327. When you got down did you travel principally north or south from your point?—South.

2328. And the distance that you examined would be something like 50 feet, did you say?—Somewhere about that.
2320. When you got down there I suppose you found the girders?—Yes.
2321. Did you find it entire or broken?—It was entire when I was there.
2322. Did you find anything else on the list of January except the girders?—Not that I am aware of.
2323. On Friday you were not down?—No.
2324. It was too stormy?—Yes.
2325. On Saturday did you go down several times?—Yes.
2326. Where did you descend first on Saturday?—I think it was abreast of No. 4, somewhere about abreast of No. 4, to the best of my knowledge.
2327. When you got down on your first dip on Saturday, you found the girders as formerly?—Yes.
2328. Is the result of your whole examination that the girders were lying pretty much in a continuous line from north to south?—Yes.
2329. In your first dip on Saturday did you find anything?—I got hold of a lamp on Saturday.
2330. Inside the girders or outside?—Inside the girders.
2331. Was it broken?—Yes.
2332. I need not follow you through all your different dips on Saturday, tell me whether in the course of Saturday's examination you found anything else but a lamp!—I was taken to the west of the bridge on Saturday, and examined the west part of it.
2333. You went down on your first dip on the east, I understand?—Yes.
2334. Tell us all that you got upon the east first?—I do not think I found anything upon the east but just the girders, and I tried to get under it.
2335. Did you get the lamp there?—I got the lamp there.
2336. Was that all you found on the east of the pier on the Saturday?—To the best of my knowledge, that is all.
2337. You were let down on Saturday to the west of the pier also?—Yes.
2338. Between what pier did you go down to the west?—I think it was close to No. 4.
2339. Did you find anything there?—I found a coupling of a carriage underneath it.
2340. Underneath what?—Underneath the bridge altogether.
2341. Underneath what had been the bridge?—Yes; it was standing at an angle you know.
2342. Was it entirely separate from the girders, or was it near the girders, or within the girders?—The west part of the bridge was lying like that (describing it), at about an angle of 45°. I had to get underneath it, and I fetched this coupling from underneath it, but the tide was too strong, and I knocked off from that part of it.
2343. Do you say that you found that coupling to the west of the girders?—To the west of the easternmost part of the girders.
2344. It was in the girders?—In the girders.
2345. You went down at the west side, and came through the bridge up to the girders?—Yes, I crept in.
2346. And there you found the coupling of a carriage?—Yes.
2347. You came eastward as far as the girders, and then you found a coupling of a carriage?—Yes.
2348. Was it entangled in the girders?—It was lying on the sand, on the clear sand, with the girders around about it.
2349. You found the girders at that point broken?—I would consider them to be bent.
2350. Was the coupling under the girders?—On the sand inside of the girders.
2351. Sand is sliding up there?—In places it is.
2352. Was the coupling entire or broken?—Broken.
2353. At what part of it?—The end that goes into the carriage.
2354. On Saturday did you find anything else; you said something about having to knock off; when did you knock off?—The flood tide carried us away then; we were done with that part of it.
2355. Was the finding of that broken coupling and the lamp the whole that you found on the Saturday?—Yes.
2356. Was there a piece of a carriage found by you on the Saturday?—I could not be positive as to whether there was or not.
2357. To the best of your recollection you have told us the whole result of your dips on the Thursday and Saturday?—Yes.
2358. On Sunday did you go down again?—Yes.
2359. How often did you go down on Sunday?—I could not say how often.
2360. Several times?—Several times.
2361. You were again below the whole time that the tide was flowing and the weather permitted?—Yes.
2362. When you went down on Sunday where did you go down from?—To the east side of the girders.
2363. Near what pier?—I could not say exactly.
2364. Was it near where you had been previously going down?—A little to the north.
2365. A little to the north of your previous dips?—Yes.
2366. You had been going down before between Nos. 3 and 4, and therefore you were to the north of that a little?—Yes.
2367. Then what did you find on Sunday?—A first-class carriage.
2368. How fast was it lying?—It was lying hard against the girders, inside the girders.
2369. On its side or on its wheels?—Standing on its bottom, on its wheels.
2370. Did you go into it?—Yes, I smashed one of the doors and got in.
2371. Was there more than one door that you found?—I smashed one door way, and there was part of another door there.
2372. Was the one door that you smashed the only entire door that you found?—The only entire door that I found.
2373. Is the roof of the carriage on?—Off.
2374. And the ends?—One end is out.
2375. Which end?—The north end.
2376. And the internal compartments, are they out too?—They are all in a wreck together.
2377. Did you bring anything up from the carriage, did you find anything in it?—I fetched some floor-cloth out.
2378. Anything else?—I think not.
2379. Is the bottom or floor of the carriage entire?—Part of it.
2380. At the north or south?—It runs north and south.
2381. Is it the north end that is away or the south end that is away?—The south end of it is away.
2382. The flooring is there at that part of the carriage where the end is out?—Yes.
2383. And it is away at that part of the carriage where the end is still remaining?—Yes.
2384. Do you find anything else on Sunday?—I was taken further north again.
2385. North of the first-class carriage?—Yes.
2386. Did you find anything north of the first-class carriage?—I went down between the girders, and I thought I put my hand into the funnel of the engine, but the tide was too strong; I was in a confused state, trying to get out; and I could not give a proper statement whether it was the funnel or not.
2387. You went down further north, and you touched what you thought was the funnel of the engine?—Yes.
2388. But the state of the tide prevented you from making a further examination, and you had to come up?—Yes.
2389. You have told us all about the Sunday?—Yes, I think so.
2390. Were you down yesterday?—Yes.
2391. When did you go down yesterday?—Yesterday morning.
2392. And were you several times down?—Yes,
2402. At what part of the broken bridge did you go down yesterday?—The east side of it.
2403. Near what piers?—I think it was to the south of No. 4.
2404. Had you any particular purpose in going down yesterday?—Yes.
2405. Did you find any break?—Yes.
2407. Where?—In the bottom of the girder.
2408. How do you mean the bottom boom?—The boom so they call it.
2409. How did you get at it?—I went down my rope and went along the girder till I came to it. 
2410. Along the top of the girder?—Along the bottom of the girder.
2411. On the ground?—Yes.
2412. Till you came to the break?—Yes.
2413. Whereabout did you find the break? You went to the south of No. 4, how far did you travel southwards before you got to the break?—I went about 25 or 36 feet.
2414. How far south altogether would that be from pier No. 4, as near as you can judge?—I think about 40 yards.
2415. South of pier No. 4 you found a break?—Yes.
2416. (Mr. Barlow) Half-way between No. 4 and No. 3.
2417. (Mr. Trayner) Nearer No. 3, I should think. (To the witness) You think it is a little more than half-way?—I do not think it is quite half-way.
2418. Nearer No. 4 than half-way?—Yes.
2419. Of course you are judging, to a certain amount, from more guess?—That is all.
2420. You could see nothing?—My tender takes notice of all these things.
2421. You yourself could see nothing of this?—No. 

The witness withdrew.

HENRY WATTS SAYS:

Examined by Mr. Trayner.
2441. You reside in Sunderland?—Yes.
2442. Are you a diver?—Yes.
2443. How long have you been so?—Between 15 and 16 years.
2444. You have been diving at the Tay Bridge. You began on Saturday last?—Yes.
2445. In whose employment?—I came down by instructions from Captain Roberton, I think.
2446. Where were you when you were diving along with the man Norley, were you?—Yes.
2447. You went down on Saturday for the first time?—Yes.
2448. How often did you go down on Saturday?—I cannot say how many times I went down.
2449. Several times?—Yes.
2450. Where did you go down on Saturday?—Near No. 4 pier.
2451. Were you to the north or the south of No. 4 pier?—Rather to the south.
2452. And to the east of the girders?—Yes.
2453. When you went down did you travel nor or south?—I travelled south.
2454. First P? First?
2455. But I suppose you travelled both north and south in the course of the day from that point?—Yes, in the course of the day.
2456. What did you find?—I found a round bar, which I thought was an axle, and I felt very anxious to get it; the top of it was covered with sand.
2457. Has it been recovered?—Yes.
2458. Was it an axle?—No.

2462. You found this break, will you describe it, the beam was broken?—It was in a terrible rugged mass, and about two feet and a half open.
2463. There was a distinct break and a displacement of the line?—Yes.
2464. This is the beam of the girder that you are speaking of?—Yes.
2465. Just describe the thing that you found broken, what is it?—The bottom of what I would call the top of the bridge.
2466. What would have been the bottom of the bridge when it was standing?—Yes.
2467. And now on the ground, on the lowest, at any rate of the girders?—Yes.
2468. There is a distinct break, and you say the parts are 2½ feet separate from each other?—About that.
2469. And the line is altered, they are not in a straight line with each other?—The northernmost part has got up the river.
2470. Rather westward?—Yes.
2471. After you had found this break, did you go to any other place?—I was ordered to examine the river.
2472. How far down the river did you go?—I think about 100 yards from the bridge.
2473. For what purpose?—To seek for bodies.
2474. But you found none?—No.
2475. Did you find anything else?—A piece of a carriage.
2476. What class carriage?—I think it was a third-class carriage.
2477. Is it a part of the side of the carriage?—It is a piece of the siding of the carriage, and a portion of the iron.
2478. With an iron rail on it?—Yes, and a lamp I found down there, and a stanchion.
2479. Is that the whole result of Monday's diving?—I think so.
2480. You have been careful in carrying on your operation. You have carried them on to the best of your ability?—Yes.

H. Watts.
2479. You went from end to end of it?—Yes.
2480. You think the bottom is still there?—The bottom of the carriage I except upon the north side, and there was a bit of brattice in the middle like.
2481. So far as you went through the carriage you found the flooring entire?—Yes.
2482. Is it standing upright?—It is upright.
2483. Did you find anything else on Sunday?—No.
2484. Nothing but that?—Nothing but that.
2485. Were you down yesterday?—Yes.
2486. Where did you go down?—To the north of No. 4.

The witness withdrew.

John Gray sworn.

2497. And you went down on the 1st of January?—Yes.
2498. That would be Thursday?—Yes.
2499. I believe your dress leaked, and you had to come up?—Yes.
2500. And you have not been down since?—No.

The witness withdrew.

William Thomas sworn.

2501. You are a diver?—Yes.
2502. Residing where?—In Dundee.
2503. How long have you been a diver?—Four years.
2504. You went to dive at the Tay Bridge on Saturday last for the first time?—Yes.
2505. Saturday, the 3rd of January?—Yes.
2506. Under whose instructions?—The Harbour Trustees.
2507. On Saturday, I suppose, you were down more than once?—Yes.
2508. Where did you go down first?—A little to the southward of the fourth pier.
2509. To the east?—Yes, to the east of the girders.
2510. You found the girders as the other witnesses have described?—Yes.
2511. Did you find any railway carriage?—I travelled south. I found no carriage.
2512. You travelled south from the fourth pier, and you found no carriage?—No carriage.
2513. Then did you travel at another time in a different direction?—I travelled north.
2514. Going again south of pier No. 4?—South of pier No. 4.
2515. How far south, as near as you could judge?—Between 30 and 40 feet.
2516. After you got 30 or 40 feet south of No. 4 how far did you travel northwards before you came to any carriage?—I did not feel any carriage.
2517. Not any carriage north at all?—None north.
2518. How far north did you travel?—Twenty feet.
2519. You had not got north of the fourth pier?—No.
2520. And you found nothing there, I believe, except the girder?—Except the girder and a piece of handrail of a third-class carriage.
2521. And you found the girder broken there?—Yes.
2522. What part of it?—The lower boom, that is the top of the bridge when it was standing.
2523. Have you heard one of the other witnesses state the condition in which he found it broken, and two feet apart?—I did not find the other part of it. I got a signal to come up, the tide was getting too strong.
2524. You got a signal to come up, but before you came up you found that the girder was broken?—I was beginning to examine it when I got the signal to come up.
2525. That was the result of Saturday's diving?—Yes.
2526. You found this break about 20 feet south of No. 4 pier?—Yes.
2527. On Saturday the 4th of January you were also diving?—Yes.
2528. Where did you go down on Sunday?—To the north of No. 4 pier.
2529. How far northward?—About 30 feet to the northward.
2530. When you got down, what did you find?—I came on the first-class carriage.
2531. You brought up some pieces of wax cloth from it?—Yes.
2532. Is the carriage standing on its wheels?—On its wheels.
2533. But the roof gone?—Yes.
2534. The inside gutted?—The inside entirely gone.
2535. Did you find anything else that day, did you find any other carriage that day?—I was in a third-class carriage that day.
2536. Whereabouts was the third-class carriage, in relation to the first-class carriage?—To the north of it.
2537. Directly to the north of it?—Yes.
2538. Close to it, but to the north of it?—Yes.
2539. Is it entire or wrecked?—It is entirely wrecked.
2540. Is it standing on its wheels?—It is standing upright with the roof gone.
2541. Did you get anything out of that carriage?—I got two hot-water pans underneath the girder.
2542. Those were underneath the girder?—Yes.
2543. Were these foot-pans out of the third-class carriage or the first-class carriage?—Out of the third-class carriage.
2544. And you sent those up?—Yes.
2545. And some lampholders?—Three lampholders.
2546. Are those lampholders from the roof?—They are fixed on the roof of the carriage.
2547. Was the third-class carriage standing upright too?—Yes.
2548. Did you go still further north?—No.
2549. Was that the result of Sunday's examination?—Yes.
2550. That is all you have seen and done?—Yes.
2551. You have not been down since?—No.

The witness withdrew.
You are a diver?—Yes.

Where do you come from?—South Queens-bery.

How long have you been diving?—18 years, the last 12 constantly employed.

On whose instructions did you come up here?—My own.

You came up to get employment?—Yes.

Who employed you?—After working on Sunday Captain Robertson guaranteed to pay my expenses.

Sunday was the first day you went down?—Yes.

Where did you go down, at what part of the bridge did you go down?—Close by No. 1, between No. 2 and No. 4, nearer to No. 1.

When you went down did you travel northwards?—I made a circle; I went round by the west and came round east.

What did you find; what extent north would your circle take you; how many feet or yards?—20 feet.

In the course of that circle what did you find?—Nothing but broken columns and parts of the girders all lying in a confused mass.

Were there any stones or masses of concrete, or anything of that kind?—There was a pillar that the concrete had been in, part of the metal was away and the concrete remained like a granite pillar.

You said you went from west to east, were you able to go over this mass and come round?—Yes, by climbing over them, and if I came to anything too high I worked round it.

In the course of that 20 feet search north of pier No. 1, you came across nothing but the debris of the bridge, broken pillars, and so on?—Nothing more.

Your next dip was where?—A little to the northward of it.

If your first one?—Yes.

How far?—About 30 or 40 feet, I am not sure.

Were you still to the south of the second pier?—Still to the south of the second pier.

But about 40 or 50 feet north of where you had first started?—Yes.

Did you take the same course of travelling in a circle that way?—The same way.

What did you find on the second dip?—I found girders more intact, but still broken and twisted, and a great many bits of columns.

Were you able to get over from the east to the west side?—No; I did not go right through; when I thought I was about the centre of the girders I came back and kept towards the east.

You kept on the second entirely to the east of the girders?—Yes.

But you found nothing except the same kind of thing as on your first visit, with the difference that the girders was not so much demolished?—Yes.

You went down again still further to the north; how much further to the north?—I suppose I would be very little to the southward of No. 2 at that time.

I do not know how much the bridge would shere.

The third dip was very little to the southward of No. 2?—Yes.

What did you find there?—Much about the same.

Was that the result of your Sunday's diving?—Yes.

Yesterday where did you go down?—In a line with No. 4, nearly in a line.

You mean in a line easterly?—Easterly?

To the east as near as possible of No. 4?—Yes.

To the east of the girders?—To the east of the girders.

When you went down did you travel north or south?—I have away down to the place where I thought would be the best, and still made circles round and tried in the circle, then I would wait a little and make other circles, and I found some lamps.

I want to know, first, if you can give me an idea of the extent of the ground that you covered in your circles?—20 feet.

Ten feet to the south of No. 4 and 10 feet to the north of it?—15 to 20 feet.

Altogether?—Altogether.

In that first dip yesterday what did you find?—I found lamps. I found first one, then two, and then, I think, three, or two and part of another one.

And those were sent up?—I sent them up without coming up.

You found the first-class carriage?—I found the cord.

What led you to the carriage?—I found the cord hanging down, that came across my hand in making these circles.

That was the cord that ran along from the guard to the driver?—I understood it to be that.

And holding by this cord it led you along to the first-class carriage door?—Yes.

Did you go into the carriage?—Yes. I went up to it first. I found that the door was close up against it; the window was open or had been broken, but in placing my hand over I found the roof was off, so in place of going in by the door I went in by the roof.

And you got in?—Yes.

Was the inside of it entirely wrecked?—Nearly gutted out; it was the remains of what had been a compartment.

But the dividing walls were not there?—They were gone.

And you felt the seats, the cushion?—I felt the seats and the cushion.

You satisfied yourself that it was a first-class carriage?—Yes.

Did you bring anything out?—I took the cord and what I understood to be a parasol or an umbrella, and tied them up and sent them up by my line.

You say you found this cord, and keeping by the cord it led you southwards to the door of the carriage?—Southward to the don of the carriage.

Did you continue to follow the line of that cord to the north?—I cut it off at the door.

After you had made that visit to the first-class carriage, did you go further north?—I came up.

Did you go down again?—I went down again.

Where did you go the next time?—To the south end of the carriage.

To the south end of the first-class carriage?—Yes.

Did you go north from that or south from it?—I put my hand down and found the buffers of the carriage.

Of the first-class carriage?—Yes, of the first-class carriage, and a coupling hanging.

Hanging on the carriage?—Yes, hanging on the carriage.

Did you go any further north than that?—I was going south. I went south a little, but another diver being south I made tracks for the north.

That is where I want to bring you, did you go north?—Yes.

How far?—I went to the end of the carriage. I went down below at first and found some of the boards hanging down.

The flooring?—The flooring, as I understood it to be. I was amongst it and tore it away and sent it away, picked the pieces up.

Did you go further north than the first-class carriage on that dip?—I went to the end of it, and found something else floating about.
2615. Did you discover any other carriage to the north of the first-class carriage?—I understand it to be part of another carriage, but I did not examine it, I went as far as my light would take me, and by that time it was too late to come up.

2616. Is that all you discovered on your Sunday's and Monday's visits that you have told us now?—All that I examined.

Examined by Mr. Balfour.

2617. This is a new part that you have been to; and I wish in supposing that you were three times down on the Sunday between Nos. 1 and 2—Yes, three times.

2618. Between Nos. 1 and 2—Yes.

2619. Beginning first near No. 1, and then going a little northwards, and then going northwards still?—Yes.

2620. You told us that when you went down first that was the further south, you know, you found a confused mass of pillars and girders, as I understand?—Yes.

2621. Would you describe what bits of the girders it was that you found in this confused mass?—There were booms lying in the sand, that is the lower booms, I understood them to be, but being in pieces I did not follow them out. The object of my search was bodices or carriages. I made no remarks, even to myself, about where the break was.

2622. How many separate pieces of booms of the girders did you find?—I could not say; I came upon them several times, and it might have been the same piece.

2623. What length of boom did you feel along at any one time?—According to the circle I was making, it might be 10 or 15 feet perhaps going along.

2624. And then did you come to another break, or did you go away from the girders?—I left it and went to the centre.

2625. So that you could not say how many breaks there were in the boom?—I could not say.

2626. Was any lattice work attached to the boom?—Yes; the lattice work and great deal lying on its flat.

2627. Was the lattice work broken or twisted in the place you went down first?—Both broken and twisted.

2628. How many strands of lattice did you come upon in your first dip?—I could not say.

2629. A good many?—A good many.

2630. How many breaks or fractures in the lattice work did you come upon?—I could not say.

2631. How deep was the twisting of the bits that were twisted?—Some of them were in the sand coming up again and coming against others.

2632. But how deep could you not tell?—No.

2633. What was the length of the twisted bits?—I could not say. I made no remarks even to myself about them. It was the carriages and bodies that I was looking for.

2634. Were you able to say what that twisting had been occasioned by, or did you form any opinion?—I formed no opinion upon that.

2635. Whether it had been something coming against it, or what it had been?—I formed no opinion.

2636. You told us that in your second dip on the Sunday you found the girders still somewhat broken and twisted, but more intact?—Yes.

2637. Did you find any part of the boom or booms of the girders broken in your second dip?—Twisted.

2638. The boom was twisted?—Twisted.

2639. You know what the boom is?—Yes.

2640. You found the boom twisted, but not broken, in the second-dip?—I did not feel any break.

2641. But you felt a twist?—Yes, out of the line.

2642. Was it a sharp twist? I mean was it an acute twist, or was it much or little out of line?—I did not form any opinion.

2643. You cannot tell whether it was twisted much out of the line?—I could not tell.

2644. Along what length of boom did you feel on that second dip; how much of it did you feel along?—I could not say how far I went. I came to the boom. I understood from my own views in the dark that if I got the east boom I might show in for the centre to find a carriage; therefore, I left the boom without making any remarks to myself about it.

2645. Did you find any lattice work attached to the bit of boom that you struck on your visit on the second dip?—Yes.

2646. How many pieces?—I could not say. As I came up against them, I thought it well to keep clear of it.

2647. Were any of the lattice pieces that you came on in your second dip broken and twisted?—Both, broken and twisted.

2648. How many breaks did you come on in the lattice work on the second dip?—I could not tell.

2649. How many lattice pieces were twisted?—I could not say.

2650. Did you ever find two ends of any bits of lattice that would fit to each other?—I did not go into that.

2651. You found a bit of broken lattice separate from anything else, but attached to the boom?—Yes.

2652. What length of broken lattice did you find attached to the boom?—I could not say.

2653. Did you see what the depth of the twist was, on the second dip?—I formed no impression.

2654. In regard to the third dip you were still further north?—Further north.

2655. Did you find any broken boom on the third dip?—No, no booms, but lattice work.

2656. Did you find a boom at all on the third dip?—Yes.

2657. But what?—Yes.

2658. Was it twisted?—Yes.

2659. Off the straight?—Yes.

2660. Was it much off the straight?—I might have been deceived with its being bent, whether it was the lower or the upper.

2661. I only wish to know how the thing was; can you tell me whether the boom that you struck on the third dip was twisted or not?—I believe it was twisted.

2662. But you cannot be sure?—I could not be sure.

2663. Did you find any lattice work attached to the piece of boom that you struck on the third dip?—I felt the lattice work, the lattice work that I came across, sometimes I would feel it on the boom; at other times I never went to the end of it.

2664. Did you find any lattice work broken on the third dip?—Yes, I believe I did.

2665. How many breaks were there?—I could not say.

2666. Did you find any lattice work twisted on the third dip?—Yes, twisted.

2667. To what extent?—I could not say.

2668. Was the boom that you have described as having found broken on the third dip the lower boom of the girder as it is now lying?—I could not make a remark.

2669. Was it on the east side of the girder as it is now lying?—The east side I went down, and as I came across it, it was a boom lying on the east.

2670. You walked from east to west, and came on the boom?—Yes.

2671. So that the boom must be the lowest boom on the east side?—I understood it to be.

2672. In what direction was the lattice work going from that boom?—There was some lying on their flat, and some pieces standing up.

2673. Would that correspond to what might have been the side and the top of the girder?—I understand it has been twisted all through. I made no particular remark to myself.

*2674. Was the lattice work so much twisted that you could not tell whether it had been the top or the side of the girder?—If I had made an examination,
and sat down and thought upon it I might have made remarks of that sort, but I did not go into that.

2675. (The Commissioner.) Do I understand you to say distinctly that you found any portion of the boom actually broken? I would rather make no remarks, because I did not make a very careful examination.

2676. You could not say whether any part of the boom was broken, or not?—It was twisted, I felt it was twisted.

2677. It was twisted, but you found no part where it was broken?—I felt pieces; it was a break, I understood it to be the end.

2678. I am talking of your dips on Sunday, when you made three dips, and you made circles, as I understand, coming occasionally to the boom, which I understood was the boom lying on the bottom of the river?—Yes.

2679. Can you tell me whether any portion of that boom was broken in any part whatever, or only twisted?

---as my opinion was that it might have been the end; it was a break.

2680. There was a break in the boom?—The end of the boom.

2681. You found the end of the boom which might have come away from the pier which now stands, is that what you mean?—Yes.

2682. Did you find any other break besides that?

---I made no special remarks to myself.

2683. You did not find any break before that that you can speak to?—There was so much jagged work there that I could not exactly tell where the break was.

2684. (Colonel Valland.) You say there was a break in the boom, can you tell us whether that was a bottom boom or a top boom of the bridge when it was standing?—I could not say.

2685. You could not tell which?—I could not tell which.

2686. (The Commissioner.) But I was lying on the bottom of the river?—It was lying on the bottom, on the sand.

(Mr. Trautner.) It was to the east of the girders.

2687. (Mr. Barlow.) You have described a great deal of broken work upon which pier was that?

---Between Nos. 1 and 2, nearer to No. 1 than to No. 2.

2688. (The Commissioner.) Do you mean by “No. 1” the pier next to the pier that is standing?

---In the gap between Nos. 1 and 2 from the pier that is standing to the first broken pier.

2689. You are calling the one that is standing No. 1?—Yes.

2690. (Mr. Barlow.) You were somewhere near No. 1 pier, you were the first broken pier?—Yes.

2691. Near that pier which has got two columns left on it?—It was even the one that is broken and the one that is intact.

2692. You have mentioned having seen a great deal of broken lattice work, what size piece of lattice work did you see broken?—All different sizes.

2693. Was it a foot wide?—I was speaking of the columns.

2694. You have spoken of lattice work, you have given an impression that you found the lattice work of the girders broken, are you sure it was not the columns and their lattice work that you found there broken?—The lattice work was twisted.

2695. What size was the lattice work?—About 9 or 10 inches, I suppose that.

2696. Did you see straps of the lattice work broken?—I could feel, not see.

2697. Did you feel them, or ascertain them to be broken?—Yes, and some broken, bent and broken.

2698. Could you say that one of them was broken?

---Yes.

2699. Is there a single one that is broken?—Yes.

2700. Which?—I could not say.

2701. (The Commissioner.) In order that there may be no confusion about it I ask you this again. You count your No. 1 as being the one that stands now, do not you, your No. 1 pier is the one that is standing at the south end?—It is the first pier that I refer to.

2702. (Mr. Trautner.) That is what you refer between 1 and 2?—Yes.

2703. You found some iron work. I do not know whether it was a girders or lattice work, but you found iron work with a jagged end?—Yes.

2704. Whether that was a natural termination which had been wrenched off, or was a break in the middle of the ironwork, you could not tell?—No, I made no remarks.

(The Commissioner.) So far as this man's evidence goes, he finds no break in the girders.

(Mr. Trautner.) He cannot fix a break in the girders.

The witness withdrew.

WILLIAM NORLEY sworn.

Examined by Mr. Trautner.

2705. You were on board the “Lord Warden”?—Yes, but I am on the gunboat "Norley" at present.

2706. But you belong to the crew of the “Lord Warden,” do you not?—Yes.

2707. What is your station?—My rating is second captain of the main-top, seaman gunner, torpedo man, and a driver.

2708. You were sent round here on the instructions of the captain of the “Lord Warden”?—Yes.

2709. You went down diving for the first time at the wreck of the Tay Bridge last Saturday?—Yes.

2710. The 3rd of January?—Yes.

2711. You went down three times?—Yes.

2712. Where did you go down, between what piers?—I think between the third and fourth piers.

2713. The broken piers?—The broken piers.

2714. Of course to the eastward of the girders?—To the east of the girders.

2715. Can you tell us which of the piers you were nearest to, the third or the fourth?—Nearest the third.

2716. When you got down, how did you travel, north or south?—I made a circle.

2717. What would be the distance of the circle from the one end to the other of it, from top to bottom?—I think I must have gone about 10 or 12 feet in a circle before I came to any girders at all.

2718. There you came to a girders, was it north of the place where you had first dived?—When you took your circle, you had gone to the north, I suppose?—North and west in a diagonal direction.

2719. Then you came upon a girders?—The broken part of a girders.

2720. Tell us what you did to discover that it was broken?—I came right upon the end of it, say the third pier was here, the end of the broken girders was here (describing).

2721. To the north of it?—Yes, as I made a circle, so I came round upon the end of the girders.

2722. Did you feel it with your hands?—Yes.

2723. That is the part of the girders nearest the bed of the river?—It was in the sand.

2724. Did you feel if the break had separated the parts any distance from each other?—I could not feel the other end of it.

2725. You came to one end of the girders that showed that it was broken, but the other end of it if you did not trace?—No.

2726. That was the result of your first dip; that was all you found on your first dip?—There was a sandbank there, and I felt something in the gravel or sand, I could not make out what it was. At all
TAX BRIDGE DISASTER.

6. You will recall that I was a wide plank about this width (describing).
7. I came up and reported what I had found.
8. I hardly knew what I was diving for more than parts of carriages and bodies. I came up and reported the sandbank. I took a line down with me again and tried to find this log of wood again. I went over the baulk and went round it, and I could not find any trace of it.
9. That was your first two dips on Saturday.
10. Did you go down a third time? I went down a third time.
11. Where did you descend the third time, at which of the piers? — The barge was shifted more towards the third pier.
12. That is a little south? — Yes, further south.
13. And you went down there? — Yes.
15. I suppose you came upon the girder? — Yes, I came upon the girder, a continuation of it.
16. But you found nothing? — I found nothing.
17. That was the result of your diving on Saturday? — Yes.
18. On Sunday last did you go down? — Yes.
20. On your first dip where did you go down? — I think it was to the north of that part of the wreck that is showing at low water.
21. Just at the north of the girder that is showing? — Yes.
22. When you got down there how did you travel? — I travelled west.
23. Up the river? — Up the river, underneath that part, and I travelled north after that, and I travelled south after that, but I could not go too far under when on account of the broken parts of the bridge, the latticework they say it was. It was about that width (describing the same). It was rugged, and it fouled my pipe. I intended to go through the top of the girder, but Captain Robertson and I was to go further over.
24. On that first dip on Sunday you found nothing, you went nothing up and brought nothing up? — No, I found the columns that were there all lying about in one confused mass, everything all broken.
25. You say the latticework was all jaggard and broken? — Yes, it was above my head, some of it as I came out from the west.
26. On your second dip on Sunday where did you go? — I worked further towards the south.
27. That would be between the first and second piers, on that second dip? — Yes, I was nearly abreast of the first piers, we hauled a good way in. I think it was nearly abreast of the first piers.
28. Did you get into the girder there? — I went right down on the centre of it.
29. Did you find on getting down in what state the girder was? was it broken or entire, or could you judge? — There were broken parts in it, but I should say the main part of it was whole. I went through two parts as it was on its side.
30. But down below the part that is lying on the ground you think is broken? — Part of it; it came up to about my middle from the sand.
31. Did you find anything down there, did you find any pipe? — I went up a piece of hand-rail or something.
33. On your third dip where did you go down? — Nearly against the main structure of the bridge.
34. The last standing pillar? — Yes, in the first gap.
35. What did you find there? — I went down through the girders again there.
36. Did you get down beyond the girder? — I went right down between the lattice, the diagonal stays, right in the centre.
37. What did you find down there? — I found it more solid, not so confined as it was further to the north.
38. Less twisted or crushed? — Yes.
39. But you found nothing, and sent up nothing from there? — Nothing.
40. That was the result of your Sunday's diving? — Yes.
41. You were down yesterday? — Yes.
42. Where did you go down yesterday? — Between the fourth and fifth piers.
43. You were to the east of the girder; you went down to the east of the girder? — Yes.
44. When you got down there, how did you find the girder? — By making a circle I found that the girder was to the west.
45. To the west of where you went down? — Yes.
46. Is it broken? — No, solid right along.
47. What distance north and south did you travel along the girder in order to ascertain its condition? — I should say a good 40 feet.
48. Did you find any part of the roels, that the telegraph wire goes round? — Yes.
49. Was there any wire on them? — No.
50. Did you find anything else? — There was a piece of lead, the sole of a diver's boot or something; I lost that.
51. You found nothing belonging to the train or the bridge? — No.
52. On your second dip you went down where? — I went down in the same place again.
53. Between the fourth and fifth piers how did you go, in what direction? — I made for the girder again, and I went north, about 10 or 16 feet, and I climbed up the girder, and got in through the angling iron and worked along inside. I suppose the girder was that wide (describing) till I came to a part of the carriage.
54. Was that the first-class carriage? — The first-class carriage, by appearance there were cushions, all round, and a kind of network at one end, there was a rod and network inside of it.
55. Did you find anything in it? — There were two foot warning pans.
56. The roof was gone? — And the sides, most of it, it was a total wreck.
57. How does that carriage stand, inside of the girder? — The carriage stands nearly flat, leaning rather towards the west.
58. Standing on its wheels? — Standing not on its wheels.
59. With the roof off? — Yes, the back of it is nearly whole, the rear part.
60. And the front of it is gone? — Yes.
61. After you had examined this carriage where did you go? — I came up.
62. Did you find any part of the buffers of the carriage? — Yes, when I went down again.
63. When you went down again the next time, tell us what you found? — I went underneath the girders, about to my breast from the sand I went underneath, and put my hand along and found it was the rear part of the carriage that I had been in before, both buffers were there and the coupling iron, and there was a kind of a female screw as it were connecting two couplings together.
64. You found that there? — Yes; I found another part of a handrail there.
65. This coupling had snapped? — No, I think it was drawn.
66. You were down again, were you, or was that the last dip? — Yes.
67. That is the result of your wholo diving? — Yes.

(Mr. Ralfure.) Am I right in understanding you that Sunday's dips, Nos. 2 and 3, were in gap No. 1.

(Mr. Trapper.) In the second.

(Mr. Ralfure.) Between piers 1 and 2 counting as we have done from the first broken pier.

(Mr. Trapper.) You have been calling the first broken pier, pier No. 1? — Yes.

(Mr. Ralfure.) You were not down in what we may call the first gap between the end of the
standing bit and the first pier that has nothing above it?—Yes, I was down in the second gap.

2787. But not in the first gap?—Yes, I was in the second gap; I came there afterwards.

2788. You were down three times on Saturday?—Yes.

2789. Where were you down, on your first dip?—Between Nos. 1 and 2 piers.

2790. Is that the second gap?—The second gap.

2791. Then you were down again on Tuesday, and again a third time, where did you go down on your second dip?—Further south, nearly abreast of the No. 1 pier that is broken.

2792. And then where was your third dip?—Further south still.

2793. (Mr. Balfour.) Those two are nearly opposite the first gap (to the examiner). In your second dip on Sunday, did you come upon any laticework of the girders?—Do you know the lattice-work of the girder; do you know the lattice of the girder?—No.

2794. (The Commissioner.) I think I understood you to say that you found the columns all broken up and all in a heap?—Yes, they were.

The witness withdrew.

PETER HARLEY sworn.

2800. You reside at Tayport?—At Tayport.

2801. Are you a diver?—A diver.

2802. How long have you been so?—14 to 15 years.

2803. You have been diving at the Tay Bridge?—Yes.

2804. On whose instructions?—Captain Roberton’s.

2805. You went down for the first time on Wednesday the 31st of December ?—Tuesday.

2806. Was it Tuesday the 30th?—Yes.

2807. How many dips did you make on Tuesday?—I am not certain how often I went down.

2808. Do you know where you went when?—Yes.

2809. Where did you go down on Tuesday?—When I went down I landed in the bed of the river.

2810. You would not land anywhere else than in the bed of the river; where did you go down?—About abreast of No. 3 pier, I am not certain, I did not take the bearings.

2811. Why you got down what did you find?—After I got to the bottom I went away towards the bridge, by the scours that was on the bottom I went towards the bridge 6 or 8 yards.

2812. What did you find?—Nothing.

2813. Were you down again on Tuesday?—I was down on Wednesday.

2814. Did you find anything on either of your dips on Tuesday?—I came up the ladder.

2815. Did you find anything on either of your dips on Tuesday?—I found the bridge.

2816. You found the girders?—Yes.

2817. Did you find anything else?—I got along—

2818. You find anything else?—No.

2819. You went down Wednesday the 31st ?—Yes.

2820. How many dips did you make on Wednesday?—I am not certain how often I went down.

2821. Where did you go down first?—By the first-class carriage.

2822. (The Commissioner.) Where was that?—About abreast of No. 4 pier or thereabouts.

2823. (Mr. Traill.) You followed Fox, I believe?—Yes.

2824. Did you go through this first-class carriage?—Not then.

2825. At any time that day?—I tried to get access to it; if I found I could I got access to it with safety. I commenced to work it up, to tear some portions of it away.

2826. Did you find anything else besides the first-class carriage and the girder on Wednesday?—No.

2827. On Wednesday the 1st of January you did not go down?—No.

2828. Nor on Friday the 2nd?—No.

2829. On Saturday last were you down again at the first-class carriage?—Yes.

2830. Did you search it thoroughly that day?—Yes, the two compartments.

2831. Did you find anything in them?—I found the inside fittings.

2832. You found no bodies, and no luggage; nothing except what belonged to the carriage?—No.

2833. I believe you did not do anything on Saturday except examine the first-class carriage?—I was anxious to see if any bodies.

2834. You did not do anything on Saturday except examine the first-class carriage?—No.

2835. On Monday did you go down?—Yes.

2836. Where?—About No. 5 pier.

2837. What did you come on there?—I came on the girders.

2838. What state was the girder in there?—It was broken there.

2839. How did you discover that?—By going along, I detected it with my hand.

2840. You came with your hand to an end of it?—Yes.

2841. Did you discover where the other end was, the broken bit?—I found the crook, and felt it all round, and felt it was gone.

2842. Did you get the other bit of it?—Yes.

2843. How far was it away from the first bit that you found?—What was the distance between the two points?—I could not say what was the distance between the two splits, 20 or 30 feet, I could not tell distinctly.

2844. You do not mean to say that the space between the two broken pieces was 20 or 30 feet?—No, I beg pardon.

2845. How much space was there between the two ends of the broken bit?—About as much as I could get my hand in.

2846. Nothing more than that?—There might be more, but that is how I tested it was gone, by feeling with my hand.

2847. After that you came up and went down again?—Yes.

2848. Did you go down further south or further north of pier No. 5?—I cleared away the wreckage there, these broken portions.

2849. Did you go down further north or further south of No. 5 on the second occasion than you did on the first?—Further south.

2850. Did you find anything?—No, I found I was coming too far south.

2851. The tide stopped you?—Yes.

2852. That is the result of your diving?—Yes.

2853. (Mr. Barlow.) You state that you found the girder broken at No. 6 pier?—Yes.
2864. Are you aware that it never was joined at No. 5 pier, that the two girders terminated on No. 5 pier, and therefore there was nothing to break at that place?—It was where I was yesterday. I do not know the numbers of the piers.

2865. You told us that it was No. 5?—Yes

The witness withdrew.

(Mr. Trauner.) Can the railway company give us the length and weight of the carriages that composed the train.

Mr. Dugald Drummond sworn.

Examine by Mr. Trauner.

2867. What is your position in the service of the North British Railway Company?—Locomotive superintendent.

2868. You have heard that this train was composed of an engine and tender, two third-class carriages, a first-class, a third-class, a second, and two brake vans?—One engine, one tender, two thirds, one first, one third and one second, and one brake van.

2869. We have already got the weight of the engine and the tender, can you give us the weight of the carriages?—Approximately I can. The first-class carriage would weigh about 13 tons, one of the third-class carriages would weigh the same.

2870. (Mr. Trauner.) And the other thirds the same?—No, they would weigh 12 tons each; the second-class carriage would weigh about 10 tons, and the brake van 12 tons.

2871. And how much the engine and tender?—The engine weighs 34 tons 12 cwt, and the tender 24 tons.

2872. (Mr. Trauner.) That is a total of 130 tons 12 cwt?—Yes.

2873. Having got the approximate weight, will you now give me the approximate length?—The whole train, from the engine to the brake van, would be about 254 feet.

2874. (Mr. Barlow.) What was the length of the first-class carriage?—About 32 feet.

2875. And the third-class carriage which you say weighs 13 tons?—The same length.

The witness withdrew.

(Mr. Trauner.) I have this morning had put into my hands the preoccupation of a witness whose evidence I was not acquainted with before, or I should have called him at a different part of the case, but as it has been put into my hands I feel bound to call him.

Mr. Peter Bardon sworn.

Examine by Mr. Trauner.

2876. And the second-class?—About 26 feet.

2877. (The Commissioner.) And the other two thirds?—About 28 feet.

2878. (Mr. Barlow.) Taking a first-class carriage, do you know how much it is from the bottom of the carriage to the top?—7 feet inside and 7 feet wide.

2879. (Colonel Yolland.) The framing would add how much to the height?—The framing is about 11 inches.

2880. (Mr. Barlow.) I suppose you take from the bottom of the framing to the top of the lantern, how much would it be?—8 feet.

2881. The total external height would be 8 feet—8 feet. I am speaking of the first-class carriage; one of the third-class carriages would be the same height, and the others are about 6 inches lower.

2882. Did you ever know a carriage upset by the wind?—Never.

2883. You never heard of one?—I never heard of one.

2884. (Mr. Commissioner.) Can you tell us also the superficies of the engine and tender, the side surface?—I have the drawings of the engine here. I could give it you in a short time; the boiler would stand from the rail level about 7 feet.

2885. (Colonel Yolland.) Perhaps you would send us the superficial surface of the whole train?—I will do so.

2886. (Mr. Barlow.) A tracing showing the carriages would be most convenient?—I will do so, giving the superficial surface of the whole train and its weight as well.

The witness withdrew.

2892. Did you ever know a carriage upset by the wind?—Never.

2893. You never heard of one?—I never heard of one.

2894. (Mr. Commissioner.) Can you tell us also the surfaces of the engine and tender, the side surface?—I have the drawings of the engine here. I could give it you in a short time; the boiler would stand from the rail level about 7 feet.

2895. (Colonel Yolland.) Perhaps you would send us the superficial surface of the whole train?—I will do so.

2896. (Mr. Barlow.) A tracing showing the carriages would be most convenient?—I will do so, giving the superficial surface of the whole train and its weight as well.

The witness withdrew.

(Mr. Trauner.) I have this morning had put into my hands the preoccupation of a witness whose evidence I was not acquainted with before, or I should have called him at a different part of the case, but as it has been put into my hands I feel bound to call him.
them, and as I think yet, something about the first or second girder passing into the river, as it appeared to my eyes. I looked immediately behind, and then another fell, and I saw a light, as it was just a mere blink.

1902. You saw as you believed then, and believe now, two distinct parts of the bridge fall into the river; on what side?—On the east side.

1903. Those were the parts of the bridge to the south, or beginning of the high part of it?—Exactly.

1904. Did the first part that you saw fall far away immediately from the place where the high part began?—As near as I could guess in my mind it would have been about the first girder or the second girder upon the large girders. I just immediately got nervous at once, and rubbed my eyes, and in a second I saw another movement at that time, and I saw a light.

1905. What light was it?—I could not tell.

1906. Do you mean on the bridge?—Yes; on the southernmost part of the high girders, or near it.

1907. Further south than where you saw the pieces of fire?—Decidedly, just a blinking light; just a second.

1908. Was it a white light or a coloured light?—I would not speak upon the light. It was just a blink that I got altogether, just a sort of blink. I cannot speak to the colour; it was a clear light.

1909. Did you see the light before the girder fell?—No.

1910. The first thing that struck you in reference to this was the fall of one piece of a girder of the bridge?—Yes.

1911. Then there fell a second bit, and then a third bit?—Yes. What I saw first, as I thought then, and think still, was a part of the second girder going off, and then in a second or two I saw another lump going; and just at the time that I saw the southernmost part of the high girders, I saw a blink of light, and the blink of light had cleared away. The moon was shining as clear as could be on the river, and I saw the large pieces from end to end nearest to the girders.

1912. You had not observed the light before you saw the two bits giving way?—No.

1913. If I am right you saw the light blink just as the second bit parted?—Exactly.

1914. Did you look at the time at your watch to see what the time was?—I remained a second or two after the whole scene was over. I had my watch in my pocket, and I took it out, and it was very near gun-time, 13 minutes past seven.

1915. Did you wait to see whether there was any other portion of the bridge parted, but the two bits that you saw go with the light?—I remained three or four seconds, a little time, and I just looked to make myself sure; and then I saw the whole abutment in the water, and then I went into the house and told my family.

1916. Had the bridge gone over; is that what you mean?—No, the abutments.

1917. The bricks of the pier?—Yes, exactly, the pier heads.

1918. Do you mean without the bridge standing?—Minus the bridge. I then went to Mr. Goulary, an engineer and boat-builder, to his house, and I told him what I had been, and he could hardly credit it, and he came with me to the spot. It was rather darkish, and he said, "I cannot see it yet." Then the moon broke out, and he looked, and he saw the whole of the piers broken, minus the girders. I expressed my opinion that the train was on the bridge at the time, but he would not allow it. He said if the train had been on the bridge, the bridge would have been all right, because there would have been additional weight to it. I could not say, but I know it was just about the time the train was due.

1919. Did you think that the train was on the bridge at the time, and if so, why did you think so?—Because it was about the time; it was simply the time and this light that I saw.

1920. Did you think the light you saw was the light of the train?—No.

1921. And you think so still?—Yes.

1922. Did you see that light fall into the river?—No.

1923. How long a time was there between the two falls?—Perhaps you might count four or five seconds or more, just the time I rubbed my eyes.

1924. As nearly as possible together?—Yes.

1925. After the second fall was the gap left as it is now?—Yes, as it is now, as distinctly as you could see it in daylight; the moon shone brightly.

1926. Did you see any flashes of light as the full-took place?—I could say that I saw anything but the one light, just a clear light for a second. It was simply for a second that I saw it.

1927. Where did you see it?—It was perhaps, as near as I could calculate, two or three girders' lengths from the south side of the high girder.

1928. It was on the high girders that you saw the light?—Yes.

1929. Did the light disappear with either of the falls?—Exactly.

1930. Which of them?—The moment I saw the pier going out of sight the light disappeared.

1931. Did it disappear when you saw the fall, or when did it disappear?—Just when I noticed the second fall. It was just simply a blink of light that I saw. I could not see whether it was a lamp light; the moment it went down it went out of my sight.

1932. Just tell me this, where was the light with reference to the flooring of the bridge?—I could not say as to that. It was at the end of the girders that I saw the light.

1933. Was the light moving or was it still?—I could not tell; it was just a blink that I got.

1934. What was the colour of the light?—I cannot say; it was just between a white and a yellowish light.

1935. Will you describe it?—It was a red or a white light, or yellow light?—It was between a white and a yellow.

1936. Was it like a flash or like the flame of a lamp?—It might have been a flash; I could not tell; it was so sudden to my eye.

1937. Did it appear and disappear with the suddenness of a flash?—It just appeared to me; I merely saw it once.

1938. Did it appear and disappear with the suddenness of a flash?—It might do that.

1939. Can you say whether it was a flash, or whether it was the light of a lamp appearing for a short time and then disappearing?—It might be. It appeared like the light of a lamp for the second that I saw it.

1940. Why did you think so?—My reason is now, and even then was, that there was something on the bridge. I said to Mr. Goulary that I was afraid there was something wrong on the bridge.

1941. You are a railway man, and acquainted with railway lights; I ask you what light do you think it is?—I think it must have been the red light of the engine, in my own mind; but I cannot say.

1942. Being a railway man, cannot you distinguish whether it was what railway people would call a red light or a white light?—It was not a red light. It was just a pure simple light for so short a time that no man could describe it.

1943. Does it then come to this, that you are not in a position to describe the light any more accurately than you have done?—Yes.

1944. Whether it was a flash or a lamp which you might have seen for a short time you cannot tell?—No.

1945. Was that the only light that you saw on the occasion of the fall, or had you seen any light.
travelling along within the lattice work before the fall? — No.

2946. You saw no light travelling behind, and you saw no light travelling on the bridge that night? — Not except that flash.

2947. Did you see any light at all moving towards the water? — No.

2948. You said that 7.15 was the bow? — Yes.

2949. In saying that it was near gun time that would be near the true time? - Just that.

2950. Let me understand you; were you holding on to the post when you saw this happen? — Yes.

2951. Why did you hold on to the post? - Because the wind was so strong.

2952. Did a very heavy gust come at that time? — It was about the heaviest of the gale.

2953. Was it the very gust that made you clutch the post? — Yes.

2954. You were afraid of being blown down? — Yes; I was to say myself.

2955. How long had you been holding on by the post when you saw this occurrence? - A very short time, a few seconds, or nearly a minute.

2956. Had you got yourself well steadied on the post? - Yes, for a short time.

2957. How long did you hold on after? - A few seconds afterwards.

2958. But how long, you cannot say? — No, perhaps it was half a minute or a minute, but I could not tell, I was rather stupefied.

2959. What did that? - The horrible sight before me.

2960. Have you told us all you saw on that occasion? - Yes.

2961. How long did it take to happen? — Not exceeding, I suppose, 13 seconds, the whole concern.

2962. (Mr. Trayner). Although those two things that fell from the bridge side were quite distinct and separate from each other, they followed rapidly, but they were short? - Just separate.

2963. The first fall from the bridge had taken place before you saw any light? - Exactly.

2964. It was just on the instant of the second fall that you saw the light? - Yes.

Examined by Mr. Balfour.

2965. What is the distance of Balsay Lodge, your house, from the bridge? - I mean the distance to the land end of the bridge? — Perhaps about a mile.

2966. About a mile to the large girders? — Yes, thereabouts.

2967. It would be about a mile, in short, from the place where you saw the occurrence happen? — Yes; it was 60 to 70 feet high.

The witness withdrew.

(Mr. Trayner). I have to state that that closes the inquiry so far as it is, to be made locally, and that the rest of the inquiry will be made at a time and place such as the Court, with the concurrence of the Board of Trade, will fix; but at present there is no further local evidence bearing upon this matter, other than the evidence of Mr. Balfour, and the information upon the subject which has been given by the divers to ascertain those two circumstances, and probably one set of them will serve both purposes.

(Tax Commissioner). May I observe one other thing, which is this. Assuming this to have been a portion of the girders, it seems to have fallen on the side here (pointing to a drawing). This is the boom which has been examined, which was the top boom, but the lower boom, which is to the west, has never been examined. If there be any girders broken, it must be the lower one.

(Mr. Trayner). Without knowing how the train would affect the boom, we are not in a position to say; but as the Court has indicated its desire to have information on the subject, the divers will direct my attention to ascertain those two circumstances, and probably one set of them will serve both purposes.

(Tax Commissioner). We shall be glad if you will direct attention to that to see whether or not there is anything to the west.

The Court would rather appear from what has been said that the divers have hitherto been directing their attention to discovering the bodies and the carriages, and probably it would be well at the present time to direct them to go along the girders.

(Tax Commissioner to Mr. Dunbar). I have not asked you whether you have any witnesses to produce.

(Mr. Dunbar). I have no witnesses. I was simply directed as Procureur Fiscal to appear here and watch the case on behalf of the Lord Advocate.
(The Commissioner.) Having exhausted for the moment all the local witnesses that are ready to be examined, I think we had better adjourn the case indefinitely, but of course without saying whether the examination will be continued here, or where it will be continued. It may be that the result of the further examination that takes place may render it necessary that we should pursue the inquiry here again to obtain further local information, but there is one part of the evidence which of course is the most important part, as having a bearing upon the construction of this bridge, upon which it is most desirable that we should have as much evidence as possibly can be given to us, that is to say, such evidence as can be given to us in writing before any further examination takes place.

(Mr. Balfour.) Just so, sir. (The Commissioner.) I see that reference is made to a paper that was read by Mr. Gilkes, who was the constructor of the bridge, when he contended for the stability of the bridge. I presume that that paper was published. Could we have copies of it?

(Mr. Balfour.) We shall get it if there is such a thing.

(The Commissioner.) There was a discussion before some engineers, in which Mr. Gilkes maintained that the bridge was stable. Have you got any note of that discussion?

(Mr. Balfour.) I believe it can be got, and will be furnished. I am told it is simply a paper which was read by Mr. Grothô, the resident engineer, and probably the Court and the Board of Trade would like to have that.

(The Commissioner.) Mr. Grothô, I presume, will be examined at a later stage of the inquiry, and probably any statement he may have made with respect to the matter will be useful; and it would be as well that we should have any written papers that can be furnished; they should be sent to us before the next examination takes place.

(Mr. Balfour.) Would you require to see the specification for the bridge?

(The Commissioner.) I think we ought to have all plans and specifications, certainly.

(Mr. Traynor.) I rather thought that the specifications would have accompanied the working plan that Mr. Meik gave us.

(Mr. Balfour.) We shall take care that all the persons who can give the Court information with regard to the structure of the bridge will be in attendance when the inquiry is re-opened.

(Mr. Balfour.) After what has been said about so much breakage, it will be desirable that the metal of this bridge shall be tested. Of course there will be the test in their own specifications, but some of the fractured parts should be taken out and tested. It is certainly very desirable that that should be done. After what has been said about fractures, it will not be satisfactory unless that matter is attended to.

(The Commissioner.) That will be attended to, sir.

(The Commissioner.) Is it the wish of the parties that we should go to see the wreckage at Broughty Ferry? I certainly think there would be no use in our going to see it now. If anything occurred hereafter I am sure Colonel Yolland and Mr. Balfour and I would certainly come down again if there was any necessity for it, but at the present time it seems to me very unnecessary that we should go to Broughty Ferry.

(Mr. Traynor.) Nothing I believe has been recovered that can throw any light on the catastrophe.

(The Commissioner.) Our information is that the wreckage at Broughty Ferry is there, if the Court desire to see it, but that it does not shed much light upon the disaster. The Court has seen the wreckage here.

(Mr. Traynor.) Yes, at the station.

(The Commissioner.) Colonel Yolland suggests whether it might not be possible to have the girders raised.

(Colonel Yolland.) All I mean to say is that if it is determined to raise the girders by blowing certain portions of them to pieces it will be necessary that the actual state of the girders at those parts where the gunpowder or dynamite is applied should be accurately ascertained before that dynamite is applied.

(Mr. Balfour.) That will be certainly done.

(Mr. Traynor.) Do not let it be assumed that in the meantime the Board of Trade will give any authority for blowing up these girders. That is a matter upon which, with great deference to the Bench, we should not say anything upon now, because after the suggestion of the Bench yesterday Mr. Balfour has put himself in communication with me, and the result of the Board of Trade's deliberation upon that matter will be duly communicated to you.

(The Commissioner.) I think that will be the best way. We have to thank the learned counsel on both sides for the excellent way in which they have conducted the examination.

Adjourned sine die.

AT THE ASSIZE COURT, DUNDEE.

FOURTH DAY.

Thursday, 26th February 1860.
Provost and Town Council may think necessary to be produced.

(Mr. Trayner.) There is one matter which I would like to say a single word upon before I call the first witness, and it is this: It is within your knowledge, sir, that the Court is not at present in a position to proceed with what is more correctly the scientific branch of this inquiry, and therefore the evidence which I have been instructed on behalf of the Board of Trade to lend in deference to the wish which you have alluded to just now, will relate more to the facts of the alleged undue speed of the trains upon the bridge, and some other facts in connection with its construction. But what is properly scientific evidence is matter which, at this moment, I have no instructions to proceed with.

(The Commissioner.) By "scientific," may I ask, do you mean purely "scientific"?

(Mr. Trayner.) I mean not only what is purely scientific in the way of opinion with reference to the cause of the disaster, or the probable causes of it, but also involving an inquiry into what that scientific opinion would be based upon—among other things, the construction of the bridge.

(The Commissioner.) Then, it is your intention at the present time, as I understand, only to produce evidence relating to the speed of the trains, and not anything that relates to the structure of the bridge.

(Mr. Trayner.) That is so, except perhaps, that some of the evidence which I have to adduce will relate to what some persons who were engaged in painting the bridge saw, that may have a bearing upon the construction of the bridge itself, but the proper work of construction is not within the subject which I have at this moment information upon to lay before the Court.

(The Commissioner.) You are preparing to produce some painters who will inform us of what they saw?

Mr. Henry Gourlay sworn.

Examined by Mr. Trayner.

2982. You are an engineer in Dundee, are you not?
—I am.

2983. Do you reside at Balgany House?—Yes.

2984. Do you know Peter Barron, a carriage inspector, in the employment of the Caledonian Railway Company?—Yes, he resides at my lodge.

2985. That, I presume, from "Yes," is near your residence?—Yes.

2986. Do you remember the evening of Sunday, the 28th of December, when the bridge gave way?—Yes.

2987. On that evening did Mr. Barron come to your house?—He did.

2988. About what o'clock did he come?—I do not know exactly the time. I think it was shortly before eight—about eight o'clock.

2989. What was the purpose of his visit?—He came to me, and he said to me, "I have just come to say that the bridge is down," and after talking a little bit, we went out to see it.

2990. You doubted the accuracy of his observation, I believe?—I was very much astonished, indeed, and shocked to hear it.

2991. As he persisted, I believe you then went out with him?—Yes.

2992. Tell me what it was exactly that he communicated to you. What did he say?—As far as my recollection goes he said just in these words: "I have just come to tell you that the bridge is down."

2993. Did he give you any details as to what he had seen, or what had led him to that opinion?—No, he did not. I did not ask him very much about it. I was very much taken up about the matter, and I went to see for myself. I went with him.

2994. How far is your house from the bridge, the north end of it?—I think about where I went to see it, I think about a mile.

(Mr. Trayner.) Yes.

(The Commissioner.) As to what they saw with reference to the condition of the bridge?

(Mr. Trayner.) They will speak to the condition of the bridge at the time when they were there. It may be within your recollection that on the second day of the last inquiry Mr. McKelvie was examined. He was a gentleman who had taken some interest in the question of the velocity and force of wind, and was in the habit of making reports to the Meteorological Society in Edinburgh, I think, and in the course of his examination he was asked at question 1529, "Tell me how often you have done this within the last 12 years?" and his answer was, "It would take me some little time to tell you that, but I will undertake to furnish you with an answer to that question." Mr. McKelvie has made up a statement from his notes, which I will hand in to the Court, and he will be in attendance, if the Court desires, after looking at it, to ask any questions with reference to it.

(The Commissioner.) Has Mr. Balfour seen it?

(Mr. Trayner.) No; it has only just been handed to me; but it will be communicated to Mr. Balfour.

(Mr. Balfour.) It seems to be quite correct. I may say I had put into my hands what perhaps the Court might desire to see, namely a Report which has been obviously made by Mr. McKelvie to the Meteorological Society, of which he is a member, on this subject with reference to the state of the wind at the time.

(The Commissioner.) I think if Mr. McKelvie is here he ought to put it in himself, and then questions may be put to him upon it.

(Mr. Trayner.) I will call him later, so that you may look at the statement in the meantime.
Cross-examined by Mr. Balfour.

3005. Do you mean that you made it out after fixing your eyes upon the spot for some time?—Yes, I do.

3007. If it had not been suggested to you that the bridge was down, would you have observed it?—I might not.

3008. How long did you require to fix your vision upon the spot before concluding that the bridge was down?—Perhaps after a minute, I think.

3009. After a minute's fixed gaze?—Yes; I was very anxious to believe that it was not down.

3010. It was after gazing fixedly on the spot for a minute that you concluded that it was not there?—Yes.

3011. And the absent girders not where they had been before?—Yes.

3012. Was the light such when you went out that you could have distinguished the first from the second or any other girder?—I could not. I could not have distinguished the first from the fourth, I think.

3013. But you could not distinguish minutely one part from another?—No.

3014. Was it a cloudy night?—Yes; clouds were drifting across the moon occasionally.

3015. Would you kindly just tell us the words that were used by Barrou? I think you said the words he used were that he had come to say that the bridge was down?—Yes.

3016. Did he say he feared the bridge was down?—No.

3017. I am anxious to know the precise words that he used?—He said very distinctly that the bridge was down.

3018. Did he say how he knew it?—He said he had gone out and was in the road, as near as I can remember, and he just said the words that I have mentioned, that the bridge was down; he said that he had been there; that he had been on the road.

3019. He did not tell you anything that he had seen?—No, I have no recollection of his saying that.

3020. Or his telling you anything he had seen?—No, I have no recollection of his saying that he actually saw it fall.

Re-examined by Mr. Truner.

3021. I understand from you that you were a good deal put about by his statement that the bridge was down?—Yes, of course I was.

3022. Although you cannot remember the particulars, would you go the length of saying that he did not tell you that he had seen a part of the bridge fall?—No, I could not say that.

3023. You knew him before?—Yes.

3024. I suppose he is a reliable man?—Very much so.

Examined by the Commissioner.

3025. I think I understood you to say that there were clouds passing over the moon?—Yes, I think there were.

3026. And that at one time it might be clearer than at other times?—Yes.

3027. Were there clouds over the moon when you went out and looked at the bridge, and had a difficulty in making out what portion of it had gone?—Yes, the clouds were drifting very rapidly over the moon.

3028. Did they clear up afterwards?—Now and then they did.

3029. And it was now and again when they cleared up, that you were able to see?—Yes.

3030. When the clouds were over the moon you could not see whether there was a gap or not?—After fixing my attention on the bridge, I then could have felt certain that the bridge was down.

3031. Even when there were clouds over the moon?—Yes, I think so, except for a very short period.

The witness withdrew.

Examined by Mr. Trayner.

3032. You are an engineer in Dundee?—I am.

3033. Are you, the Provost of the burgh?—Yes.

3034. You are, I believe, the Provost of the burgh?—Yes.

3035. You remember the evening of the 28th of December last?—Yes, I do.

3036. It was a night of great storm, was it not?—Yes.

3037. Did that lead you to look more than once at the bridge from your house?—Yes.

3038. Was it the storm that induced you to regard the bridge exceptionally that night?—Yes.

3039. Were you looking at it from your windows about the time when the evening train from Edinburgh was due?—Yes.

3040. With what purpose did you do it?—The special purpose that induced me to keep an eye very closely on the train that evening was in consequence of my son, who is an apprentice in Dundee, being a passenger. He generally came to Newport on Saturday, and returned by the train across the bridge home to Dundee on the Sunday, and I was concerned about him getting a boat on Sunday in time, as I was anxious about his safe transfer to his lodgings at Dundee, to be in Dundee in time for his work on Monday morning.

3041. That led you to regard the effects of the storm upon the river with care and anxiety?—Yes.

3042. Looking at the bridge about this time, shortly before the Edinburgh train was due, did you see lights upon the bridge?—Yes.

3043. There were lights upon the high girders, were there not?—Yes.

3044. And those were distinctly visible to you?—Yes.

3045. Did you see the train enter the bridge from the south side?—I did.

3046. Did you see the train enter the bridge from the south side?—I did.

3047. And you kept your eye upon the bridge after that?—Yes.

3048. What happened—what did you see?—After seeing the train move from the south shore on to the bridge, a little way off the part of the bridge that is visible from my house from the south shore, a building intercepts the view of the bridge for a short distance—then the bridge comes full into my view again, counting say from the seventh pier from the north end—then I can see very distinctly seven of the fallen piers from the north end and can trace them from my window after losing sight of the train by its view being intercepted by this building. I kept my eye very steadily upon the part of the bridge which was visible beyond this building, and I did not see the train pass that building, that is to say, I did not see anything that I could regard as a train, but within a couple of minutes—not more than two minutes after I had lost sight of the train leaving the south shore—I saw two columns of spray brilliantly illuminated with the light, first one flash and then another. Those flashes would be between what I should say was the summit of the bridge and the north end of it, because I was not straining my eye looking at it.

3049. Let me quite understand you. Did those two columns of spray that you saw come into view before the train had time to go past the building that intercepted your view, or are you of opinion that the
train although not observed by you had actually gone past?—No. The conclusion I came to was that the train could not have passed the spot where I saw the columns of spray.

3050. You thought that the train had not reached that point when you did see the columns of spray?—Just so.

3051. Did anything occur to you at the time as to what had caused those columns of spray?—No, not at the very instant; but immediately afterwards it did occur to me what had caused those flashes of light.

3052. Immediately afterwards, I suppose, or how long?—Just almost instantly.

3053. It did not occur in you the moment you saw the flashes. When you began to reflect did it then occur to you?—Yes.

3054. What then occurred to you as the probable cause of the columns of spray?—I may say that almost simultaneously with my observing those columns of spray lighted up the bridge was then dark, and the only inference I could draw from what I had seen was that it was the lights upon the bridge turning off, that produced the illumination that I saw immediately after that before the lights were extinguished and the bridge dark.

3055. Your opinion was that the bridge had gone over?—Yes, that the bridge had gone over.

3056. Your opinion then and now is, as I understand, that the bridge had so gone over before the train reached the point at which it had given way?—Yes.

3057. Can you fix accurately the time?—No.

(The Commissioner to Mr. Trayner.) Do you say that his impression is that the bridge had given way before the train could have reached the high girders point?—(Mr. Trayner.) Before it reached the high girders point at which he saw the columns of spray?

(The Commissioner.) Quite so.

3058. (Mr. Trayner.) Your opinion is that the bridge had given way at the place where the spray appeared, and had so given way before the train could have reached it?—Yes. I do not say it is the point at which the bridge gave way first. What I say is, that the flash produced by the light at that particular point took place before the train could have reached that point.

3059. (The Commissioner.) You mean before it could have reached that particular point where you saw the spray?—Yes.

3060. (Mr. Trayner.) Can you say whether in your opinion the train had entered the high girders or not when you saw the columns of spray?—Judging from the speed that the train was running at when I saw it I should say that it had certainly entered the high girders.

3061. Immediately afterwards the columns of spray were observed did you notice that the lights on the bridge had disappeared?—Yes.

3062. Will you kindly fix as closely as you can the time of night when it took place?—It was between 15 minutes after seven and 20 minutes after seven o'clock. I did not retire out of the dark room in which I was directly after I had seen those columns of spray, but within a minute or two I did retire to the light and found it was 20 minutes after seven o'clock.

3063. You, living in Newport, have been frequently a passenger across the bridge?—Yes.

3064. Have you observed on various occasions the speed at which the passenger trains run across the bridge?—Yes, I have.

3065. Was this a matter to which you paid occasional attention?—Yes.

3066. Did you observe the speed of the train from shore to shore, or from any particular point in the bridge to any other point within the bridge?—I only timed a train from shore to shore once, and the part of the bridge on which I timed the train was the high girders part.
3090. Did you ever observe a train going through the high girders at a less speed than that?—Yes.
3091. Often?—Yes.
3092. What was the lowest speed at which you found it going through the high girders?—75 seconds.
3093. Was that 75 seconds or 60 seconds what you would call the usual speed, what would you call the usual speed of the train?—With special reference to the train I travelled with, 60 seconds would be the usual speed.
3094. Was there anything to account for or did you observe at the time whether the train was going only at the rate of the lessoned speed which occupies 75 seconds?—Yes, I always observed when that train was late that it ran faster, and if the train was well up to time it ran slower.
3095. Usually being in time, you found that it went through the girders in 60 seconds rather than 75?—Yes.
3096. Is that the lowest rate, 75 seconds, that you have observed?—Yes; with the trains that I travelled by I observed trains at 60 seconds, particularly on the central portion, taking my observations from the last.
3097. Having given as the lowest, kindly tell me what was the highest speed of speed at which the train passed those high girders, you being a passenger?—50 seconds.
3098. That was at the rate of 42.94 miles per hour?—Yes.
3099. Did that rate of speed happen often?—I have just had twice.
3100. Apart from the exceptional cases of the highest speed that you have given us, and the lowest speed you have given us, it seems to be the results of your personal experience that the train usually went across the girders at a rate of nearly 36 miles an hour, 35.78?—Yes; I should say as to the whole of the observations that I have taken, which have been not only as a passenger, but when I have not been travelling, the range of speed would be from 30-67 to 35-78 miles per hour.
3101. You commenced travelling by the bridge, I believe, from Dundee to Newport in April 1879?—Yes, only going southwards, however.
3102. You returned to the north by boat?—Yes.
3103. Did you travel from the south to Newport always by boat, or did you at any time commence to travel both ways by rail in 1879?—I commenced to travel both ways by rail in 1879.
3104. I believe on the 4th November you took out a season or composition ticket for twelve months?—Yes.
3105. After obtaining that ticket you travelled both ways once, and sometimes both ways twice daily?—Yes.
3106. That was in the month of November?—Yes.
3107. When did you finally give up travelling by the bridge from south to north?—To the best of my recollection I think it must have been about the 18th or 20th of December, probably the 18th. I am not quite certain as to the day, but about that day.
3108. You continued, however, to cross from north to south by the bridge until the day before it fell?—Yes.
3109. Having a ticket which warranted you in crossing both ways, why did you cease travelling from south to north by the railway?—On going to Dundee of a morning I always travelled by the 8:55 train from Newport.
3110. Will you be good enough to answer my question first. Having a ticket which entitled you to travel both ways, why did you give up, in the middle of December, travelling from south to north by railway?—I did not feel comfortable on the bridge.
3111. And it was this discomfort which made you give up this travelling by it in that direction?—It was.
3112. By discomfort do you mean bodily discomfort or mental discomfort?—Mental discomfort.
3113. And that mental discomfort arose from what?—From the high speed at which the train was travelling.
3114. From anxiety as to your safety, occasioned by this high speed?—Yes.
3115. In a word, did you consider it dangerous?—Yes.
3116. The same cause did not exist with reference to your travelling from north to south?—Not to such an extent.
3117. It did not produce anxiety in your mind, and therefore you continued to use the train in that direction?—Yes.
3118. Did you make any complaint with reference to the speed at which the train ran through those high girders?—Yes.
3119. To whom?—To Mr. Smith the station-master.
3120. When?—Very shortly after I had taken out my season composition ticket.
3121. Did you complain to him more than once?—Yes.
3122. Did you do that frequently, or can you give me any idea of the number of your complaints?—As far as I can recollect, I only spoke to Mr. Smith three times altogether on the subject.
3123. What was his reply?—His reply was that he was not aware that the trains were travelling on the bridge faster than the time allowed on the bridge, but he told me that the whole of the drivers had been particularly warned with reference to that, to keep strictly to the time, and that he himself would keep a very strict eye on the trains to see that the time was not exceeded. He received the complaint that I made to him with the greatest civility, and manifested a most anxious desire to have those trains keep the time set down for them.
3124. Did you intimate to Mr. Smith, at any time, that you were about to give up using the trains from south to north before you did so?—No.
3125. Did you notice whether, after you complained to Mr. Smith, the trains still maintained a rate of speed which you thought dangerous?—Yes.
3126. They did?—Yes.
3127. As the complaint which you made, and was received, did not result in what you desired to bring about, you simply gave up using the railway from south to north?—Yes.
3128. The first complaint you made was shortly after you took the season ticket, and the third, I believe, was before you gave up travelling from south to north?—Yes, immediately after that train, when it passed over the whole line in 4 minutes and 20 seconds. I spoke to Mr. Smith that evening at the Dundee Station.
3129. Was that the first time?—No, the last time, I do not remember that I travelled after that night. I cannot be certain.
3130. But your impression is that you did not?—Yes, that is my impression.
3131. Did you make a complaint to anybody else?—I spoke to Mr. Noble once very particularly upon the subject of the speed. I could not make a complaint to him, as I do not think he had any control.
3132. Who was he?—One of the Inspectors on the construction of the bridge.
3133. At what date was it when you spoke to him?—It would be about the middle of November.
3134. I think it right to ask you to give me, if you can, the time of these particular trains. Can you speak generally to your observation of any particular train of which you have a note; the date of it, and the speed at which it went? Have you, for instance, a note of the train that left Newport at 7 a.m. on the 20th November?—Yes.
3135. When did it leave? It should leave at 7 a.m., should it not?—Yes, it was timed to leave West Newport at 7 a.m. and it left that morning 10 minutes late.
W. Robertson.

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3136. It did not leave that morning till what time?

3137. That was one of the trains that ran at what rate—42-94 miles per hour on the centre of the bridge.

3138. Through the high girders?—Yes.

3139. There was another one that you spoke of specially leaving West Newport at 7-13 p.m., about the middle of December?—That was the train that I referred to that went across in 4 minutes 20 seconds from cabin to cabin when I was a passenger.

3140. And the speed on the high part between the girders was 35-78?—Yes.

3141. There is a train timed to leave West Newport always at 7-13 p.m., one of the regular trains?—Yes.

3142. Where does that train come from?—It is local to Newport, or it was so.

3143. Was it local also from Newport to Dundee?—Yes.

3144. Was it sometimes detained until the Aberdeen express had passed?—Yes.

3145. On the occasions when it was so detained did you observe at what speed usually it crossed the bridge through the high girders?—I should say that the average was 60 seconds an hour—35-78 miles.

3146. That was the average speed of that train when it was kept behind time by the express which it had to let past?—Yes.

3147. It waited till the Aberdeen express went past?—Yes; the express to Aberdeen.

3148. Can you tell me from observation whether it was usual for that train to have to wait past its advertised time to let the express go past?—It had very frequently to wait.

3149. So that very frequently it had to go at the increased speed which you have mentioned?—Yes.

3150. There is a train timed to leave West Newport at 8-35 a.m., is there not?—Yes.

3151. Was that the train that you generally took in the morning to come to town by?—Always.

3152. At what rate did it usually travel through the high girders?—An average of 35-78.

3153. So that the result of your observation is this: that the usual speed at which the trains ran through the high girders was 35-78?—Yes.

3154. Sometimes higher and sometimes lower, but that was the usual speed?—Yes, of course, when I say so. I make special reference to the train I travelled by.

3155. The result of your observation as a passenger was that the usual speed between the high girders was 35-78 per hour?—Yes.

3156. When you ceased using the railway from south to north, what mode did you take of reaching town?—By the boat.

3157. Was that as convenient for you as the train?—Yes, it was equally convenient.

3158. It was not so quick was it?—Not always.

3159. By convenient, I meant was it as suitable for getting to business, or was it as convenient, or was the terminus of the steamboat or that of the railway equally convenient to your house?—The railway was more convenient than the boat, and more comfortable.

3160. You took the less convenient and less comfortable mode simply because you apprehended risk or danger from using the train going at the speed at which you had observed it generally to travel?—Yes.

3161. When you saw the flashes the spray, you say, was illuminated?—Yes.

3162. You mean streams of light?—Yes.

3163. I suppose they lasted only for a second?—Just a second.

3164. Were those streams of light vertical or horizontal?—They were in a slanting direction from north to south.

3165. From the opposite side towards you?—Yes.

3166. Not from west to east?—No, from north to south, probably at an angle of 75°.

Cross-examined by Mr. Balfour.

3167. Your attention was called to the state of the weather apparently that night, the 28th?—Yes.

3168. Was it a very unusual storm that evening, at about 7 o'clock?—I should say it was.

3169. And it was that circumstance that led you to be observant, as you were?—Yes.

3170. Kindly tell me what was the condition of the light at the time you looked at the bridge before you saw, and when you saw, what you have described?—There was moonlight, but the moon was shrouded by clouds, and I could not detect the lights upon the bridge very readily.

3171. You did not see the bridge; you merely saw the lights upon it?—Yes.

3172. You did not see, or did you see, any part of the bridge?—No, I did not.

3173. So that you saw none of the girders?—No.

3174. But merely lights, which from your knowledge you knew to be upon the high girders?—Yes.

3175. At the time you saw the bright flashes of spray lighted up did you see anything fall?—No.

3176. Was the light such as to enable you to see if anything did fall?—No.

3177. At the time the flashes of spray were visible to you, the illuminated lights did not permit you to see either the bridge or anything like it?—No.

3178. Then the lights which you saw before they fell had not been enough to light up the bridge?—No.

3179. I mean to make it visible?—No lights whatever between the bridge and me, of course, could light up the bridge.

3180. They did not do that?—No.

3181. So that you merely saw the flames of the lamps?—Just the lamps.

3182. In saying that you saw the train enter the bridge, do you mean anything more than that you saw lights which you knew to indicate the train so to enter?—Just so.

3183. The light at that time was not such as to enable you to see the train?—No.

3184. Apparently you saw a part of the high girders corresponding to the distance of those seven fallen piers to the north?—Yes.

3185. So that apparently there was shrouded or obscured from your view by the house part of the girders corresponding to the five southernmost fallen piers?—Yes, that is so.

3186. Is it your opinion that before the girders which were to the north fell I mean corresponding to the seven most northernmost piers, fail—the train was upon the girders which were supported by the five southernmost piers?—That is my opinion.

3187. You judged that from the progress of the lights indicating the train before it began to be obscured by the house?—Yes.

3188. You never saw any of the train lights emerge to the north of the house?—No.

3189. Did you draw the conclusion that the part of the bridge which the train was upon had gone down before the part to the north fell?—Yes; I would like to say this: I have often seen the lights of a very train entering and leaving the sea, all the way from the south shore, and failed to see the lights of the train as it went onwards about the centre of it. I have not always been able to detect the lights of the train upon the bridge, upon all parts of it, while I did not see the lights of the train emerge upon this block of building. I could not thereby conclude that it had not emerged beyond that.

3190. I quite understand you, but is not this correct too? I thought you had said in your examination in chief that you did not think the train had time to have got as far north as the seventh northernmost pier?—Yes, I said that and I adhere to it.

3191. Then taking the two circumstances into account, namely, that the train had not in your judg-
ment time to get beyond the fifth southernmost girder, and the fact that you did not see any emerging lights, you concluded that the southernmost part went down with the train on it before the northern part?—If we were asked an opinion as to what I thought upon that question, the first opinion I held, and the opinion I still hold, is that the train took down the bridge.

3192. I drew that conclusion from your evidence, and you adhere to that conclusion still?—Yes.

3193. Your conclusion is that the part of the bridge corresponding to the five southernmost girders went down with the train upon it before the seven northernmost girders went down?—Or simultaneously.

3194. That would not be consistent with your conclusion that the northernmost seven girders fell first?—No, it must have been just simultaneously. I could not put any time upon it, but my impression is that the whole thing went down just at the same instant.

3195. With not any practical interval between?—No.

3196. From what you saw you concluded that the cause was something connected with the train upon the five southern giriders?—Yes.

3197. There were two columns of spray?—Yes.

3198. What did you think the lights were which illuminated those columns of spray?—The lights of the bridge.

3199. Falling over?—Yes.

3200. Did you see any light or illumination which you would attribute to the friction of the breaking of metal?—No.

3201. Then were there no large flashes of light, but merely points of light, such as would be caused by lumps?—I can only describe the light I saw, just by taking a lantern—a watchman's lantern, for instance—and making it shine through a column of spray. The spray was illuminated just for a single instant.

3202. Then you concluded that the illumination which you saw was such as would be made by the making of small lights like lanterns or lamps shown through spray, and not by large flashes of light due to the breaking of metal?—Yes.

3203. In your observation there were no large flashes of light?—No.

3204. How long did the illumination of those columns of spray continue?—Just for an instant; just a second.

3205. Such a time as a lamp would naturally take to fall from its place on the bridge into the water?—Less time than that.

3206. Not more?—No.

3207. When the lights disappeared, did you see anything?—No.

3208. Then when the columns of spray and the lights disappeared you did not see the pier of the bridge?—No.

3209. Or any part of it?—No.

3210. Was the light at the time such as to enable them to be seen?—No.

3211. Was it dark?—Yes; there was one light.

3212. But it was obscured by the clouds?—Yes.

3213. At the moment at which the most of spray was over and after the fall was obscured by the clouds?—Yes.

3214. So that the moment the flashes were over and the bridge lights obscured nothing was seen about the bridge at all?—No.

3215. You naturally, I suppose, would fix your gaze upon the site of the bridge?—Yes.

3216. And sustain it there for some time to see what could be seen?—Yes.

3217. Having so fixed your gaze you found that nothing could be seen from the darkness at the time?—No. I have already said that I retired from that room at 20 minutes after 7 o'clock, so that I did not continue steadfastly gazing at the bridge for any length of time.

3218. You gazed, I suppose, for a minute or two?—Yes.

3219. At least?—Yes.

3220. And perhaps more?—For a couple of minutes at least.

3221. In short, you gazed long enough to satisfy you that the light would not enable anything to be seen?—Yes.

3222. Your house, I think, is so situated as to give you a favourable view of the bridge?—Yes, very much so.

3223. Your house, I think, is not far from the Newport Pier?—No.

3224. So that on the occasion on which you did see it, you saw it at such an angle as to give you good opportunities of observation?—Yes, very perfect.

3225. Much better, I suppose, than anyone standing near the end of the bridge?—Yes.

3226. You have been good enough to give the results of your observations of the travelling of the train; when did you begin to make those observations?—I made very numerous observations the whole of last summer.

3227. I think you told us that you began to travel about April, 1879?—Yes.

3228. And you ceased to travel in December?—The one way.

3229. You ceased to travel from south to north in December, still continuing to travel from north to south?—Yes.

3230. My question related to your journeys from south to north of which you have spoken. Did you make observations of the train time from the month of April onwards to December, or when did you begin?—Yes; I made numerous observations of the speed of the train from south to north all over last summer; while I was not travelling from south to north by the train, but travelling by the boat.

3231. I thought you said that you travelled from south to north by the train from April to December?—I travelled from south to north by the train only from the 4th of November to the middle of December.

3232. Then you were not travelling by the bridge at all till November?—Not from south to north.

3233. But from north to south?—Yes.

3234. Those were your observations made throughout the summer from the boat?—From the boat.

3235. Noticing from the boat from the time the train entered the high girder till it emerged?—Yes.

3236. Had the observations from the boat substantially the same result as the observations you afterwards made in the train itself?—They had.

3237. So that you took your season ticket and began to travel both ways in November, after having observed the results you have described?—I did.

3238. Would you kindly tell us how you made your observations?—Well, I have a very clear dial watch with a white face upon it, with a hand movement, and I took the watch in my hand, and the very instant that the head of the engine, the foremost part of the engine, touched the line of the high girder, I fixed the second upon my watch, and the instant that the foremost part of the engine emerged through the girder, I then fixed my eyes upon the second of the watch, and I could do it to half a second.

3239. It was done by your eye watching the second hand of your watch?—It was.

3240. Was it what was called a stop-watch?—No.

3241. A stop-watch is the best kind, is it not, for observing the speed of trains travelling quick?—I should say so, but when you have two fixed points to guide you, I should say that a moving watch is equally as good.

3242. But the other one is the one counted best, is it not, by engineers?—You have to move the hand in any case; I should say the one was as good as the other under the circumstances under which I was measuring.

3243. I think you have mentioned that you only once took observation of the time from cabin to cabin?—Yes.

3244. What led you to take the observations upon that particular time; it was in the evening, I think?—Yes.
2624. Was there anything exceptional? — The Aberdeen express was late that night, and the Newport train timed to leave New West at 7.13 was detained until the Aberdeen express had crossed the bridge, and then when we came on from Newport to the south end of the bridge I observed that the train that evening was past the cabin or approached the cabin with a somewhat unusual speed.

2625. It had got its speed up by the time it passed the cabin? — Having more than a mile to travel from West Newport to the cabin, it travels that distance, being on land at a quick speed, but it pulls up before approaching the cabin to allow the driver to take out the baton from the cabin-office; but it approached the cabin upon that particular evening with more speed than usual, and the fact of its approaching the cabin with more speed than usual induced me to take out my watch and time the train from that cabin to the other cabin.

2626. It was that somewhat exceptional circumstance which led you to make your observation? — It was.

2627. The train in going from south to north slows down to a rate of about three miles, does it not, in passing the signal cabin? — I do not think it comes so slowly as three miles.

2629. How slow do you think it comes? — Well, I should say five or six miles, and sometimes even faster than that.

2630. It has to take delivery of the baton, or of the train, has it not? — Yes.

2631. In saying that it does that at the rate of five or six miles an hour, from what have you spoken? — From my own observation of the speed.

2632. You had not you watch out at that time? — No.

2633. Is it your opinion that the train going from south to north, by which you travelled, usually took delivery of the baton when moving at five or six miles an hour? — Well, I would not say always.

2634. But I want to know usually? — Of course, you must remember that I only began to travel from south to north on the 4th of November, and ceased to do so about the middle of December; therefore, I did not have very long experience of travelling to be enabled to say what it was usually.

2635. Of course, I only put the question as regards the time over which your experience extended? — I am perfectly safe in saying that the train passed the cabin at a speed on the south side varying from four miles to six miles per hour.

2636. And it picked up the baton when so travelling? — And it picked up the baton when so travelling.

2637. During all that time? — During all that time.

2638. May I ask upon what is that statement founded—you were not timing it? — Just my observations of the movement of the train.

2639. You never, you think, timed the train at all from the south cabin till it entered the high girders? — No.

2640. Did it travel through the high girders at a pretty uniform rate of speed? — No, it was making very considerable variation from its entering the southernmost portion of the girders.

2641. All the time? — Yes, all the time.

2642. Although you did not observe it, can you say whether the train got up its speed pretty quickly after it started from the south cabin? — It did.

2643. All the observations that you have given us from your own travelling, I understand, are upon the local Newport train? — Not all. All that I have given you are.

2644. What kind of engine was that train served by? — When I say "local," of course I include trains coming from St. Andrews as well.

2645. I mean to oppose it to the long distance trains? — Yes, quite so.

2646. What kind of engines are those local trains served by? — I do not know.

2647. A tank engine? — I do not know.

2648. You are an engineer? — Yes.

2649. You never happened to observe the kind of engine? — No; I never took any observation of them.

2650. You know that a tank engine is a small kind of engine which serves the local trains, as distinguished from the larger engine? — Yes; I do very well.

2651. But you do not know which it was? — No.

2652. You do not know the diameter of the driving wheels of those tank engines? — No.

2653. Do you know the type of engines generally? — Yes.

2654. Do you know that that type of engine has a much smaller driving wheel than the engines which run the long distances? — Yes.

2655. What is the object and effect of the difference? — I do not know.

2656. Are you not aware that the object of those small driving wheels of the tank engines is to get up a moderate speed quickly on starting such local trains? — No; I never thought of that.

2657. Are you aware, or do you know, what speed these tank engines can be got up to within a mile? — No.

2658. That is not within your experience? — No.

2659. You did not note or observe the kind of break that was used upon the trains? — No, I do not think there is a continuous break on any of these trains. I think it is just the ordinary break.

2660. You do not think there was any Westinghouse break? — No, I am sure there was no Westinghouse.

2661. But you did not observe the particular kind of break? — No.

(Mr. Traeyner.) Except that he does not think there was a continuous break of any kind—it was the ordinary break van.

2662. (Mr. Balfour.) I need not trouble you about the engine if you did not observe it. I think you used this expression: that you distinguished the case with which you traversed at each end in the discomfort of the middle? — Yes.

2663. You meant that to convey that at the ends you were travelling slow and in the middle quick? — Yes.

2664. Down to what stage of the bridge did you observe the ease or slowness? — You mean in respect of distance.

2665. Taking the high girders as the point of observation, did you find that the slow and easy travelling continued substantially till you entered the single girders or till distance of over forty miles was covered? — Yes.

2666. And it then very nearly. I should say that it was worst within the high girders because the speed was being constantly increased until it reached the summit.


2668. You said, I think, that what you found uncomfortable was the vibration, both vertically and laterally? — Yes.

2669. Would you kindly describe the vibration, first the vertical and then the lateral? Can you give us any idea of what you consider the limit of distance of the vertical vibration to have been? — I could not very well tell you. I could not indicate any measurement, and I could not very easily describe the impression that the vertical vibration produced upon my mind, but I should say that if it was possible for you to conceive the train lifting bodily from the rails, that is to say leaving from the rails with a sort of bounding movement, that would indicate the impression produced.

2670. The vertical vibration which you thought you felt was, in your judgment, due to the movement of the train? — No, it was due to the movement of the bridge under the train.

2671. Upon what did you found that opinion, that it was due to the movement of the bridge? — By the spring, the vertical spring, upon the train itself, which, in my opinion, was not due to the spring upon the carriage, but to the vertical movement upon the bridge.
3291. Can you give us any idea of what the distance or limit of any movement of the bridge would be?—I could not.

3292. Can you give us any idea of what the distance or limit of the lateral movement would be?—I could not.

3293. Could you distinguish the lateral movement of the bridge from the lateral movement of the carriages upon the girders?—Yes, very distinctly.

3294. Can you give us any idea as to how much the bridge might be moving laterally?—No.

3295. Would it be a matter of an inch or inches?—It might be an inch, or it might be two inches.

3296. I suppose that any vertical or lateral movements of such a bridge are matters which cannot be ascertained precisely by the use of the theodolite?—I think it could, provided that the theodolite was properly set.

3297. I mean a competent observer with a competent theodolite—a proper workman with proper tools?—Yes, in a proper fixed position.

3298. I necessarily assumed that a competent observer with a proper instrument and in a proper position could determine that precisely?—Yes, unless the distance was too great; my difficulty, of course, when you put the question, was where the theodolite could have been.

3299. The observer will know that, but you have no doubt but it could be done?—I have no doubt about it.

3300. By a competent observer?—Perfectly.

3301. But that was a kind of observation which you never did?—No, I never did.

3302. And you do not happen to know the result of Colonel Hutchinson’s observations upon that matter?—No, I do not know.

3303. In what part of the train was the carriage in which you usually travelled?—Generally about the middle.

3304. Was the train usually made up in the same way?—Very much so.

3305. How many carriages were there?—I am not sure; there were probably six or seven carriages.

3306. And two vans; was there a van at each end?—No, only one van.

3307. At which end?—At the tail of the train.

Re-examined by Mr. Trayner.

3308. What distance, from your point of view, did you reckon the columns of spray to be at, when you saw them?—Well, I should say, as the crew files, they would be fully a mile.

3309. But the columns of spray illuminated by either the light of the lamps, or whatever it might be, that gave them illumination, were perfectly distinct to your eye?—Perfectly.

3310. So distinct that you can make mistake about it, that they were columns of spray illuminated by some other light?—None whatever.

3311. Would you like to hazard a confident opinion upon whether the light which produced the illumination was the gas light of the lamps or a flash produced by friction?—I would not; my decided conclusion and opinion is that the illuminations were produced by the lamps.

3312. But you would not exclude the other as a possible fact?—I would not.

3313. I do not know whether I rightly understood you when you said that it was like the flash of a lantern brought to bear upon the spray; do you mean a flash from one of those bulb-eyed lanterns that focus the light at the point where it emerges and spreads it out as it goes on; is that the kind of flash you thought you saw?—I am not prepared to say that the illuminated columns of spray were parallel throughout the entire length; they may have been in a tapering form; the effect was just like what a light thrown on to a spray would produce.

3314. But it was a light that illuminated the columns of spray more or less throughout the whole extent of the column?—Yes.

3315. You were asked some questions about the kind of engine used here. I suppose you are engaged enough to know that the tank engine, if it was a tank engine, could be got up quite well to the speed at which you observed the train to be travelling?—I do not know what should prevent it.

3316. And whatever the kind of engine was, I suppose you are speaking with confidence as to the result of your actual observations which you have detailed?—I am speaking with the most perfect confidence.

3317. The result of your observation took the practical form of leading you to give up the most convenient mode of transit from your house to Dundee?—Yes.

3318. Was there any difficulty in the engine taking up the baton at the south cabin, even if the train was travelling at a rate of from four to eight miles as you have told us?—No.

3319. Did you observe the train from West Newport approaching the south cabin at that rate on more occasions than one?—Yes, upon the morning of the 20th of November I did.

3320. That was one special instance, but was I right in understanding you to say that it did so on other occasions beside that one which you have specially dated?—All that I would say is that it did not approach the cabin at a uniform speed.

3321. Could you give us an opinion upon this question whether it more frequently approached the south cabin at a speed of three miles an hour or a greater speed?—At a greater speed.

3322. You made many observations from the steamers?—Yes.

3323. From the steamer’s deck were you in a position to make a perfectly correct observation if you yourself were attentive?—Perfectly.

3324. There was nothing either in the position of the steamer or in your position on board of it which hindered you from being as accurate as if you were in the train?—Nothing.

3325. You had a full view, and there was nothing to hinder your observing, if, as I put it before, you were attentive to the matter?—Nothing to prevent it.

3326. And the result of those observations, as well as the result of your observations as a passenger, was to the effect which you have already given in detail?—Yes.

3327. You observed both the movement vertically and laterally in the bridge as the result of the train passing it?—Yes.

3328. Had you any doubt at the time that the vertical movement was the result of the bridge’s movement?—None.

3329. The peculiar motion that you have described as a bounding motion was one which would not have happened on a solid basis?—No.

3330. I suppose it resembled the spring or awing of a horse, or the bounding of an antelope?—Yes.

3331. Was it markedly so?—Yes, at these high speeds always.

3332. (The Commissioner.) Only at the high speeds?—Only at the high speeds.

3333. (Mr. Trayner.) What do you bring within the phrase “high speed”?—Well, it was very much less marked in the trains going southwards than in the trains going northwards.

3334. Did you observe it in both?—Yes, but to a much less extent in the trains going south than in the trains coming north.

3335. By the words “high speed” do you mean what you consider the usual speed—35-78 miles an hour; is that one of your high speeds?—No.

3336. What do you call high speed?—It was very marked with the speed at 60 seconds, which is 35-78
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Indicating to your mind that the speed was producing the vertical movement, and producing it in greater degree in proportion to the increased rate of progression?—That was so.

Did that operate upon your mind as an indication of the danger to be apprehended from under speed through those high girders?—Yes.

And led you in your apprehension to adopt the course you have already spoken to?—Yes.

Was the vertical movement in trains going at the rate of 35-78 miles per hour sufficient to attract the attention of any intelligent passenger; or was it only sufficient to be observed by a man who was setting himself to the real purpose of observation?—Well, I think most people would be quite sensible of the movement at 35 miles an hour.

They might not be intelligent enough, or skilled enough, to attribute it to its proper cause; but they would be sensible of the peculiar movement?—Yes.

Now the lateral movement of the train you said you always attributed to the movement of the bridge?—Yes.

Did that increase also in proportion to the increased rate of progression?—Yes.

Did it increase sufficiently to indicate that the rate of progression was a serious matter in considering the safety of the bridge?—Yes.

As the vertical movement also indicated?—Yes.

You could not give us the measurement in inches, you said, of the lateral movement?—No, I said it might have been one or it might have been two, but I do not say it was either one or the other, but there was a very perceptible lateral movement.

Was it a movement much beyond anything you have ever experienced in a train at the same rate of progression on a solid basis?—Yes.

That again you have no doubt that it was the movement of the bridge and not merely the movement of the train?—I have no doubt of it.

There was a Mr. Baxter with you on one occasion when you timed the progress of the train, I think?—Yes.

Mr. T. D. Baxter?—Yes.

Do you remember when it was that you and he happened to be coming in the same compartment to Dundee?—It was by a train timed to leave Newport at 7.13 p.m. at about the middle of December; I do not remember the exact date.

But it was in December?—Yes, it was in December.

I do not know whether he took out his watch as well as you?—No.

But you did?—I did.

Examined by the Commissioner.

You are not a railway engineer, are you?—No.

And, therefore, you do not know anything about engines or anything of that kind?—No, I do not know any special knowledge of that kind.

Can you tell us whether or not the bridge was lighted with gas or with oil or paraffin lamps?—It was lighted with gas.

Were there a great many lights all the way along?—There were 14 lights in all, one at each end of the high girders and 12 in the centre; there was one over the centre of each column supporting the high girders, making 14 lights in all.

But upon the high girders was there any light at all?—None, it was vertical with the columns; there was a light vertical with each column of the high girders.

Therefore there was a light over each column in the high girders?—There was.

There would be, therefore, 12 or 14?—14 in all.
3386. But the times that you have given us have been 50 seconds, 60 seconds, 75 seconds, and 80 seconds?—Yes.

3387. They are all even numbers. Do you give those numbers as an approximation? None of them are 61 seconds or 62 seconds?—I have timed them at, I may say, every second from 55 seconds down to the slowest speed that I have given you. I have only indicated those speeds because I have only wrought out the speed of the train at those speeds.

3388. Have you any such record of anything but the exact even numbers of 50 or 60 seconds? Have you any such numbers as 53 or 54 seconds?—No, I have no special record of that.

3388. What are the numbers that you have recorded; are they all even numbers?—Yes, from 50 to 80 seconds, by 5 seconds.

3389. Then you did estimate the speed by a fractional part of 5 seconds; or when it had exceeded 50 seconds, and was nearer 50 seconds than 60 seconds, did you put it down as 50 seconds?—No, but if it was to the nearest 50 seconds I put it down as 60 seconds. I have timed the trains at all speeds.

3390. When you put it down as 55 seconds you do not mean that it was 55 seconds but that it was something between 55 seconds and 60 seconds?—I gave the train the benefit of any second out or in.

3391. But you would not give the train the benefit if you took it between 55 seconds and 60 seconds, and put it down as 55 seconds?—In other words, I might as easily have said what I have said with reference to the speed. At every second from 50 seconds to 60 seconds.

3392. Did you keep a record in your pocket-book or anything of that kind?—I did not.

3393. How did you know these particular figures?—From memory. I have the special records of the 50 seconds and the 60 seconds.

3394. Where is that record?—I made a note of it at the particular time that it occurred.

3395. Who?—In my memory.

3396. But not in your pocket-book?—I made numerous notes of exact times taken from my house in Newport upon a paper which I never thought of preserving because it occurred last summer. After I began to travel I then began to make notes again, and found the notes correspond exactly with what I had taken before.

3397. You have said that you first began to make observations from your house?—Yes, and from the boat.

3398. But how could you see from your house when the train entered upon the high girders?—Because I had not removed to the house I am in now, and in the house that I was in previously I saw the entire bridge.

3399. Formerly you lived in another house, and then you saw the entire girders?—I did.

3400. But at present you could not see them?—No.

3401. I think I understood you to say that so far as you know as a practical engineer there would be difficulty in knowing exactly where to put the theodolite in order to make an accurate observation of the vibration, because if it was put upon the bridge it would vibrate with the bridge, is that what you meant?—Yes; but I did not say there was any practical difficulty.

3402. You thought if they could get a place; where would they get the place?—On the land.

3403. Would you see a vibration an inch or two inches with a theodolite from the land at a mile distance?—Yes, I should say so.

3404. What would be the angle subtended by two inches at a mile off?—I do not know.

3405. You made a distinction also in travelling north and in travelling south; you seemed to have no hesitation in going north to the north, but in going from the south to the north; may I ask why that is; is the speed greater?—The speed was greater going from the south to the north than from the north to the south.

3406. Why is that; is the one bank higher than the other?—Travelling from the north to the south there is a very heavy gradient until you reach the very summit of the bridge, which I think was on the top of the fourth pier from the north side, which is now gone, and in consequence of that heavy gradient there was no great speed on the train until it had reached the summit, which was, I think, on the top of the fourth fallen pier from the north side; then the train made some considerable progress in gaining speed after passing the summit of the bridge, but it had not a great distance to travel when they required to pull up again in passing the cabin, and I never found any serious inconvenience in consequence of this being going south.

3407. They had to pull up at the cabin in order to deliver the coal?—Yes.

The witnesses withdrew.

Mr. Thomas Downing Baxter sworn.

Examined by Mr. TAYLOR.

3408. You are a commission agent in Royal Exchange Place, Dundee?—Yes.

3409. You reside in West Newport?—Yes.

3410. When did you begin to travel across the Tay Bridge?—I have never been a regular passenger. I have never contracted.

3411. You mean you have never had a composition ticket?—Yes.

3412. Have you been travelling more or less across it since it opened?—Yes.

3413. During the last half-year of its existence how often on an average did you cross the bridge in a week?—Perhaps twice a week.

3414. Do you remember on a Tuesday night crossing from south to north with the last witness, Provost Robertson?—Yes.

3415. That was in the month of December?—Yes, about the middle.

3416. You travelled in the same compartment with him?—Yes.

3417. Did he take out his watch to time the trains?—He did.

3418. Between the high girders?—From the time that we passed the south cabin till we passed the north cabin.

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3427. Did the Provost at that time communicate to him the result of his observations by his watch?—I
would not say to that.

3428. You simply know that he did in your presence complain to Mr. Smith of the rate of speed, and that Mr. Smith sympathised with the complaint?—Yes.

3429. Had you noticed upon any other occasion in crossing the bridge from south to north speed to
be what you thought to be excessive?—No, not
dangerous.

3430. Had you felt any alarm on any other occasion that day?—Well, I cannot particularise any date, but there was one day that I was glad to get off
the bridge.

3431. Was that day before or after?—It was before.

3432. Did you ever go from north to south
afterwards?—No.

3433. You had had enough of the bridge that night?—Quite.

3434. But on a previous occasion to that you had felt anxiety?—I did not think it was very dangerous, but I was most glad to get off.

3435. And on the last occasion your happiness at
getting off induced you to stay off?—Yes.

3436. Where is your house situated in Newport; is it to the east or to the west of the bridge?—It is to the east of the bridge.

3437. Is it on rising ground?—No, I am on the
low ground.

3438. But your windows overlook the river?—Yes.

3439. And have you a view of the bridge?—Yes.

3440. Have you a view of the bridge from end
end?—No; there is one part that I do not
see.

3441. What part?—The southernmost part.

3442. Roughly stated, how much of the southernmost part is excluded from your view?—I think I
may be safe in saying that I do not see the southernmost high girder.

3443. Then you can see all the bridge to the north
of the second span of the high girders?—Yes, I can
see all that perfectly.

3444. On the night of the 28th December last you had a brother who was going to Dundee that	night?—Yes.

3445. The night was very stormy?—Extremely
so.

3446. And I believe you went to your window to
look out and see how the weather was, with a view of
advising him as to going back to Dundee?—Yes.

3447. Was it with a view of advising him whether he should go or not go, or was it with a view of
advising him by what means or what conveyance he
should go?—By the conveyance.

3448. Had he to go?—Yes.

3449. And you looked out with a view of advising him as to the mode he should take of getting across?
Yes.

3450. By boat or by train?—By boat or by train.

3451. What o’clock was it when you looked out?—As near as I can mind, seven o’clock.

3452. Upon that occasion did you observe the
lights on the high girders of the bridge?—Distinctly.

3453. Having looked out did you form any opinion as to how he should go?—I thought it would be
perhaps as well to go with the train, because there
would be some uncertainty about the boat from the
state of the tide. It was low water at that time.

3454. You went, I believe, away from this front
window of your house to the back part of your house?
Yes.

3455. After you had gone to the back part of your house was there anything that attracted your
attention?—Yes.

3456. What was it?—I had not been above 10
minutes in the back parlour when I heard two
distinct reports, and I said to my brother, "It is a
good job that the ‘Britannia’ is up; that is the
London steamer, and we generally hear the ‘Britannia’
firing two guns at night.

3457. When the London steamer comes into port she fires two guns?—Yes.

3458. And you thought when you heard the
two reports those were the reports of the two
guns usually fired by the London steamer?—I
did.

3459. And you said to your brother that you were
glad that the London steamer had got in?—Yes.

3460. And what was his reply?—He replied that the
‘Britannia’ was up between four and five o’clock
in the afternoon.

3461. Then it could not be the ‘Britannia’ reports
that you heard?—No.

3462. Did that suggest anything to your mind?—Well, I thought there might be something wrong,
and I went to the front window again, and the lights from the bridge were not there.

3463. I suppose you connected the two things at
once?—No.

3464. Did you connect the disappearance of the bridge with the reports?—Afterwards I did. I
naturally thought that that was the cause of it.

3465. But you did not do it at the time?—No.

3466. But you saw that there was something
wrong?—Yes, I saw that the lights were out.

3467. The lights that you had previously quite
distinctly seen?—Quite distinctly.

3468. What interval would there be, as near as
you can calculate, between the time when you looked out at the window and saw the lights and the time
when you looked out at the window and saw there was none?—Just about 15 minutes, as near as I could
judge.

3469. Did you say at what o’clock it was when you
looked out?—About seven o’clock.

3470. So that it would be about 15 minutes past
seven when you looked out and found there were no
lights to be seen?—Yes.

3471. Having ceased to use the train I suppose you
have since used the boat?—Regularly.

3472. You come to town, do you, every day?—
Yes, every day.

3473. You cross backwards and forwards every
day?—Every day.

3474. On an average you crossed the bridge, you say, twice a week the last half-year of its existence?
—I could not be particular, but I suppose so.

3475. Why did you prefer the steamer as an ordinary mode of transit to the train?—Simply because
I prefer the steamer.

3476. But ultimately am I right in saying that you
gave up your occasional use of the train on account
of apprehension from the speed at which the train
went?—Well, I did not have much occasion
to cross, but I would have taken the boat in preference
to the train after Provost Robertson taking the time and the speed at which we were travelling.

3477. And it was in consequence of the speed that
night that you did not again use the bridge, and from the alarm which that speed occasioned?—Yes.

Cross-examined by Mr. Balfour.

3478. When you looked out at seven o’clock on the evening of the 28th could you see the structure of the bridge, or merely the light which you knew to be the lights of the bridge?—Merely the lights.

3479. You could see nothing of the bridge itself?—Nothing of the bridge itself.

3480. When you looked out about 20 minutes
after, and saw that the lights were gone, could you see anything of the pillars of the bridge?—No.

3481. It was too dark?—It was too dark.

3482. In short, even although the bridge had
remained there, the light was such that you could not have seen it?—Yes.

3488. Was the light very much the same at seven o'clock and at the time when you looked out after, at 7.15?—Well, it varied a good deal; clouds were floating past the moon very quickly.

3489. It may have changed in the meantime, but, comparing the two times, you could not have seen the bridge on either of them, but merely the lights—all the lights.

3490. In regard to the occasion when you were travelling with Provost Robertson, had you observed anything about the speed till he spoke to you on the subject?—Yes, I did; I noticed it when we got in the big girders. He sat with his watch in his hand the whole time.

3491. Had he called your attention to the subject of the speed before you got into the high girders?—He did not speak to me; he simply took out his watch when it was the hour very near the time that night that was the character of the night?—No.

3492. And after you got within the high girders what made you feel uneasy was seeing the rapidity with which you flashed past the lattice work?—Yes.

3493. Nothing else?—Nothing else.

3494. There was nothing in the movement of the train which caused you any particular uneasiness?—I did not take any particular notice of it.

3495. The lattice work, of course, was very near to the train?—Quite close.

3496. Down to that evening your attention had never been directed by anybody to the speed of the train?—No, I never would have been afraid to cross it.

3497. And you had never directed your own attention to it?—It was the first time that I noticed the Provost do it.

3498. Have you ever travelled with the Provost on any other occasion?—I have travelled in the same train with him, but possibly not in the same carriage.

3499. You do not recollect happening to travel in the same carriage?—No, I may have done it, but I do not recollect.

Further examined by Mr. Trayner.

3517. You desire to make some correction in an answer given by you?—I just desire to say that in giving an answer to a question put by the Court with reference to my evidence, bearing only upon the subject, I did not take any particular notice of it.

3518. The lattice work, of course, was very near to the train?—Quite close.

3519. Down to that evening your attention had never been directed by anybody to the speed of the train?—No, I never would have been afraid to cross it.

3520. And you had never directed your own attention to it?—It was the first time that I noticed the Provost do it.

3521. Have you ever travelled with the Provost on any other occasion?—I have travelled in the same train with him, but possibly not in the same carriage.

3522. You do not recollect happening to travel in the same carriage?—No, I may have done it, but I do not recollect.

Re-examined by Mr. Trayner.

3500. Is the southernmost part of the high girders which you could see from your window nearest the Newport side or the Dundee side?—It is nearer Newport; I only see about one of the high girders.

3501. That point of the bridge is nearer the Newport side than the Dundee side?—Yes.

3502. The night was stormy when you looked out?—Yes.

3503. Did you see that there was moonlight?—Yes.

3504. But occasionally there were heavy clouds?—Yes.

3505. When those clouds were not obscuring the moon was it a pretty clear night?—Yes.

3506. So that between the time when you looked out at seven o'clock, when it was dark, and a quarter past seven, when it was also dark, there might have been a distinct light that you did not see?—Decisely.

3507. Both before seven o'clock, and after seven o'clock that night that was the character of the night?—Yes.

3508. Good moonlight?—Good moonlight.

3509. But occasionally obscured by the dense clouds?—Yes.

3510. Others might have seen the bridge itself as well as the lights, although you did not observe it?—Yes.

3511. Did you see the structure of the bridge that night at any time?—Well, I saw part of it because I would be very nearly as far west as the bridge.

3512. But I mean from your window?—No.

3513. You looked from your window on two occasions?—Yes.

3514. And on the second occasion having missed the lights you went out?—Not until about two hours afterwards.

3515. And then you saw that the bridge was down, I suppose?—Well, I heard about it first.

3516. Did you use your eyes when you went out?—No, I cannot say that I went far enough west to see it.

The witness withdrew.

(Mr. Trayner.) Mr. Robertson has sent a note to me stating that he wishes to correct an answer which was given by him to a question put by the Court.

W. Robertson.

Examined by Mr. Trayner.

3519. You are a ship's store merchant in Dundee?

—Yes.

3520. And you have your dwelling at Newport?—Yes.

3521. And you have lived there since before the bridge was opened?—Yes.

Mr. George Thomas Hume sworn.

G. T. Hume.

3522. Were you a regular passenger by the bridge?

—I was.

3523. Both to Dundee and thence homewards?

—Both ways.

3524. Did you cross daily each way?—Yes, I crossed twice each way every day.

3525. The whole time after it was opened?—From the date of its opening on the 12th of May.
TAY BRIDGE DISASTER.


3526. Until the day before it fell, I suppose—Yes, perhaps with some few exceptions, but as a rule. The date of the opening of the Newport line was 1876.

3527. Did you notice at what rate the trains went, usually, speaking, across the bridge?—I have taken the times of the trains from the signal cabin to the other cabin, but I do not remember the times. As a matter of curiosity, I took them occasionally, but I do not remember them.

3528. From the figures that you have taken, although you cannot give them now precisely, what was the impression upon your mind at the time as to the speed at which the train was going?—Probably from five to six minutes; from cabin to cabin a little over five minutes.

3529. Were you of opinion that the train was going at too great a speed?—Frequently in the central part of the bridge in these high levels.

3530. Did you on any occasion time the train passing through the high girders?—Only on one occasion; but only on one occasion did I reduce the time to miles.

3531. You observed more than once the time which you occupied, but only on one occasion did you work it out into so much time per miles, or miles per minute, or per hour?—Yes.

3532. Upon that occasion, at what rate did you make out that the train was going through the high girders?—35 miles an hour.

3533. About what date was that?—I do not recollect. Perhaps about two months before the bridge fell.

3534. What led you upon that particular occasion to time the train passing through the high girders?—I found that the train was getting up speed pretty quickly; and, as a matter of curiosity, I took out my watch before we entered the girders.

3535. Had she been going faster than usual as you approached the south box?—Yes; not until after we were on the bridge.

3536. As you were approaching the high girders you thought they were getting up an unusual speed?—Yes.

3537. And that induced you to look at your watch and time it?—Yes.

3538. Can you tell me what time she did take to pass through the girders?—No; not until after we were on the bridge.

3539. But you made the calculation at the time?—I made the calculation at the time.

3540. And you reduced it to 35 miles an hour?—I reduced it to 35 miles an hour.

3541. Did you feel any vibration upon that occasion?—I did not.

3542. Was there anything to disturb you or to alarm you upon that occasion?—Nothing.

3543. Or upon any occasion?—No.

3544. Were you of opinion then that she might go quicker than that without any danger?—Yes; unless from the breaking of an axle—that was the only thing that was ever present to my mind.

3545. You had probably perfect confidence in the stability of the bridge?—Perfect.

3546. And therefore the only thing you feared from the extra speed was accident to the train itself?—Yes.

3547. Was it anxiety with regard to the stability of the rolling plant rather than anything else that made you look at the time?—No; it was mere curiosity.

Cross-examined by Mr. HAlpouR.

3548. I understand that you continued to travel until the bridge fell?—I continued to travel till the bridge fell.

3549. With the same confidence that you had travelled with from the first?—I did.

3550. Did you at any time feel any vibration in crossing?—Never in the carriages.

3551. I suppose when one went through the girders there would be a sort of flashing from passing with the lattice work so near the carriage windows which might strike people who were not accustomed to it?—Yes.

3552. And it was an unusual thing to have such lattice work so near the carriage windows?—I am not aware that it is.

3553. It was only when you were about to pass through that you thought of looking at your watch?—Yes.

3554. You do not recollect the number of seconds that you took to pass through the girders; do you recollect how many yards you took to be the length of the girders in order to work out the calculation?—I do not recollect the number of yards, but I multiplied 245 feet by 12, and got at it in that way.

3555. But the number of seconds which was the real factor you do not recollect?—No.

Re-examined by Mr. TrAtnE.ER.

3556. 245 feet being as you know the distance between pier and pier?—Yes; I am aware now that two of them were only 253 feet.

3557. So that you have given the company the benefit of one extra length in your calculations?—Yes.

The witness withdrew.

A. HUTCHISON.

Examined by Mr. TraInEE.

3558. You are an architect in Dundee?—Yes.

3559. Where do you live?—I live in Broughty Ferry.

3560. Were you professionally engaged over there?—Yes, at Tayport and Newport.

3561. On an average how often did you go across in a week?—I crossed the bridge about twice a week.

3562. That is to say you crossed it both ways?—Yes, once going and once coming back.

3563. Did you cross both ways once a week, or both ways twice a week?—Sometimes I was twice a week.

3564. Over what period did you use the bridge in that way during the summer?—I should say from about April till the beginning of September.

3565. So that you had frequent opportunity of judging of the speed at which the trains travelled?—Yes.

3566. Did you take advantage of this opportunity to time the train in passing the bridge?—Yes, frequently.

3567. And, as a rule, which way did the trains travel fastest?—From south to north.

3568. Markedly so?—Yes, very much so.

3569. Did you time the trains on many occasions?—Yes.

3570. With your watch in your hand?—Yes.

3571. What was the time ordinarily occupied by the train passing over the bridge from cabin to cabin going from south to north?—It would be between four minutes and four and a half minutes.

3572. Did they ever do it in less than four minutes?—Yes, I crossed in three and a half minutes on one occasion.

3573. From south to north?—From south to north.

Mr. AlexAnder HutchIson sworn.
MINUTES OF EVIDENCE

3874. How long was that before the bridge fell?—

3875. Shortly before the train fell there was one night when you noted the time she took going from south to north?—Yes, the Saturday week before the bridge fell.

3876. How long?—Four minutes.

3877. From cabin to cabin?—From cabin to cabin; then on the main line.

3878. (Mr. Balfour.) A main line train?—A main line train.

3879. (Mr. Trayner.) That is a train that would stop at the station about a mile to the south, St. Fort Station?—Yes.

3880. The other trains were local trains—the Tayport trains?—Yes; the train I refer to was the Tayport train—that one that came over in three and a half minutes.

3881. I understand that all the trains you have spoken to were the Tayport trains, except the one?—No, by no means.

3882. Then your observations generally extended over both the Tayport trains and the main line?—Yes.

3883. But the particular instance of crossing in three and a half minutes was of a Tayport train?—Yes.

3884. Did you think this speed too great?—Yes, I did.

3885. After that night, a week or so before the bridge fell, when you say you crossed in four minutes from south to north, did you form any resolution about using the bridge in the future?—I gave up using the Tayport train in the beginning of September. I thought after I timed the train I should have to give up the main line train also. My experience was that the local trains travelled faster.

3886. After the Tayport train, which came across in three and a half minutes, you resolved that you would have to give up using the Tayport train in coming from south to north?—Yes.

3887. On account of that speed?—Yes.

3888. You still came with the mail train once at any rate after that?—Once.

3889. And you did come over in four minutes?—Yes.

3890. And when you found that the main line trains were also, in your opinion, going at too great speed, you resolved not to use the train again from south to north?—I do not know that I made a resolution to that effect, but I thought I should have to give it up; it is not very easy giving up the train when you have got to go to other places which there are no other means of reaching; but I felt uncomfortable.

3891. After that time you would not take the train by choice if you had had other means?—No.

3892. You say this speed made you uncomfortable?—Yes.

3893. Mentally or physically?—Mentally.

3894. Do you apprehend any risk or danger?—I did.

3895. From what?—From the movement of the girders.

3896. I presume from that that you had experienced motion in the train which you attributed to that motion of the bridge?—Yes.

3897. You have felt it more markedly in the high girders than outside?—Yes.

3898. Was the motion which you felt vertical or lateral?—Both.

3899. I suppose the vertical motion is quite observable?—It was quite noticeable, much more than the lateral motion.

3900. A distinct bounding movement?—Yes, you feel as if the carriage floor rose up beneath you, just as you feel sometimes in coming to the foot of an incline, you feel a sort of impulse while the train seems to rise.

3901. And you felt the same motion coming through the high girders to such an extent as to make you uneasy?—Yes.

3902. Did you attribute that motion at the time to anything connected with the train, or did you attribute it entirely to the motion of the bridge?—To the motion of the bridge; there was, of course, a great motion from the bridge.

3903. That would be lateral, would it not?—That would be lateral.

3904. But I am speaking now of the vertical motion, and you attributed that then, as I understand you still attribute it, purely to the motion of the bridge?—Of the girders.

3905. And that, in your view, was increased by the rate of progress at which the train was going?—Yes.

3906. And if the train had been going at a less speed that motion would have been less, if observable at all?—It was less. When the train was going from north to south the motion was not so perceptible.

3907. You observed it?—Yes.

3908. (The Commissioner.) Do you mean that the speed was not so great?—The speed was not so great.

3909. (Mr. Trayner.) I think you said there was a distinct difference in the speed depending upon the way you were going?—Just so.

3910. To get to the summit of the bridge from the west station in Dundee you have to go up a very considerable gradient?—Yes.

3911. In that way they could not get up speed towards the summit of the bridge in the same way in which they could get up speed from the south of the bridge towards the high girders?—Yes, that is so.

3912. Practically the bridge was on a level between the south box and the south end of the high girders?—I presume so.

3913. But there was no observable gradient or incline from the high girders southwards?—No; the gradient on the north was much more marked.

3914. And it was very obvious to the naked eye from the north side to the summit of the bridge?—Yes.

3915. You were in the habit of crossing the bridge occasionally. I suppose, from the turn it opened?—About a month after it opened I crossed first.

3916. Was the oscillation of the bridge more marked in your later experience than at first?—Yes.

3917. (The Commissioner.) The oscillation or vibration?—Both, I should say.

3918. (Mr. Trayner.) Did you form any opinion as to the cause of that increase in the oscillation and vibration as the bridge got older?—I imagined that it was mainly due to the increased speed of the trains.

3919. What I meant to put to you was this: Did it ever occur to you that the oscillation or vibration, especially the oscillation of the bridge, arose from its getting looser than it had been when it was originally screwed up?—Do not take that from me, but did that ever occur to your mind before?—I imagined it might be due to something of that kind.

3920. Did that occur to your mind before?—Yes, it did.

3921. But your view was that the primary cause of the movement, both vertical and lateral, was chiefly at all events the speed at which the train was traveling?—Yes, the excessive speed of the train.

3922. Which was greatest, the vertical or the lateral motion?—The vertical.

3923. Did the vertical motion of the bridge impress your mind, when first observed, as tending to risk or danger?—Yes; anything which produces an oscillation of the bridge, I should think, would be attended with risk.

3924. And that was present to your mind when you first observed these movements?—Yes.

3925. As they increased, I suppose your apprehension of danger increased?—Yes.

3926. And with the result that you subsequently took to crossing the river from south to north by the steamer?—Yes,
3648. Such as you have experienced on solid ground?—No, I do not mean that. I have never felt such a rise on solid ground, but I mean when the train reaches an incline when it is passing from a level to an incline, but then the motion is repeated all the way across.

3649. In taking the progress from level ground to an incline, do you mean travelling upon solid ground?—Yes.

3650. Then these rises and falls you have felt on solid ground, between the flat and the incline?—Yes; but it was much more marked on the bridge than on solid ground. I merely gave you that as a simile.

3651. When you were on solid ground, what did you attribute the rise and fall to?—When I knew there was an incline.

3652. How did the incline produce it, in your judgment?—On approaching the incline I felt as if it were, the bottom of the carriage rose up. You felt as if it were, the bottom of the carriage rise up while you were carried forward in the same line in which you were travelling.

3653. You mean that you yourself were carried forward in the same line, but the bottom of the carriage rose?—Yes, I felt that, just as in a carriage drawn by horses, and going up the incline of a bridge, or anything of that kind.

3654. Has this been the same sensation, but in a greater degree, that you experienced on the bridge?—Yes, something like a suspension bridge.

3655. To what did you attribute the sensation that you felt or observed in travelling on dry ground?—To mounting an incline, to a commencement of it.

3656. Did these bounds seem to you to correspond to the revolutions of the crank?—No.

3657. Did they correspond to anything?—I could not say; it was just the bounding movement which I had felt on a bridge.

3658. You are an architect; have you no theory of or explanation of the bounds that you felt upon the dry land?—I have never felt more than one bound on dry land on approaching an incline.

3659. Have you never felt on travelling along a line on ground, especially when a train was light, a series of bounds all along?—Yes, you can feel that in any train.

3660. Was it the same thing in a greater degree?—No.

3661. What was the difference?—It was the difference caused by the motion of the girder, I believe.

3662. I want first the effect and not the cause. What was the difference between what you felt on the solid ground and what you felt on the bridge?—There is no similarity between what I felt on the solid ground and what I felt on the bridge. I simply give you an illustration that I felt the floor of the carriage rise up and go away again, just as if you were bounding.

3663. Is it something else than this: that what you felt on the bridge was in a greater degree to what you felt on dry land?—Yes, much greater.

3664. But it is a difference in degree and not in line, is that so?—Yes, and repeated.

3665. You attribute that, whether rightly or wrongly, to the vertical vibration of the bridge?—Yes.

3666. Did you form any opinion as to the amount or limit of that vibration?—No.

3667. Whether it was an inch or less?—I should say it was more than an inch.

3668. Two inches?—I could not say.

3669. This is a thing susceptible of precise ascertainment, I suppose, by observation by a theodolite?—It would be difficult.

3670. But do you happen to know that it is susceptible of precise observation?—Yes, if you have a proper point of observation.

3671. As regards the lateral movement you appear to have a difficulty in distinguishing how much of that is attributable to the movement of the carriage and
how much is attributable to the movement of what the carriage is travelling upon?—Yes.

3672. And you would hardly feel it safe to attempt
to draw that conclusion?—I am certain it was lateral
motion, but it was not noticeable as compared with
the vertical motion.

3673. And therefore it was very much less.—It
was much less.

3674. Were those trains going faster latterly than
they did at the first when you began to travel?—Yes,
that was my experience.

3675. Did you attribute the increase of the move-
ment, vertical and lateral, to the increase of the speed
in the trains?—Mainly to that.

3676. Whether it was wholly due to that or not
you could not tell?—No.

3677. Or whether it was wholly due to a loosening
of the structure?—No.

3678. You never examined it to see if it was
loosening?—No.

3679. Did you ever make any complaint to any of
the officials on the subject of the speed?—No.

3680. Why not, if you thought it was excessive?—
Because I never found the benefit of making com-
plaints at any time.

3681. Have you ever tried?—I have complained
about other matters many times.

3682. Did you ever suggest to any of the officials
of the company that the bridge was getting loose?—No,
certainly not.

3683. If you had thought it was getting loose,
would it not have been a proper thing to give them a
hint of the matter to know it up?—I should require to
have been convinced before I took such a step.

3684. Has not the idea of its getting loose grown
up in your mind after the bridge fell?—No.

3685. Do you still think it would have been right
if you had seriously thought that the bridge was
getting loose to suggest this to those who might
tighten it up?—The mere fact of the oscillations
being repeated so frequently on the bridge had a
tendency to loosen it. That was all I knew.

3686. But you did not think it was loosened to the
extent of danger?—I did.

3687. Then why did you not tell anybody that?—I
may not have thought that it was loosened to the
extent of danger, but I felt that the excessive speed of
the trains had a tendency to loosen it.

3688. But you have no further explanation to give
for not calling the attention of anybody to that fact?
—No.

Re-examined by Mr. Tritton.

3689. Your experience of complaints to public
companies has not been favourable?—No.

3690. But I suppose you were aware that the
railway officials had been going along the bridge
constantly, who should have been aware of this oscil-
alation, or looking after its causes?—Perfectly so.

3691. And if the bridge was loosening it was their
business to look after that?—Yes.

3692. I have no doubt if you had thought the
bridge was loosening to such an extent as to produce
an immediate danger, you would have felt it your duty
to have spoken upon the subject?—I certainly should.

3693. If you were of opinion that this high rate of
speed leading to oscillation would, if continued, lead
to serious defects in the structure itself?—Yes. There
were other dangers as well. There was the danger of
the Tavport train starting off at such a rate after
passing the south cabin.

3694. That was a matter which would have
been as easily discernible by the railway officials as by
yourself, if they had been attending to their duty?—
Yes. I thought there was no use in complaining,
because they ought to have been cognisant of it.
They kept a register at the ends of the bridge.

3695-6. You think they ought to have been aware
of the probable results upon the bridge?—Yes.

3697. You have described the vertical motion as
something similar in character to the motion you feel
in a train when you rise from a level to an incline?—
Yes; when you pass from one to the other. I felt
the floor of the carriage rise.

3698. On solid ground, I suppose, when you leave
the level and get on to the incline, there is just one
vertical motion, and then there is a steady progress?
—Just so.

3699. On the bridge, you did not see any motion,
but a continuous series of bounding motions from the
time they commenced till they got off the bridge?—
Yes; out of the high girders.

3700. That, I suppose, is a kind of jumping along
the railway which you are not accustomed to on solid
ground?—No;

3701. Was not its continuance also something
different from anything you have experienced on solid
ground?—Yes; or on the railway.

3702. Pretty much the difference, I suppose, that
there is between walking on solid ground and across
a suspension bridge?—Yes; just like the motion on a
suspension bridge.

3703. (The Commissioner.) As I understand you,
in going from level ground to an inclined upwards,
you feel, as it were, the bottom of the carriages coming
up?—Yes.

3704. And in going down an incline downwards
you feel it, as it were, going down?—Yes; you feel
it pass away from you.

3705. This was a succession of ups and downs?—
Yes.

3706. Not what you meet with on solid ground,
namely, a change of motion either upwards or down-
wards, and then, an even movement?—I gave the
illustration to explain the kind of motion there
was; the rising up of the floor of the carriage, the
sort of bounding.

3707. You are quite sure when you registered—three minutes and a half?—Yes.

3708. Did you make any note of it?—No, only in
my memory.

3709. And the four minutes?—Yes.

3710. Only in your memory?—Yes, I made a note
of it.

3711. No written note?—No.

3712. Were you often in the habit of doing that—
registering it?—Yes; every time I noticed it.

3713. And you generally found it to be four min-
utes?—I have found on going from the north to the
south side, they went in from 4½ to 5 minutes, and
coming over from 4 to 4½ minutes.

3714. It was generally so?—Yes.

3715. (Colonel Yolland.) The time occupied in
passing from cabin to cabin, I think you have stated
on one occasion to have been 4½ minutes.

3716. That was the greatest speed you observed?
—Yes.

3717. What does that actually represent in miles
per hour?—That depends upon the length of time
they take to get up full speed.

3718. I am speaking of the average time. What
does it represent as regards the average speed—is it
not as near as possible 34 miles an hour?—It would
be about that, but you will travel through the high
snidors at a much greater speed than that.

3719. I speak of the average from cabin to cabin?
—Yes.

3720. (Mr. Barlow.) Did you say that the vertical
movement you experienced in those vertical oscillations
amounted to an inch?—I dare say it was more, but I
had nothing to go upon for that; the motion was
sufficiently marked to be alarming.

3721. But your impression is that it was an inch?
—No.

3722. You cannot say that it was an inch?—I
might have that idea. It might have been four
inches, but it is a mere guess; I cannot tell. I have
no data to go upon.

3723. Upon what part of the bridge did you find
the worst oscillation?—Inside the high girders
mainly.
3724. On no other part of the bridge?—Yes, approaching them on the south side. I have felt it begin before I entered the high girders.

3725. As soon as you entered them did that motion continue all the way through?—Yes.

3726. Was it quite even all through that distance: fairly even?—Yes.

3727. Did you find any difference between the middle of the girders and the pier?—I cannot say. I could scarcely tell when I was passing the pier.

3728. Did the piers go up and down?—No; I think it would have been right.

3729. How do you account for the movement?—The train would set up a movement of vibration, and the train would also produce its own vibration; there might be a mixture of both.

3730. At any rate, you noticed no difference between passing the middle of the span and passing the pier?—I should fancy that the deflection producing the oscillation would be the greatest in the centre of the span. It must be.

3731. You noticed no difference whether in the middle of the span or over the pier?—I noticed no difference.

3732. (The Commissioner.) Whether you were over the piers or in the middle of the span?—No, I did not observe in passing. We passed the piers so quickly that you could scarcely tell the carriage having an oscillating motion, I do not think anyone could tell.

3733. (Mr. Balfour.) How did you take the time precisely—from what points?—From cabin to cabin. I timed it also inside the high girders.

3734. How did you take the time?—By my watch, on the second hand.

3735. Then you counted the number of minutes and seconds till the train passed the next cabin—was that it?—Yes.

3736. Then what sort of watch had you; one of the stop-watches?—It was not a stop-watch.

3737. Did you take it at the precise seconds?—Yes.

3738. Did you mean in saying three minutes and a half that it was three minutes and thirty seconds precisely?—Yes.

3739. No odd seconds?—No.

3740. Was it the same with all you have given?—I do not think I have given any more.

3741. Was four minutes precisely the time?—Yes.

3742. Neither out nor in?—No, neither out nor in.

(The Commissioner.) I thought he said from four to four and a half minutes.

3743. (Mr. Balfour.) You did not note any of them at the time?—No, but I have a perfect recollection of them.

The witness withdrew.

(After an interval.)

JAMES SMITH sworn.

3744. You are station master at the West Station in Dundee?—The Tay Bridge Station.

3745. You were examined at the previous stage of this inquiry, I believe?—Yes.

3746. You remember Mr. Robertson, who was examined to-day, complaining to you about the speed at which the trains were running across the bridge?—I do.

3747. When was that?—I did not take any note of the time.

3748. Can you give me an idea?—I should think it was about in December if I recollect rightly.

3749. You heard his evidence to-day, did you?—Yes.

3750. I suppose, so far as you recollect, his statement of the time was accurate?—I think so.

3751. Kindly tell me whether Mr. Baxter was with him? I cannot recollect.

3752. Did you hear him say he was with him?—Yes, I heard that.

3753. And you have no reason to doubt it?—I have no reason to doubt it.

3754. What was it that Mr. Robertson stated to you?—He first complained it was about the speed on the bridge.

3755. What did he complain of then?—The nature of his complaint was that the trains were running at too high a speed through the high girders.

3756. Did he say that he had timed the trains?—Not in the first instance that I remember.

3757. Did he say at what rate the trains were going through the high girders to which he objected?—Not in the first case.

3758. In general terms he simply complained that the trains were going through the girders at too great a speed?—Yes.

3759. Did he say anything about the effect it had had upon his own mind or upon his person?—No.

3760. Did he not suggest that it was found that it might incur risk?—I do not think he mentioned his going to incur risk.

3761. But obviously you have no distinct recollection of what actually was said?—Not on the first occasion.

3762. But simply that Mr. Robertson did make a complaint about the rate of speed?—Yes.

3763. To consequence of that did you do anything, or what did you say to him in reply?—I told him that I would see about the matter, and I went both to and from the south end myself with several trains timing them.

3764. Immediately after he spoke to you?—Yes, immediately after he spoke to me.

3765. The drivers, I suppose, of those trains would know that you were there?—No, they did not know it.

3766. Did you time the trains on those different occasions?—I did.

3767. What time did they take to go from south to north, from cabin to cabin?—From south to north, on our occasion the train took five minutes; on another, five and a half; and on another, six minutes.

3768. Was the five minutes the quickest train that you ever travelled in from south to north?—Five minutes was the quickest time that over I timed a train on the bridge from south to north.

3769. Did you give any instructions to your railway servants and drivers and others with reference to the time at that time?—I told the drivers that a complaint had been made.

3770. Did you give them any instructions?—I told them what the result would be if it was repeated.

3771. What was the result?—The result was that I was not aware that they were travelling at too high a rate of speed.

3772. You told them what the result would be if they did not obey your instructions; what was to be the result?—The result was to he that they would be suspended or dismissed by the locomotive superintendent.

3773. Did you give those instructions to all the drivers?—I think so.

3774. Did you give them by some general notice posted up, or did you personally speak to each?—I personally spoke to them, to every driver, but
MINUTES OF EVIDENCE.

3775. There were many drivers who were not on the local line, were there not?—There were, but there was no complaint made about the main line trains. I never heard of it on that occasion.

3776. You never heard a complaint about the main line train?—No.

3775. Did Mr. Robertson specialize the local trains as those that were in fault, or did he generally speak of the trains that ran across with?—The trains he came across with.

3778. And those might have been main line trains as well as local trains?—I know that Mr. Robertson only travelled on rare occasions with the main line trains.

3779. Then he usually travelled by local trains?—Yes.

3780. You say it took place on the first occasion; how many times did he speak to you altogether?—Twice, as far as I can recollect.

3781. When was the first occasion?—I did not take a note of that.

3782. The second occasion was how long after the first occasion?—I think it was about the middle of December on the last occasion.

3783. Have you any idea of the interval that there was between the two complaints?—No, I cannot say that.

3784. On the second occasion what did he say to you?—He mentioned the speed on the second occasion. I do not remember whether it was 43 or 47 miles an hour.

3785. It was largely in excess of the regulation speed?—Yes, it was.

3786. Which was 25 miles an hour?—Yes.

3787. How was that made known to the drivers; was it printed in the regulations?—Yes.

3788. Was each driver furnished with a copy of it?—The locomotive superintendent will be able to speak to that.

3789. But you know that it was so stated in the regulations?—Quite so.

3790. And should have been communicated to the drivers if it was not?—Yes.

3791. On the second occasion Mr. Robertson told you that the trains had gone at the rate of either 43 or 47 miles an hour?—Yes.

3792. Were you not aware that the trains were going beyond 25 miles an hour?—I was not aware of that.

3793. At what rate would a train be going at, suppose one to start from the south, would it increase in speed before it reached the north, and would it be still increasing in speed after it left the south cabin?—It would increase in speed until it came to the summit. I think so, but I cannot speak as to that.

3794. It would not decrease its speed going down, would it?—It ought to do.

3795. If a train was going from cabin to cabin in five minutes, what would be, in your opinion, the highest rate of speed that it would reach between those points?—I could not give it you in figures.

3796. Is it not probable that it would rise to about 25 miles an hour?—I do not think it would.

3797. What is the average rate of speed per mile doing the bridge from cabin to cabin in five minutes?—Twenty-four miles an hour or a little under that I should say.

3798. Do you think the train would not increase in speed between those points beyond 25 miles an hour?—I should not like to give an opinion upon that.

3799. You have not done it in figures?—No.

3800. I suppose you do know, as a matter of fact, that the train increases in speed from the south cabin until it reached the summit of the bridge?—I cannot say as to that.

3801. What was the speed at which the train ought to have been going so as to pick up the station?—It was limited to a speed of two miles an hour.

3802. If the train was going at that speed at the south cabin, it must have increased considerably from that point to the summit of the bridge if it was to travel the whole bridge from cabin to cabin in five minutes—do not you see that?—If the speed is two miles an hour at the south cabin, how long would it take to go across the bridge at that rate?—I never put it down, and I should not like to go into the figures.

3803. Does it not show you or anybody that looks at it, that it must have increased in speed very much from the south cabin if it was observing the regulation speed there, or before it even reached the regulation speed at the summit of the bridge?—Yes, I quite agree to that.

3804. Have you any idea what was the highest speed that any train reached on any part of that bridge between cabin and cabin?—I have not.

3805. Has anybody else complained to you except Mr. Robertson of the speed of the trains?—Mr. Laing did on one occasion, but he did not complain for himself.

3806. Who is he of the "Advertiser" newspaper?—Yes.

3807. And he stated that complaints had reached him?—Yes, that several ladies had spoken to him about it.

3808. Was anything said by Mr. Robertson or anybody else about the oscillation of the bridge?—No.

3809. Was it never mentioned?—No, not by anybody.

3810. Did you report any of those complaints to your superior officers in the railway company?—No.

3811. Why?—Because I was not able to substantiate a rate of 43 or even 47 miles an hour.

3812. You know Mr. Robertson well, do you not?—Yes.

3813. He is a gentleman who has been in a very responsible position in the burgh, and he made that statement to you deliberately?—Yes.

3814. If that statement was even true, and the speed was an excessive one, did you think it right to report to any of your superior officers that Mr. Robertson had made such a complaint, with a view of having it carefully investigated?—I checked it for myself to begin with—I mean the speed—not only at the high girders, but from point to point, and I considered if I had been sending in reports at that time that I was not able to prove what I had stated.

3815. You did not need to prove what he stated, and you did not report it to any of your superiors?—No.

3816. Did you do anything to check his statement after he gave you his second complaint?—I did.

3817. You had done that after the first?—Yes, I did it after the first.

3818. And also after the second?—Yes.

3819. How many times did you cross the bridge with a view to check his second statement?—I believe I went half a dozen times.

3820. Within how many days?—Within three or four days on each occasion.

3821. Your crossings were on each occasion within three or four days of the complaint?—Yes.

3822. After you had warned the drivers that you had heard of complaints?—Yes.

3823. You did warn them on each occasion?—Not the second time. I spoke to the locomotive foreman the second time.

3824. You spoke to him with a view of his communicating at once with his drivers?—Yes, I did.

3825. It was within three or four days after you had so spoken to the drivers on the first occasion and to the locomotive foreman on the second occasion that
you made your journeys for the purpose of testing the speed?—I believe on the second occasion—I went direct—after Mr. Robertson made the complaint the second time I went directly to the locomotive foreman.

3826. And it was after you had done so, within three or four days after you did that, that you made the journeys to test the speed?—Yes.

3827. On both of those occasions when you made your journeys for the purpose of testing the statements which had been made to you, it was after those complaints had been communicated to the drivers or to a person to tell the drivers?—It was.

3828. In one case you knew that the drivers were aware of the complaint, and in the other case you had reason to believe that they would be made aware of it?—I was aware that they were made acquainted with it.

3829. Your tests were taken within three or four days after the drivers were told that the complaints had been made, were they not?—It was so.

3830. Did it occur to you to test those complaints at any time after those three or four days, when probably the force of the observations to the drivers had passed away?—I watched them in crossing and recrossing; I did not watch any train, but I watched half a dozen trains in the day.

3831. Without a watch in your hand you were not timing the trains?—No, but I could tell generally.

3832. It was general observation, not exact timing of the trains?—No.

3833. Did you, in travelling across the bridge, five minutes time, not feel any movement at all?—Nothing particular.

3834. Did you feel anything in general?—Nothing but what you might expect in crossing a bridge.

3835. It was more than you would feel going across solid ground?—Not in a train. I have walked it so often. I felt it when I was walking, but not in a train.

3836. Do you mean to say that you have felt the effect of the train when you were walking?—No.

3837. Your own walking across the bridge would make no impression, would it?—No.

3838. You have been on the bridge when trains passed and you have felt the motion that has been produced?—Yes.

3839. What kind of motion was it?—It was a vertical motion.

3840. Was it of the same character as the spring in a suspension bridge?—I cannot make a comparison. I do not like to speak upon it if I am not certain.

3841. You felt the motion, and it was a vertical motion?—Yes.

3842. You have walked upon a suspension bridge, I suppose?—Not often.

3843. But you have been on one?—Not for 20 years.

3844. Twenty years ago, did you then feel any vertical motion?—I cannot remember.

3845. The vertical motion was perfectly perceptible to you when the train went past?—Yes.

3846. Did you feel it preceding the train—did you feel the motion before the train came up with you?—Yes, I did.

3847. There was a wavy motion more or less as it appeared to you before the train that caused it had reached you?—Yes, I felt it then and heard a sound too.

3848. You felt the motion?—Yes.

3849. Before the train reached you can you give me any idea what distance in advance of the train the motion was distinctly perceptible?—I cannot give you that in figures, but I felt it a pretty long distance.

3850. (The Commissioner.) You could feel the movement a long distance?—Yes.

3851. (Mr. Trayner.) Occasioned by the advancing train?—Yes.

3852. Will you put it into yards?—I could not do it conscientiously, not into yards.

3853. Or the angular of span?—I cannot even do that.

3854. Was it several spans?—It was.

3855. That is the vertical motion; did you never feel a lateral motion?—I never did.

3856. Whether with a passenger or a goods train?—With no train.

3857. No matter with what speed?—No.

3858. Did you feel any lateral motion when you were in the carriage?—Not that I can remember.

3859. At no time and under no circumstances?—At no time.

3860. Were you aware that the local trains were sometimes detained on the south side past their advertised time of starting in order to let the northern express go past?—I am quite aware of that.

3861. That often happen?—Very often.

3862. Do you think or does it appear whether the driver of a train that was thus detained, did not try to make up his time a little in coming across?—I do not think so.

3863. They have no orders not to do it?—They have general orders not to exceed the speed.

3864. Had they no orders not to go across the bridge at a greater speed than 25 miles an hour; had they no orders to regulate the trains in that exceptional case?—Not that I am aware of.

3865. Do you not know that trains that have been detained on the south side by the coming of the express have made up time?—I am not aware of that.

3866. Cannot you tell that by time at which they reached your station?—The guard's report sheets would show that.

3867. I speak of your own observation. You cannot say that you have ever observed that?—I have had certain complaints from the other end of the bridge at the station a hundred times.

3868. Of trains that have been detained beyond their advertised times—the time behind its time?—Not of one particular express, but I have known it when I have timed the trains.

3869. That were detained behind their own time?—I have.

3870. Did you find whether or not those trains had made up a little time in coming across?—I never timed a train come in half a minute or a quarter of a minute before its time—any train that ever I timed.

3871. If it was kept within 10 or 15 minutes waiting for the express, it would be that time behind, would it not?—I took the time from the train when it started to Dundee.

3872. You would get that time at a subsequent period by applying to the men at the south box?—I have stood and watched the trains starting, and I have timed them when they have come in, thousands of times.

3873. Is it not consistent with your knowledge that a train which is behind its time at the point of starting generally tries to make up its time between that place and the point of its arrival?—My experience is not so open at all occasions.

3874. Will you say that so far as you are aware there never was a train detained beyond its advertised time on the south side of the Tay which did not make up some of its time before it reached your station?—I am on oath, and I should say that I never knew it.

3875. Was your attention drawn to that particular matter, or to any other matter, or is that the result simply of general observation?—It is simply the result of general observation.

Examined by Mr. Balfour.

3876. And very frequent observation apparently?—Yes, it was.

3877. You told us about two complaints—one by Mr. Robertson, or, rather, two by Mr. Robertson, and one by Mr. Lang, on behalf of some ladies?—Yes.
3878. These were the only complaints that you ever heard?—As far as I can recollect,......
3879. There are a very large number of persons who travel daily between Newport and the adjoining districts on the south and Dumfries on the north?—Yes.
3880. Daily travellers who, live on one side, and come daily, once at least, on the other?—Yes.
3881. And from none of those have you ever had a complaint?—None whatever.
3882. Nor from any of the numerous persons who travelled by the distant trains?—Never a single complaint.
3883. Can you give us an approximate idea of the average daily number of persons coming and going to Newport?—I can scarcely give you that just now.
3884. Between hundreds and tens?—I dare say, taking a rough calculation, we should carry upwards of a thousand passengers both ways, in and from, each day.
3885. Counting all the trains?—Yes; they are always increasing in Newport, the trains.
3886. There must be some of the people who cross twice?—Yes; many of them cross twice.
3887. It was not a mere, exceptional complaint, but the complaints were those that you have mentioned?—Yes.
3888. Have you very often travelled by trains, both before and after the Provost, Mr. Robertson, complained?—Yes.
3889. You have very often walked across the bridge when trains were passing?—I have.
3890. Both before and after?—Yes.
3891. Speaking of the motion, you said that the vertical motion you felt sensible; would you describe it as a tremor or as a wavy motion?—I would describe it as a tremor. I think when a train is a good way off I should call it so.
3892. As it approaches, how would you describe it?—was there any perceptible rising and falling of the bridge?—Not perceptible.
3893. Was there anything which excited the slightest apprehension in your mind?—No.
3894. Or which you thought was likely to excite apprehension in the minds of others?—None.
3895. With regard to lateral deflection, you have not found that to exist?—No.
3896. If there had been anything like a habit or system of drivers making up for lost time on that bridge, you would have failed to know it from your observation?—No, I could not.
3897. From the frequent opportunities that you had for watching the trains?—Yes.
3898. You are acquainted, I suppose, with the speed of the trains generally?—I am.
3899. How long have you been in the railway service?—25 years.
3900. Would you have the slightest difficulty in knowing from observation whether a train was travelling at 25, or at 40, or at 47 miles an hour?—I could tell it within 5 miles.
3901. Would you have any difficulty when travelling by a train in saying whether it was going at the rate of 25 or up to 40 or 44 miles?—I should know the difference in a moment.
3902. Would you also know the difference when you were standing not on the train, but observing it either when it passed you on the bridge, or when you were stationed at any point?—No difficulty whatever.
3903. Although you could not time it within a mile, you could not be in error?—No.
3904. Can you say from your observation whether you were looking or travelling in a train it ever went through the girders at from 45 to 47 miles an hour?—I am certain it never did, or anything approaching it.
3905. Do you think that a train could get up that speed between the time it passed the signal-cables at either the regulation rate of two or three miles, or anything near it and the middle of the bridge?—It is impossible, I am satisfied of that.
3906. The Provost, Mr. Robertson's complaints, I understand, related to the Newport train exclusively?—Yes.
3907. What kind of engine serves that train?—It is what we call a tank engine.
3908. A different type of engine from what runs long distances?—Yes.
3909. With a small driving wheel?—Yes.
3910. You know the type of engine?—Yes.
3911. Do you know the difference between the facility with two types of engines with regard to getting up a moderate speed quickly?—I would not go the length of that.
3912. Are you satisfied that it would not be possible to get up a speed of 40 or 47 miles within that distance with any kind of engine?—That is my opinion from what I have read, and my former experience.
3913. You were asked why you did not report the matter to your superiors. Did you take all the means which in your judgment were requisite to ascertain whether the complaint was well founded or not?—I did.
3914. By observation, experience, and inquiry?—Yes.
3915. And the conclusion you came to is what you stated?—I thought that the Provost, Mr. Robertson, was mistaken. I knew he did it in good faith; but still I thought he was mistaken.
3916. Is it a matter in which you think a person might have made a mistake, especially, if he was not a correct observer?—I think so.
3917. Then you did reiterate the standing directions to the railway servants?—Yes, I did.
3918. I suppose the directions or orders have never been withdrawn?—Never.
3919. Having taken the means to see whether the complaint appeared to be well founded, reiterating any orders, and seeing whether they were obeyed, did it appear to you that anything more was called for?—Not at that time.
3920. Does it appear to you now that anything more should have been done?—If any other complaint had been made, and there had been a locomotive foreman, I should have been obliged to bring it before him.
3921. But none was made?—No.
3922. Did you do all that appeared to you proper to be done in the circumstances?—Yes, I did.
3923. Looking back upon that, does it appear that you should have done anything more or anything different?—I do not see any reason to think so.
3924. Speaking generally, are you satisfied that the 25 mile limit was observed in the use of that bridge?—I am; that is from cabin to cabin.

Re-examined by Mr. Traynor.
3925. Without saying what rate of speed might be attained between those two points?—That I cannot speak to. I should not like to speak to that.
3926. You say that you never had seen a train going through the high girders at the rate of from 43 to 47 miles an hour?—Yes, I did.
3927. Looking back upon that, does it appear that you should have done anything more or anything different?—I do not see any reason to think so.
3928. Speaking generally, are you satisfied that the 25 mile limit was observed in the use of that bridge?—I am; that is from cabin to cabin.
3931. Just answer the question. Do you think that the Provost, standing with his watch in hand, from the time the train entered the high girders till it went out, was likely to be correct in the result of his observation?—I should say that he was quite capable about taking notes.

3932. And of course correctly representing what he heard?—Yes.

3933. Did not the Provost tell you, although he only complained to you twice, that he had found the trains going at what he thought an excessive speed on more than two occasions? I mean on more than the two occasions on which he spoke to you?—Not that I remember.

3934. When he told you of the excessive speed on each occasion, did he not say that it was a matter that he had to complain of, not on account of one occasion, but on account of others?—I could scarcely say how he put his complaint, but I should not like to say that he did not.

3935. You got more than one complaint; you got two complaints from him, and you got one complaint from Mr. Leng?—Yes.

3936. What more complaints did you want to induce you to go to your superiors?—I did not get a complaint in an official way at all.

3937. Mr. Robertson's complaints were made to you in an official character, were they not?—He merely met me on the platform.

3938. You were on the platform as station-master, and therefore officially the complaint was made to you as station-master, and because you were station-master. Having got those complaints from him, while you were acting officially, and from Mr. Leng, what more complaints did you want before you mentioned the matter to your superiors?—There was no want in reporting unless I was able to substantiate my reports.

3939. Your checking would never have tested whether Mr. Robertson's statement was correct: it would tell the result of your own observation, but it never could have checked the fact that he had spoken to you of it? Why did you not communicate to your superiors what Mr. Robertson on two occasions and Mr. Leng on one occasion had distinctly brought before your notice?—The only reason is what I have mentioned.

3940. You thought that you had done enough by speaking to the driver and to the locomotive foreman?—Yes.

3941. You took the same means of checking the statement made by the Provost, Mr. Robertson, whether or not the drivers were contravening their regulations?—When you went across on those occasions did you go ascertaining the speed trust to your general knowledge, or did you time the trains watch in hand?—I timed the trains watch in hand.

3942. How often?—About half a dozen times on each occasion.

3943. Did it take exactly 5 minutes and 30 seconds 6 minutes exactly on the three occasions you have given us?—I could not give it you a second or two. 3944. But it was there or thereabouts?—Yes.

3945. Might it be a second or two less or more?—It might have been.

3946. What part of the train did you occupy when you were making those observations?—The rear part of the train.

3947. In the way?—Not on all the occasions.

3948. On some occasions were you in—were you beside the guard?—No, I do not remember being in the van at all.

3949. You said at the end of the train—I thought you meant the guard's van?—No.

3950. You were in one of the carriages?—Yes.

3951. On how many occasions did you check the speed that way, watch in hand, after Mr. Robertson first complained, can you say?—I could not say—several times.

3952. When you say "several times," you mean after the second complaint?—Yes.

3953. After Mr. Leng's complaint about the ladies who had been frightened, did you go and check it again?—No, I did not check it then.

3954. Was Mr. Leng's complaint before Robertson's or after?—It was between the two, I think.

3955. You have had three complaints: first Mr. Robertson's, and then Mr. Leng's, about the ladies who felt alarmed?—Yes.

3956. Alarmed at the rate of speed, as I understand you?—Yes, that was what was communicated to me.

3957. Then you got finally a statement from Mr. Robertson in the middle of December, and you did nothing except to take two or three trains to check the first and the third complaint, speaking to the drivers on the first complaint, and to the locomotive foreman on the third?—That is it.

3958. When you heard that the ladies were alarmed, whether with much or little reason, what did you do on that complaint to remedy any error there might be?—I asked Mr. Leng if he could mention the train, and I never got it from him.

3959. Still he said that ladies had come across and were alarmed at the speed?—Yes.

3960. Did you do anything in consequence of that complaint?—I was always watching the trains.

3961. Did you do anything?—Nothing whatever.

3962. (The Commissioner.) You said you timed the trains, watch in hand; did you?—Yes.

3963. For what purpose—to see what time was taken between the signal station on the south side and the signal station on the north side?—Yes.

3964. Then I understand you to say that you thought it was all right in the event of the total distance run from one point to the other not exceeding 25 miles, or whatever might have been the speed between the two points?—I did.

3965. You never tested the speed between the girders?—I never did.

3966. Then in what respect is it that you said that the Provost, Mr. Robertson, must have made the mistake that you have said he did. In what respect could he have made the mistake if he tested the speed between the high girders?—Because I have felt that no driver would attempt to descend an incline of 1 in 72 approaching the cabin, and then to stop to take the hatch.

3967. It was simply because you had greater faith in the drivers than in Mr. Robertson?—I should not like to say that.

3968. Do you read these instructions simply as meaning that they are not to exceed a speed of 25 miles for the whole distance, but they may go slower at first and quicker in the middle, so that they do not exceed a total of 25 miles in the whole distance?—That is it.

3969. Therefore they might have gone 45 miles an hour between the high girders, provided they went slower at the beginning or at the end?—(No answer.)

3970. The Provost, Mr. Robertson, might have been right?—So far as I have checked.

3971. You have only checked the total distance—not the speed between the girders?—I watched so many trains passing there that I am certain I never saw a train go that speed.

3972. Your position and your duties are at the station, are they not?—Yes.

3973. That is, on this side of the river, is it not?—Yes.

3974. You cannot see the trains moving on the high girders there, can you?—Not from the platform.

3975. You have to go on to the bridge to see them?—We can see them from the goods' yard where I go several times a day.

3976. That is what you are accustomed to do, is it?—Yes.

The witness withdrew.
MINUTES OF EVIDENCE.

JOHN BLACK sworn.

Examine by Mr. TRAYNER.

3979. You are engaged in the parcels' office of the Caledonian Railway at Dundee?—Yes.
3980. What is your age?—Twenty-one.
3981. On the 28th December last, I believe you came from the south side of the Tay to the north, across the Tay Bridge, in a train that passed over immediately before the last train that passed over?—Yes.
3982. From the south?—Yes.
3983. That was the train that left Tayport for Dundee at 5.50?—Yes.
3984. The guard of which was a man named Shand?—Yes.
3985. And the driver a man named Kennedy?—I don’t know his name.
3986. You were in the guard’s van?—Yes.
3987. Who else was in the van besides you and Shand?—A man named Bevick.
3988. That is a man who is in the Caledonian Company’s engine shop at Dundee, is he not?—Yes.
3989. How did you and Bevick come to be in the guard’s van?—We were late, or I was late.
3990. How did you and Bevick come to be in the guard’s van?—There was no room in the train at first. I came to the station late, and had not time to seek for a seat.
3991. You first jumped into the guard’s van?—Yes.
3992. Had you known the guard?—Yes, I had seen him.
3993. You had crossed from Tayport to Dundee previously, and you knew move or less of the guard?—Yes, I know most of them by sight.
3994. And they would know you?—I do not know that.
3995. The night was very stormy, was it not?—It was extremely stormy.
3996. Do you remember approaching the south cabin?—Yes.
3997. At what speed were you going?—I should say from three to four miles an hour—a very moderate speed.
3998. They pick up the laston there?—Yes.
3999. After you passed the south cabin, was there any increase of speed?—Yes.
4000. Soon after you left the south side, was anything observed to which your attention was called?—Mention was made that there was fire flying from the wheels of the train.
4001. Who mentioned that?—I think Bevick.
4002. Where had he been?—He was standing looking out at the time.
4003. At one of those little windows in front of the carriage, that enabled him to look forward, and he called attention to this?—Yes.
4004. Did you look out?—Yes, I did.
4005. Did you see sparks?—Yes, I saw sparks.
4006. On which side of the train were they?—On the east side of the train.
4007. Were those sparks numerous?—Yes, they were.
4008. Were they coming from one of the carriages, or were they coming from the wheels more or less all along the train?—When I first looked they were coming from the rear carriage, the carriage next the van, but immediately afterwards I noticed them from the whole of the carriages.
4009. You first noticed them from the wheels of the carriage nearest the van, the van that you were in?—Yes.
4010. There were two vans on to the train, were there not?—I cannot say.
4011. Immediately thereafter you noticed the sparks spreading all along the train?—I did.
4012. Did the guard look at those sparks?—He did.
4013. What did he do?—He put on his break and also held out his red lamp at the window.
4014. What effect had the break upon the train?—It decreased the speed considerably.
4015. Did it bring it up?—Not altogether.
4016. Was it very nearly brought to a stand?—Yes.
4017. Are you sure of that?—Yes.
4018. Was it brought so much up that the driver must necessarily have known that the break had been used?—Yes, he must have known it.
4019. Or anybody in the train must have felt that the speed had sensibly decreased?—Yes, they must.
4020. At what side did the guard hang out his red lamp?—On the east side.
4021. The side on which you saw the sparks?—Yes.
4022. Did you look out on the west side?—I did.
4023. Did you see any sparks there?—No.
4024. How long did those sparks continue?—Till the train was brought very nearly to a stand.
4025. Did they then entirely go out?—Not altogether, I do not think.
4026. Did they continue, although in a decreased measure, until you got to the gliders on the north side?—I was not looking out steadily, that is to say I occasionally saw them.
4027. Did you see them, I suppose, until you came near to the north side?—Yes.
4028. The driver took no notice either of the break or of the signal-lamp, so far as you know?—When the break smacked he would know most likely that the guard was to allow the train to proceed.
4029. Did you hear the sound of his whistle, or did he do anything to indicate that he was answering the break by bringing up the train?—No.
4030. So far as your observation went, the driver disregarded the putting on of the break, and certainly gave no answer to the signal-lamp?—No, so far as I saw or heard.
4031. He paid attention to neither of those things?—No.
4032. The wind was blowing from the west?—Yes.
4033. When the train was brought nearly to a standstill, did you see whether the sparks continued to proceed from the whole train, though in an abated measure?—Yes, they did.
4034. After the guard loosened his break again, and you went on, did you notice whether the sparks were more in number than they had been when the break was applied?—They were fewer in number after we went on.
4035. Were they fewer in number after you went on than they had been before the break was put on?—They were.
4036. The putting on of the break did not occasion any of them?—No.
4037. They were worst at first?—Yes, when I noticed them.
4038. The putting on of the break stopped them to some extent, did it not?—It lessened the speed of the train.
4039. It stopped the number of the sparks?—It lessened the number of sparks.
4040. When the train went on with the break eased again, the sparks did not increase, but kept decreasing?—Yes, they kept decreasing.
4041. When you looked out on the west side did you feel any motion in the carriage you were in?—Yes, I felt a motion of swaying from side to side.
4042. Was it violent?—Yes.
4043. Did you feel no other motion than swaying from side to side, no motion up and down?—No.
4044. Was the carriage swaying from side to side or lying over on one side?—It seemed to be lying over on one side.
4045. Which of the two was it; was it lying over?—When gusts of wind came they perceptibly affected the carriage.
4046. What was the effect of the gusts of wind upon the carriage?—They seemed to tilt it over in a manner.
4047. Whether it was the wind on the bridge affecting the bridge, and the bridge tilting it over, or whether it was the wind upon the carriage which tilted it over you cannot say? — I cannot say.

4048. As a matter of fact, the carriages did seem to go over to the eastwards from the effect of the gusts of wind? — They did.

4049. Either directly from the effect of the wind upon the carriage or from the effect of the wind on the bridge, which affected the train? — Yes.

4050. Did you notice when you looked out of the west side of the carriage whether the carriage was visible above, or whether the wheel was above the rail? — I did not notice.

4051. Why did you form the opinion that it was lying over; if it was lying over to the east, the wheel on the west side must have been to some extent above the rail? — The spring would give to an extent.

4052. Was it nothing more than the springs would give? — I cannot say that it was more.

4053. Will you say that it was not? — No.

4054. You do not know what the result of it was in extent, but simply that you felt that either the wind or the bridge was setting the carriage over to the east? — Yes.

4055. As far as you saw none of the wheels left the rail? — As far as I saw.

4056. You know that there was a guard-rail there? — Yes.

4057. Is that guard-rail to the east or to the west of the easternmost rail? — The guard-rails are inside.

4058. You could not see them when you looked out of the window? — No.

4059. Could you see whether the sparks were being struck from the rail or whether they were being struck from the wheel? — The sparks appeared to be caused by the wheel pressing upon the rail.

4060. By the friction between the two? — Yes.

4061. Did you feel the bridge moving at that time? — No.

4062. You felt the motion in the carriage? — Yes.

4063. And you did not know whether there was a corresponding motion at the time upon the bridge or not? — No, I did not.

Cross-examined by Mr. Balfour.

4064. Was everything that you felt and saw on that occasion consistent with the view that what you observed and felt was due to the wind bearing against the carriages, and pressing them against the rail? — Yes, that was my opinion at the time.

4065. And was that your opinion still? — Yes.

4066. Did you not then, and do not now, attribute that to any shaking in the bridge, or the blowing over of the bridge, as distinguished from the carriage? — All the giving way of the carriage I saw; all that the carriage gave way I attributed to the wind.

4067. The carriage giving way while the bridge remained where it should have been? — Yes.

4068. Nothing, as far as you observed or felt, gave way, except that the carriage slightly canted over, as the force of the wind might cause it to do? — That is so.

4069. And when the break was put on the sparks ceased at once? — They decreased.

4070. When the break was put on to the carriages, then, in your judgment, they ceased to bear over as much as they had done when they were going at greater speed? — I must explain that I only saw the carriages tilting over when I looked out on the west side, I did not feel it on the carriage, I only saw it, was it as if the wind was slightly bearing them out of their perpendicular a little? — Yes.

4072. Was that quite consistent with the sparks coming from the east side? — Yes.

4073. And falling against the rail? — Yes.

4074. When you saw the sparks diminish, did not that show to you that the carriages were bearing less against the rail? — The decreased speed of the train would account for that.

4075. The friction was less and the bearing less? — Yes.

4076. Then, was the canting over of the carriages observed by you before the brake was put on? — I was not looking out before.

4077. But just when it was put on? — Yes, then I looked out at it.

4078. Did you observe any canting over after the train was slowed or not? — Yes, it did to a certain extent.

4079. To a less extent? — I cannot say.

4080. Can you describe how much of the carriage would be out of the perpendicular? — My opinion at the time was that it had not given way more than the springs would allow, seeing that the pressure of the carriage was thrown over on the east side.

4081. Is that your opinion still? — Yes.

4082. You do not think that the bridge was out in perpendicular? — No.

4083. You had looked out of the carriage window in going round the curve? — Yes.

4084. Was that very much what you saw there? — It was different in kind.

4085. You had seen the train bearing slightly over? — Yes.

4086. And you attributed that solely to the action of the wind upon the carriage? — Yes.

4087. (Mr. Trayer.) What is the meaning of "different in kind"? — I mean when I saw the wind strike the carriage I saw it give way.

4088. You could see that? — When I heard the gale of wind coming, I could see when they struck the carriages.

4089. Did you ever see a railway carriage on any other occasion than that put out of the perpendicular by the wind? — No.

4090. You have seen a carriage going round a curve, have you not? — Yes.

4091. That throws it slightly out of the perpendicular, does it not? — Yes.

4092. Was there any difference, so far as the incline of the carriage was concerned, between what you saw that night and what you might see at any time going round a sharp curve? — In going round a sharp curve the tilting is continued until the curve is passed. As far as I could see, that was just a sudden shock driving the carriage over, and then it gained its perpendicular again.

4093. The carriage was more or less lifted up, and went back again to its place? — Yes.

4094. As the heavy gusts of wind came the carriage rose gradually on one side, and then went back again? — Yes.

4095. How often did you observe that vertical motion that night? — I saw it as often as I looked; two or three times possibly.

4096. Every time you looked out you found that the carriage was rising and falling in that particular way on the west side? — Yes.

4097. Did you look out at the east side at all? — At first, when I heard that fire was flying from the wheels.

4098. Did you see whether anything was visible on the east side of the incline, showing that the carriage was rising and falling from the west side? — I did not notice it at that time.

4099. You are sure that each time you looked out of the west window you could tell that the carriage was rising and falling again, at least, to the extent to which the spring would give? — Yes.

4100. Can you tell me whether or not it was just the motion that would have been produced by the bridge itself swaying? — I cannot say that.

Further cross-examined by Mr. Balfour.

4101. Mr. Trayer asked you in your examination-in-chief, whether the driver had disregarded or paid no attention to the brake? — Yes.

4102. And you said, I think, that he had not? Did you mean anything more than that he did not answer to the brake? — He did not answer to it.
4103. Did you mean to convey that the driver having observed the brake did not discharge his duty?—I did not.

4104. (The Commissioner.) When you said that the carriage on the west side was slightly raised above the rail, but it was pressed over it so that the spring on the east side was compressed?—That is what I mean.

4105. That is to say, not that the carriage was bodily lifted up so far as you could see, but only that it was by being pressed upon the side that the spring on the east side, or the right-hand side, was pressed down?—That is what I mean.

4106. When you looked out on the east side did you observe that the carriage was pressed down in that way?—I did not observe it on the east side.

4107. You could not observe it on the east side when it was tilted up on the other side?—No.

4108. You are sure that the carriage was put out of the perpendicular?—Yes; blown out of its centre of gravity to a certain extent.

4109. Was that always so when gusts of wind came?—Yes.

4110. At intervals?—Yes.

4111. When did you first observe those sparks before you got between the high girders?—Two or three trains' lengths past the signal box on the same side.

The witness withdrew.

JOHN BURK sworn.

Examined by Mr. Trayner.

4122. I believe you are engaged as a litter in the engine shop of the Caledonian Railway?—Yes.

4123. And you reside at Dundee?—Yes.

4124. On the night of the 26th of December last, did you leave Tayport for Dundee by the train leaving Tayport at 5.50?—Yes.

4125. You were in the guard's van?—Yes.

4126. Shand is the guard?—Yes.

4127. And the last witness, John Black, was in the van along with you?—Yes.

4128. How did you come to be travelling in the van instead of in a carriage?—I went to the water-closet; two or three times and could not get in, and I was away down the line, and came running up and jumped into the van just as the train was starting.

4129. Was there anybody else in the van except you three?—No.

4130. You travelled in the train from Tayport on to the south end of the bridge?—Yes.

4131. Did you stop at Newport?—Yes.

4132. At what rate were you going when you got to the cabin at the south end of the bridge?—Three to four miles an hour.

4133. How do you happen to fix that; were you observing it at the time?—Yes.

4134. You picked up the baton there?—Yes.

4135. What o'clock was it when you passed there?—I cannot say.

4136. Do you not know how long you took to come from Tayport to the south cabin of the Tay Bridge?—I could not exactly say.

4137. The night was very stormy?—Very stormy.

4138. After the driver got the baton, at the end of the south cabin, did you notice anything?—Yes.

4139. What did you notice?—Fire coming from the wheels.

4140. Was it flashes?—Just something seemed as if it had been a brake put on.

4141. Then was it a distinct shower of sparks, a flash following flash?—Just following flashes.

4142. Where were those flashes coming from?—From about the centre of the train, as I thought.

4143. Not from the carriage next you?—No, it was further forward.

4144. Was it, specially—seemingly only from one carriage or from several?—It appeared to come worse from one.

4145. Where was that one?—About the centre.

4146. You were sitting in the van?—On the right side.

4147. In front of the van, and looking through a small window that enabled you to look forward along the side of the train?—Yes.

4148. Did you call attention to this?—I called the attention of the guard.

4149. What did you say to him?—I said, "Shand, there is something up with the train; look out.

4150. And what did Shand do?—He went and looked out, and he said, "It is hard running against the check rail"; that is what the guard thought. We looked again, and it appeared to be getting worse.

4151. And then what did he do?—He put on the brake.

4152. Did he put on the brake fully?—He turned it round as fast as he could?—Yes, he gave it a good twist.

4153. Had it any effect upon the train?—It slackened the speed a little.

4154. But if he gave it a good twist it should have slackened it a good deal, should it not?—Yes.

4155. Did it slacken it a good deal?—Not so much as you would have thought.

4156. Was it slackened so much that anybody in the train, in an ordinary carriage, would have known that the speed was diminished?—Not much.

4157. Do you think it might not have been noticed?—It might not have been noticed.

4158. Then the driver might not have noticed it either?—The driver told me he thought it was.

4159. Never mind what the driver told you. Do you think the speed of the train was so much slackened that the driver might not have noticed it?—I do not think it was sufficient to attract his attention.

4160. If it was not enough to attract the attention of the driver, did you see any use in it?—It appeared to steady it a little.

4161. But apart from that there was no good that you saw brought about by using the brake?—Except to keep the train tighter.
4162. Except that there was no other effect produced by the tightening of this brake?—No.
4163. Did the guard do anything else but put on the brake?—No, put out the red lamp.
4164. Where did he put out the red lamp?—Over the driver.
4165. On which side?—On the east side.
4166. When the brake was put on did the brake make the flashes better or worse?—I thought they were better.
4167. Were they very much less, or were they in doubt about that?—They were a good deal better.
4168. That is to say, there was less fire?—There was less fire.
4169. When the brake was taken off did the fire increase?—It kept about the same.
4170. It kept the whole way across the bridge in the reduced condition to which it was brought by the putting out of the brake?—Yes.
4171. How long was the brake on altogether?—I could not exactly say.
4172. Have you no idea?—I could not say. I was keeping close, watching to see the movement.
4173. Were you afraid?—Well, I was a little.
4174. What were you afraid of?—Well, I thought it would fall to the west.
4175. And that might have done anything? Did you feel any motion in the carriage?—She was bearing up on the west side with the wind as I thought, as you find a train carrying up and down with the springs.
4176. Did the train do anything more than race and fall on the springs?—Nothing.
4177. Did you look out of the west window at all?—No.
4178. So that you could not see whether the carriage was tilted up or not?—You could feel her just sort of moving.
4179. You felt it shaking?—Yes.
4180. From side to side?—No, not much.
4181. From top to bottom?—Yes.
4182. Was it canting over rather to the east?—Yes, it was canting over rather to the east.
4183. How much did it cant over to the east?—I could not say exactly.
4184. But you cannot tell whether it was the wind that was canting it up?—Well, I suppose it was the wind.
4185. But it might have been the wind on the bridge as well as the wind on the train?—I do not think there was anything wrong with the bridge, the bridge was right enough. 
4186. Just tell me how long that up and down motion continued; in the first place when did it commence?—About half-way between the high girders and the land.
4187. And that was before the brake was put on at all?—Yes.
4188. When the brake was put on did that motion continue?—It lessened down a little.
4189. But it still went on to some extent?—Yes.
4190. It went on to some extent although it did tighten it?—Yes.
4191. After the brake was taken off did it get better or worse?—There was not much difference.
4192. Do you mean that there was not much difference between what it was before the brake was put on, and what it was when the brake was on?—When the brake was on and when it was off, it canted a little over.
4193. So that the brake made very little difference in the movement of the carriage, but what difference it did make was to steady it a little?—Yes.
4194. The guard's putting on the brake and showing the lamp did not bring it to a standstill so far as you saw; the driver did not pay any attention to those things?—As far as I saw.
4195. There was no sounding of the whistle nor stopping of the train, nor anything of that kind?—No.
4196. What speed did you go at across the bridge?—I think we were running between 14 and 20 miles an hour.
4197. Was that when the brake was on?—Yes.
4198. And you would be going quicker when the brake was off?—But it did not make much difference.
4199. The brake does not seem to have made much difference?—It made really very little difference, but the driver thought it was.
4200. Never mind that; we will ask the driver. After the brake was taken off and you continued your journey, did you see fire continuing till you got all the way to the north side?—It stopped after we got to the curve.
4201. When you reached the curve on the north side, it very much decreased?—Yes.
4202. Up to that time it continued very much the same from the time it began?—Yes.
4203. You have told us about that moving up and down of the carriage or the van; did you feel it going from side to side as well?—No, not much.
4204. Did you feel it all?—A little; the motion of the train.
4205. But there was nothing unusual in the motion of the train from side to side?—Nothing.
4206. Then the wind was making no difference upon the train, in so far as the motion from side to side was concerned, different from the ordinary night, or on land?—Not to my knowledge.
4207. Did you tell anybody at the railway station when you had got in about the fire you had seen?—No.
4208. Did you never speak about it at all?—No; I saw the guard and another man going along the train and examining the wheels afterwards.
4209. Did you not mention it to anybody that you had seen fire there?—No.
4210. Did you form an opinion as to what was causing the fire?—Yes; I thought it was the wind pressing the carriage over.
4211. Pressing the carriage over to what?—Over on the check-rail or the guard-rail.
4212. Is not the rail that the carriage runs upon outside of the guard-rail?—Yes.
4213. And how was the wind blowing from the west pressing the carriage up against the east rail?—The wind would drive the sparks over.
4214. Then your notion was that the wind was blowing the carriage over upon the rail it was running on to produce sparks which were blown by the wind from the west to the east?—Yes.
4215. In your view, then, it was the pressure of the wind pressing the carriage down upon the rail that the carriage was running upon?—No, not at all.
4216. The wind was blowing from the west?—Yes.
4217. Can you tell me how the carriage was being crushed against the guard-rail; which guard-rail was it being pressed against?—Against the west one.
4218. And you thought the fire was being produced on the west side of the carriage, but driven by the wind under the carriage, and making its appearance on the east side?—Yes.
4219. That was a pretty big fire to be blowing from the west side through the carriages to the east. Is that your opinion?—Yes, it was coming from the west.
4220. Did you form an impression, apparently, was that something was wrong with the axle?—Yes.
4221. And when there was nothing found to be wrong with the axle, looking to the wind, then you adopted this view?—Yes.
4222. When you arrived at the north side, did the people in charge of the train examine the wheels to see if they were all right?—They did.
4223. And did this examination show that they were all right? —Yes.
4224. And when they were found to be all right, could there have been so many cause the fire except the pressure of the wind? —Nothing except the pressure of the wind.
4225. Did the fire cease whenever you got so far north as to be out of the direct blast of the wind? —Yes.
4226. You described the effect that the putting on of the brake had in diminishing the sparks? —Yes.
4227. Would the effect of putting on the brake be to tighten down the train at the tail-end? —Yes.
4228. And the heavy engine would have been held her down at the front? —Yes, it kept the train all tight.
4229. So that the train would be tightened down to the rail? —Yes.
4230. And therefore it would be loose at the tail than before the brake was put on? —Yes.
4231. Would it not be quite consistent with your view as to the effect of the wind? —Yes.
4232. You told us, I think, that you were quite satisfied that there was nothing wrong with the bridge? —Nothing wrong with the bridge.

Re-examined by Mr. Tinney.

4233. I suppose you do not know much about bridges, although you know a good deal about engines? —I know a little.
4234. You said that if the brake was put on it would tighten down the train at the tail, and the engine would tighten it down at the front, but did you not tell me a little while ago that the effect of putting on the brake was very slight? —It tightened the train.
4235. How much did it affect the movement of the carriage, and how did it affect the tightening of the train? —It slackened the speed.
4236. And therefore it tightened down of the train? —I could not tell the pressure.
4237. Would it not depend much upon the pressure that was upon a van tightening it down whether it stopped the train or not? —It would depend much on whether the engine got more steam or not.

The witness withdrew.

Examinad by Mr. Tinney.

4255. You were previously examined on this inquiry? —Yes.
4256. And you then mentioned you were the driver of the train that left Tayport at 5.50 p.m. on the night of Saturday would that be quite consistent? —Yes.
4257. And you were bound for Dunbee? —Yes.
4258. Between Tayport and Dunbee how many stoppages had you? —Two.
4259. What were they? —East and West Newport.
4260. When you came to the south cabin of the bridge, at what rate were you travelling? —Two miles an hour, and possibly a little under that.
4261. What speed had you been going at between West Newport and the south cabin? —About the usual speed.
4262. What is that? —I could not exactly say the speed.
4263. What is the usual speed between West Newport and the south cabin? —It would be 25 miles an hour.
4264. Then you had reduced your speed very much at the cabin? —Yes.
4265. When did you begin to reduce your speed? —About a quarter of a mile, or scarcely that.
4266. And you had brought yourself down to a little under two miles an hour? —Yes.

A. Kennedy recalled.

4267. What are your instructions with regard to the speed at which you can pass that south cabin? —Two miles an hour.
4268. Why did you bring yourself below that? —It is difficult to pass over one staff and take another unless you are going very slow.
4269. Were you much below the two miles? —No.
4270. I suppose you were as near to it as in your judgment you could come? —Yes.
4271. You got your baton there? —Yes.
4272. And proceeded across the bridge. Was there anything happened between the two cabins to attract your attention? —Nothing.
4273. Was not the brake put on? —It was, about the summit of the bridge; it is usually put on there as you go down the incline.
4274. But was there no putting on of the brake before you reached the south end of the high girders? —I did not feel it.
4275. If the brake had been put hard round, with the view of stopping the train, would you have felt it? —Oh, yes, I might.
4276. You must, I suppose, if you had been attending to your duty? —Yes.
4277. Then your opinion is that that was not done between the south cabin and the high girders? —It must have been near about the summit — about the centre of the high girders.
4278. Between the south cabin and the time you
entered the high girders from the south, that cannot have been done? — No, not hard.

4279. There may have been a turn upon it, but nothing to affect the train? — Yes.

4280. I suppose the guard would know quite well, from experience, how many turns, or how great a twist, to put upon the brake with a view of stopping the train? — I should think so.

4281. And if he intended upon that occasion to put an extra brake so as to call your attention to something wrong with the train, he did not succeed; he did not put it on sufficiently? — No.

4282. You saw nothing of a red lamp which he held out, I believe? — No.

4283. If you had felt the brake at all you would have looked out behind, I suppose, to see whether the guard was signalling to you? — Yes.

4284. But to the usual idea not having felt the brake at all at an unusual place, you did not look out? — No.

4285. What side of the engine were you standing on? — On the west side.

4286. Was that your right side? — Yes.

4287. And therefore if she was going head-forward you would be on the east side going north, on the west side of the train? — Yes.

4288. If she had been going backward you would have been on the other side? — Yes.

4289. Was there anything about the train that attracted your attention that night in the way of sparks? — No, nothing that I saw.

4290. It is right to tell you that you said before that you had seen nothing of these sparks, and knew nothing of them from your own observation; do you think there could have been flashes of fire or sparks emitted from the whole length of that train without you or the stoker, who would be on the east side, seeing something of it? — Of course, where I was I could not see it, but he might if there had been a great deal; but if there had been only a little, possibly he would not.

4291. Do you think that if there was a good deal he might have failed to see it? — Certainly, if he had looked back he might have seen it.

4292. What was the highest rate of speed that you attained on the bridge that night, after you left the south cabin and before you reached the north? — About 23 miles an hour.


4294. And possibly more than 25? — No.

4295. Why? — Because we don't go beyond that.

4296. What is to say your instructions are not to go beyond that? — Yes.

4297. Were you careful to obey those orders? — Yes, very.

4298. I do not want to press this question against you, but did you go across that bridge at a higher rate than 25 miles at the highest? — I am certain I never did.

4299. And were you careful to observe your rules? — Yes.

4300. Was there anything that night in the state of the weather or otherwise to make you observe whether the train was as steady as it had been on previous occasions? — I found nothing unusual in the steering of the train.

4301. If the train had been shifting up from any cause, tending over on the right side to the east side, would you not have been aware of that? — No; I could scarcely feel it on the engine, but I do not suppose it was.

4302. If it did happen it might happen quite well without your seeing or being aware of it? — Yes.

4303. So far as you know, nothing of that kind happened that night? — Nothing.

4304. There was nothing in the movement of the engine contrary to the usual practice? — Nothing.

4305. And nothing in the tender? — There was no tender; it was a tank engine.

4306. Do you think that you had reached 25 miles an hour or thereabouts by the time you got to the high girders? — I might have been about it, but not exceeding it.

4307. You had got that up between the time you passed the south cabin and the time you reached the high girders? — Yes.

4308. You could have got up even a higher rate if it was permissible? — Not much.

4309. What was the highest speed that you could have reached if you had been allowed to go at any rate you liked? — I do not suppose I could have got beyond 30 miles an hour without lashing up the engines very much.

4310. The greatest amount of human skill and ingenuity could not get that engine up to more than 30 miles an hour? — I do not think it.

4311. Are all the tank engines the same? — All those that work that Tayport traffic.

4312. There is none of those that could be got up to more than 30 miles an hour? — No, not in that distance.

4313. Supposing that you started from the south cabin at a speed of four miles an hour, what is the highest rate of speed you could have reached by the time you had got to the summit? — You could not have got beyond 30 miles an hour.

4314. Wherever you were you could not get more than 30 miles an hour out of that tank engine? — No.

4315. Or out of any other tank engine that you know of? — There are some of the tank engines that have higher wheels.

4316. Tank engines in the North British Company's service? — Yes; but not used in the Tayport traffic.

4317. Then there is no tank engine that is or was used by the North British Company between Dundee and Tayport and West Newport that they could possibly get more than 30 miles an hour out of, doing the best they could? — No.

4318. Did you ever try to get the most out of it you could? — No.

4319. Then it is merely an opinion? — Yes.

4320. Was there anything about the train that night to indicate, as far as you could perceive, that it was being affected by the wind? — It seemed a little stiffer to pull.

4321. And that you thought was occasioned by the wind? — Yes.

4322. And with that difference it was just as usual? — Yes.

4323. Could you tell whether your train was being pressed against the guard-rail, or could you not? — No.

Cross-examined by Mr. Balfour.

4324. About the speed at which you passed the signal-cabin, is there a regulation on that subject? — Yes.

4325. You have to deliver up one baton and take on another? — Yes.

4326. And if you drop the baton are you fined? — Yes.

4327. In order to deliver one baton and take over the other, is it necessary that you should slow down to about the regulation speed? — You must.

4328. You could not interchange the batons without? — No.

4329. Were you in the practice, during last summer and autumn, of driving the 8.35 train from Newport to Dundee? — Sometimes.

4330. You, I believe, are what is called a relief driver, are you not? — Yes.

4331. And you take the trains at the times that the other drivers take their rest? — Yes.

4332. How many days a week would you be driving that particular train during that year? — Sometimes twice.

4333. And sometimes oftener? — No.

4334. What was the man who regularly drove it at other times? — There were two, John Anderson and John Brown.

4335. Did you sometimes also drive the 7.25 train
from Newport to Dunsden?—There is one at night
somewhere about that time.
4336. Besides the 8.35 train which other trains did
you drive from Newport during the summer and
autumn? Did you drive others in the morning and
others in the evening?—Not earlier than 8.35.
4337. Did you drive any in the evening?—Yes.
4338. What others were they?—The 5.50 train
from Taunton.
4339. And later on?—The 7.30 from St. Andrews,
and round that way. Tho' 8.05 or about that.
4340. So that you drove the morning and evening
trains that you have named?—Yes.
4341. About twice a week during the summer and
autumn?—Yes.
4342. That was your regular duty during the sum-
er and autumn?—Yes.
4343. Is the only kind of engine that has been used
on that line a tank engine?—Yes.
4344. What was the diameter of the driving-wheel?
—About 4 feet.
4345. Is it 4 feet or 4 feet 6 inches?—It might
have been 4 feet 6 inches. I could not say exactly.
4346. What is the measurement across the driv-
ing-wheel of the big engines that do the long journeys?
—I cannot say. I think they are 5 feet.
4347. Are they not 7 feet?—No.
4348. I am not now asking you as to the tank
engines; I am asking you as to the diameter of the driv-
ing-wheels of the big engines that do the long journeys?—They
were about 7 feet, I think.
4349. Does a tank-engine with a wheel of a small
diameter get up to its speed much more quickly after
starting than the big engines with the 7 feet driv-
ing-wheels?—Yes.
4350. But can it ever attain to nearly such a high
speed as the engine with the big driving-wheel?—
No.
4351. Then is it correct to describe the kind of
tank-engine used on the Newport line as one which
quickly gets up to a moderate speed?—Yes.
4352. How soon after starting from the south cabin
would it get up to its standard of speed?—It might
be before it got into the high girders.
4353. In your judgment could such a tank-engine,
with a train behind it, get up to 43 or 47 miles an
hour at all?—No.
4354. Nor 35 miles an hour, with a train behind it?
—No, not really. I do not think it.
4355. Is that type of engine regularly used for that
kind of branch work?—Yes.
4356. You were asked in regard to the speed, and
I think you told us that you were careful to obey the
orders you received about the 25 mile limit, and you
were asked also in regard to the train on that particu-
lar Sunday evening. Would it be quite possible that
the low heavy engine would not be affected by the
wind, but that the carriages behind, which were
lighter and higher, might be affected by the wind?—
Yes, they might.
4357. So that the guard and the people in his van
might be sensible of an effect upon their carriages
which they were not sensible of on your engine in the
front?—Yes.
4358. And there was nothing which brought to
your knowledge in going along the bridge that there
was anything unusual about the lighter carriages
behind?—Not in the least.
4359. You did not happen to be looking round when
the red light was put out?—It was on the opposite
side.
4360. But you could not see it?—No.
4361. You neither did see it nor could you see it
from where you were?—No.
4362. And you were not conscious of anything
more than that the train was stiff to move; that you
attributed to the wind?—Yes.
4363. Might it also have been due to putting on
the brake, although he did not know it at the time?
—It might have been.
4364. But, looking to the way that the wind was
blowing, it did not occur to you whether it might be
the brake or merely the action of the wind causing
an additional bite upon the rails?—No.
4365. Did you ever time the train in passing along
the bridge?—Yes.
4366. From what point to what point?—From box
to box.
4367. What times did you get?—I never did it in
less than five, but often a little over.
4368. Six?—Yes, five and six too.
4369. Did you ever time it between the high
girders alone?—No.

Re-examined by Mr. Traylor.
4370. What made you time it when you did?—
Mr. Roberts, the locomotive foreman, told me there
were some complaints about the speed.
4371. How did you time it?—By my watch.
4372. Has it a second hand?—Yes.
4373. Tell me exactly the time that you observed
by your watch that you took to go from cabin to
cabin?—I have been just about five minutes, five and
a quarter, and five and a half minutes.
4374. Did you never come just a little inside of the
five minutes?—No, always a little over.
4375. Were you making up your mind not to be
within the five?—No.
4376. Were you trying to keep outside of the five?
—No; I just ran at my usual speed.
4377. And you held your watch in your hand to see?
—Yes.
4378. Did not Mr. Roberts tell you that there had
been complaints about the speed at which the trains
ran in the high girders?—Mr. Roberts told me that.
4379. And it never occurred to you to look at what
time you took between one end of the girders and the
other?—No.
4380. You sometimes did it in five minutes, some-
times in five and a quarter, and sometimes you took as
much as six minutes?—Yes.
4381. How did that variance occur; how did you
take a whole minute difference sometimes over that
short distance?—I do not know. Sometimes the train
was heavy and sometimes it was light.
4382. The speed varied according to circumstances.
You might do it in five minutes, and you did it in
five minutes?—Yes.
4383. There is a train that leaves West Newport,
I think, in the morning 8.35; is there not?—Yes.
4384. Did you drive that train?—Yes, sometimes.
4385. How often?—Twice a week sometimes,
sometimes twice every second week, and sometimes
twice each week and once the next.
4386. That seems to have been a very exceptional
train for you to take?—Yes, I was the relief man,
and that was the only train I could take.
4387. Did you ever drive the train that leaves
West Newport at 7.13 p.m.?—Yes.
4388. How often did you drive it?—About the
same.
4389. (The Commissioner.) I think you said you
had never timed yourself between the high girders?
—No, I never timed myself between the high girders.
4390. All that you thought yourself bound to do
was not to go more than 25 miles an hour from cabin
to cabin, was it not?—Yes.
4391. So that you kept within 25 miles there it
did not matter what speed you went between other
parts; was that so?—I never exceeded 25 miles an
hour.
4392. Not any part of the way?—On no part of the
bridge.
4393. (Mr. Barlow.) You take that staff on to
the engine at the south cabin, do you not?—Yes.
4394. Where do you give it up again?—At the
north cabin.
4395. At what speed do you bring your engine
to when you pass the north cabin?—About three
miles an hour.
4396. About the same as the south?—One mile
in advance on the south side, two miles off the Taunton
side, and three miles off the other side.
The witness withdrew.

Adjourned to-morrow at 10 o'clock.

FIFTH DAY.

27 Feb. 1880.

(Mr. Treacher.) Perhaps I may be allowed to say that I have received from the Board of Trade copies of letters which have been forwarded to the Board of Trade by different parties relative to the Tay Bridge disaster, with reference, many of them, to the causes of it, and some containing suggestions with regard to the construction of the bridge, and as to a remedy for what is supposed to have been, by the writer, the evil; and by the instructions of the Board of Trade I have to hand to each member of the Court a copy of the correspondence (handing in the same). A copy will be furnished also to the railway company, but it will not be at all referred to in the course of the present inquiry.

Mr. William Ross McKelvie recalled.

4408. But the statement and the abstract coincide, do not they?—Yes; the statement is correct.

4409. The result is that on your previous examination you stated that there were three gales instead of two?—Yes; three gales instead of two from the west.

4410. Otherwise is your statement correct?—Yes; with this exception, that it should be 16 times from the south-west instead of 15.

4411. Is that correctly shown upon this paper?—Yes.

4412. You have corrected it?—Yes.

4413. Is the statement as now corrected by you accurate?—Yes. So far as I know I have done my best.

(The Commissioner to Mr. Balfour.) Have you seen this document? (Mr. Balfour.) Not yet, sir.

[The document was handed to Mr. Balfour.]

(Mr. Balfour.) Yes; I find I did see it yesterday.

Cross-examined by Mr. Balfour.

4414. I think you made a report to the society of which you are a member relative to the wind on the night in question?—Yes, I did.

4415. Is the document which I now show you, dated the 1st of January 1880, a draft written in your handwriting of that report which has passed out of your custody?—Yes.

4416. That is the report you made. Is it a true one; is the statement accurate?—So far as I know, I meant it to be accurate.
THE WITNESS WITNESSED.

EAMINING BY Mr. TRAYNEE.

4419. You are connected with the "Dundee Advertiser"?—I am managing proprietor and editor of that journal.

4420. While your professional duties require your attendance in Dundee are you resident in Kinbrae, Newport?—I do so.

4421. In consequence of that you have to come to Dundee and leave Dundee, I suppose, daily?—Yes, generally twice a day. I cross the river twice.

4422. After the Tay Bridge was opened with a connection to Newport, did you use the bridge as your means of transit?—Yes, I think I did.

4423. Constantly, or did you sometimes go by boat?

—If during the last two or three months of the year I crossed on an average three times daily, taking one of the four crossings by the ferries.

4424. The members of your family would also be under the necessity of coming to Dundee occasionally; do you know whether they come by ferry or by rail?

—I had a composition or contract ticket by boat, which expired on the 17th of November. At that time from a preference which my family had for passing by train, I obtained a ticket for a corresponding ticket by the railway.

4425. So that from the 17th of November your family travelled when they had occasion to go to Dundee by the railway crossing the bridge?—Almost invariably.

4426. In what year was this?—1879.

4427. Did you use that composition ticket which you got in November 1879 include yourself as well as your family?—Yes, it did; but I also obtained a single ticket for myself by the ferries, as I wished to have the choice of going either way.

4428. But although you had that composition ticket by railway after the 17th of November I take it that you had very frequently used the railway prior to that time?—Almost as frequently as afterwards.

4429. Over what period did you use the railway as an ordinary means of transit extend?—From the opening of the line to Newport.

4430. You can perhaps give me the date or the approximate date of it?—I forget whether on the 1st of May or 1st of June, 1879.

4431. Did you observe on any occasion, or more than one, anything with regard to the speed at which the train travelled across the bridge?—In trains occasionally coming from the south to the north, I thought the speed exceeded what I understood to be the regulation of 25 miles an hour.

4432. Did you ever actually time it when in hand?—I did not.

4433. But the impression on your mind from merely casual observation was that the rate of speed was beyond 25 miles an hour?—It was so.

4434. As a rule, or exceptionally?—Exceptionally; perhaps one or two trains in a week.

4435. As much as that?—Of course not having kept a record I cannot speak definitely, but speaking from my general impression I should say that it would not be more than one train in 10 or 12 by which it travelled.

4436. Did you form any opinion at what rate those trains were going that exceeded your opinion the regulation speed?—It was difficult to do so on account of the lighting of the light between the lattice work and the girders, and in speaking of the matter I never expressed myself strongly because I had an impression that the passing of those lattices possibly produced a feeling that the train was going faster than it really was probably.

4437. Still making allowance for that, have you now, or had you then, any opinion as to the rate at which the trains were going which you thought were going beyond the regular speed?—If I had been asked to give such an opinion at the time I do not think I should have said it was going more than between 30 and 40 miles an hour.

4438. You would have said that it was going at that rate?—Yes.

4439. Now when the trains were going at that rate, was there any motion in the carriage which attracted your attention?—Yes; there was a motion which is not ordinarily felt on a level railway.

4440. You mean on a railway on land on a solid basis?—Yes; and not only so, but running on a dead level.

4441. Was the motion vertical or lateral, or both?—Without using scientific terms, I think I might describe it as a practicing motion.

4442. It was a motion involving rise and fall?—Yes: a bounding or prancing motion, something like that.

4443. Was it a motion which you have ever experienced in a railway running along a solid basis?—I have felt very similar motions—at least I have an impression that they were very similar motions—in going down a steep incline in a hilly district, such as that of the Caledonian in Dumfriesshire, or the North-western in the neighbourhood of Kendal.

4444. But there was no doubt in your mind that the motion was of the character you have described?

—Not the slightest.

4445. And a motion which I suppose you never experienced in the case of a railway on land which was running on a level, or nearly on a level?—Just so.

4446. Did you experience any other motion, a lateral motion?—Yes, I have repeatedly felt a movement from side to side, but I could not say whether that was the motion of the bridge; I rather felt at the time it was the motion of the carriages, and not of the bridge, itself.

4447. Was it a motion of considerable extent?—It was very similar to that which is felt in all trains going at a rapid rate.

4448. Was it greater or less than that which you have experienced yourself in trains going at a rapid rate over solid ground?—I cannot say.

4449. Did this motion and the speed connect themselves together in your mind?—They did; I thought it arose from the speed at which the train was proceeding.

4450. My question had special reference to what I have called a vertical motion?—Well, that I thought was a peculiar motion, and I did infer that that arose from the construction of the bridge.

4451. Did the speed at which those trains ran, with the motion thereby produced, create in your mind any concern?—Not at all; on my own account I never felt any apprehension whatever with regard to the safety of the bridge.

4452. Did you apprehend danger from any other cause?—I thought there might be danger if any casualty occurred to the train itself.

4453. You said that you had no apprehension with regard to yourself; had you any apprehension with regard to others?—No; it was only from hearing others expressing some anxiety on the subject with regard to themselves and the members of their families,
that I mentioned the subject to two of the officers of the railway.

4454. Before you come to that, just tell me this: some ladies complained to you, I think, of the speed, and that led to your speaking, did it not, to some of the others of the company?—It is scarcely correct to say that ladies complained to me. I think that arose from a statement which was made to me by ex-Provost Robertson that the ladies of his family complained of the velocity of the trains.

4455. Did any ladies of your own family complain?—I do not remember that they ever expressed any fear regarding the bridge.

4456. Or expressed any opinion upon the subject of the speed?—No; they were concerned about another matter, not about the speed of the train.

4457. If it is in any way opposite to the subject of the inquiry, tell us what it was that they felt anxiety about. If it is not, we need not go into it?—I will mention what it was. It was with regard to the junction of the Newport fork with the main bridge.

4458. We need not go into that. It was not only ladies but many others were decidedly anxious with regard to it. From what you yourself observed, and from what you had heard from others, you communicated on the subject of the speed of the trains with some of the other officers of the company?—I did.

4459. With whom did you communicate?—With Mr. Smith, the station-master, and with Mr. Noble, who I understood was an inspector of the bridge.

4460. Will you tell me, if you please, what it was you said to Mr. Smith?—So far as I remember, I stated to him that I and the ex-Provost had had conversation regarding the velocity of the trains, and that I also understood that some ladies were in a state of apprehension on the subject.

4461. Did you tell him what was the result of your own observation and the opinion you had formed with regard to the speed?—No; I think I entirely placed it upon the statements of others.

4462. I have no doubt that Mr. Smith received your complaints with attention?—I always found him exceedingly attentive and obliging when I have spoken to him on any subject.

4463. Did you speak to Mr. Smith on more than one occasion?—I think I spoke to him twice, but I am not quite sure on that point.

4464. If you did speak a second time to him it was upon the same subject, the speed of the trains?—It was. I think I mentioned to him the suggestion which I had previously made to Mr. Noble.

4465. Was there anything else that passed between Mr. Smith and yourself with reference to the speed of the trains beyond what you have told us?—I do not think there was. He promised me that he would look into the matter, and give it his attention.

4466. When you made a suggestion to Mr. Smith, or perhaps I should say when you repeated the suggestion to Mr. Smith that you had made to Mr. Noble, did he say anything with regard to the mode adopted by the company for ascertaining the time which a train did occupy in crossing the bridge?—I do not think he connected it with the time of the train passing the bridge; he simply mentioned to the signalman to keep a record of the passing of the trains.

4467. You also spoke to Mr. Noble, you say?—Yes; I did.

4468. Kindly tell me upon what subject it was that you spoke to him, and what it was you said?—In crossing over in a boat late one evening, I believe it was, I mentioned to him that Mr. Robertson and myself had been speaking about the velocity of the trains, and I suggested to him whether he should inquire of Sir Thomas Bouch whether or not it would be practicable to have an automatic register at each of the signal cabins which would record the passing of every train from end to end.

4469. What was Mr. Noble's reply?—Mr. Noble said that he would bring the suggestion under Sir Thomas Bouch's notice.

4470. Did he afterwards inform you whether or not he had done so?—Yes, he did; he told me that he had mentioned it to Sir Thomas Bouch.

4471. And this was the suggestion, which as you have just told us, you repeated to Mr. Smith?—Yes, it was.

4472. When you felt this motion, in what direction were the trains travelling?—Generally from south to north; in fact, I may invariably say from south to north.

4473. Was the same motion, the vertical motion, perceptible when travelling from north to south?—It never attracted my attention.

4474. You cannot say that travelling from north to south it existed?—I cannot; it must have been very slightly perceptible, otherwise I think I should have noticed it.

4475. If it was there at all?—Yes.

4476. You would doubtless have an opportunity of speaking upon the subject of the bridge and its safety with many people in Newport?—I have had such opportunities.

4477. Can you tell me whether there was any general impression in Newport with regard to this matter of the speed of the trains?—It is difficult to speak of general impressions, but I know in going over in the trains a fellow-passenger would remark, "The train seems to be going very fast," or "faster than usual."

4478. Was that a remark which you had occasion to hear on more occasions than one, or a similar remark?—I do not think I heard it very often.

4479. Still, it was more than upon an isolated occasion?—Yes, more probably five or six times during the whole time I travelled over the bridge.

4480. Did you speak to Mr. Noble more than once?—I think I spoke to him twice.

4481. Was the second time in the form of reiterating your complaint or suggestion, or was it a second communication merely alternating with him that the suggestion which you had made had been represented to Sir Thomas Bouch?—The latter was the case.

4482. So that when I say you spoke to him, and mean thereby that you spoke to him once with a view to remedy what you thought a defect, you only spoke once?—Only once. I may explain that these conversations took place to the best of my belief in the month of December, and in the latter part of December.

4483. That was very shortly before the bridge fell?—Yes, it was.

4484. The train slowed as it approached the south cabin for the purpose, we know, of taking up theodon?—Yes.

4485. After the train had so slowed at the south cabin I suppose the speed noisily and rapidly increased coming northward?—It did so. I was struck with the rapidity with which the speed was raised on several occasions.

4486. Is it the case that, so far as you observed, the speed reached its maximum in the high girders?—That was so.

4487. So that if there was undue speed, it would tell most in that high position?—That would so.

Cross-examined by Mr. RALPOUR.

4488. Was it going by the Newport trains that you were struck by the quickness with which the speed was gained?—That was the case.

4489. That is local trains served with a small tank engine?—Just so.

4490. You said, I think, that the only places other than the bridge in which you felt anything similar, any prancing motion, was in travelling on inclines of the Caledonian and North-Western Railways?—Yes; I gave them as examples merely.

4491. In such places?—Yes.

4492. Now in the case of those lines the motion must necessarily I presume have been a prancing of the carriages upon the rails while the rails remained rigid?—That would be so necessarily.
Can you say that that was not so also on the bridge?—Of course I cannot.

4495. For anything your observation disclosed, the prancing may have been the movement of the carriages upon the rails, while they themselves remained rigid on the line?—That is quite so.

4496. Did you happen to observe anything of that prancing motion in the case of long trains—I mean the trains, or was it only in the case of the "Newport train"?—The Newport trains alone, so far as I remember.

4497. Were the Newport trains much lighter than the through trains?—Yes; there were not so many carriages; and the carriages probably not so well filled.

4498. Probably they were passenger trains; in short, setting down trains?—Yes.

4499. Not so heavy either in the number of vehicles or the character of the load?—Precisely.

4500. Would it occur to you from your observations that such a prancing would be more likely to take place in a light and short train than in a long and heavy train?—That seems to be a reasonable inference.

4501. While at the same time a short and light train would be less apt to move the bridge vertically than a long and heavy train?—That is an engineering question which I cannot answer.

4502. Would it not seem to be a good sense?—Unless I was more familiar with the details, I really should not like to undertake to say.

4503. It comes to this, does it not, that your observation was quite consistent with there not having been a movement up and down of the structure of the bridge?—Except that I have travelled over a considerable number of bridges and do not remember having felt the same sensation elsewhere.

4504. I suppose the bridges you refer to are bridges that one comes upon in the case of long railway runs?—I have been over the American continent, and of course there they travel over a number of bridges of greater length than are common in this country.

4505. I suppose this was the only case where you have experienced such a motion when going with short light local trains across such a structure?—Yes.

Re-examined by Mr. Tait. 

4506. Do you understand you to say that you have experienced, as a matter of personal experience, a prancing motion in the two different places you have mentioned?—It would be wrong for me to say that it was precisely the same motion, but it had a sufficient resemblance to it to recall it to my mind.

4507. In those different cases, however, there was a continuous going down an incline?—Yes, there was.

4508. Which in itself would have occurred to your mind as probably the cause of the continuance of the motion?—Yes.

4509. The same reason would not be applicable to the railway over the Tay Bridge, taking it from the

The witness withdrew.

(Mr. Balfour.) We have just received a telegram, sir, from Mr. Walker, the general manager, stating that a "pitch-pine beam 16 feet long, with part of r', rail chair attached, was washed ashore at Dysart on the 24th, and claimed by the agent as part of the 'wreck of the Tay Bridges," asking for our instructions as to what should be done with it. If the Court desire it, we could give directions that it should be sent to Dundee for the inspection of the Court.

(The Commissioner.) Is there anything that turns upon it?

(Mr. Balfour.) No one has yet seen it, but it might be one of the beams similar to that which the Court have already seen. 

(The Commissioner.) We can hardly upon a telegram say anything.

(Col. Folland.) Is it a longitudinal beam with a rail chair upon it?

(Mr. Balfour.) It is described as a "pitch-pine beam 16 feet long, with rail chair attached." The company will preserve it, so that it may be seen if it is desired.
Examined by Mr. TRAYNER.

4526. You are a doctor of medicine, practising in Dundee?—Yes.
4527. And you reside in Tay Street, Dundee?—Yes.
4528. Had you occasion frequently to cross the Tay Bridge?—Yes, pretty frequently.
4529. Visiting patients, I suppose, on the south side?—Yes, and otherwise, too.
4530. Over the whole period of its existence, more or less?—Yes.
4531. I believe that you, on more than one occasion, timed the speed of the train passing through the high girders?—Yes.
4532. Watch in hand?—Yes.
4533. What was it induced you to do it?—Curiosity.
4534. And did you do it often?—Yes, very often.
4535. At what speed, according to your observation, did the train pass through the high girders?—The highest speed I ever noticed was 50 seconds, and that was only once.
4536. What were the other rates of speed?—I noticed 72 seconds, I recollect that distinctly.
4537. Was that the highest?—The lowest. I think it was about the lowest. 50 seconds was the highest, I know; 70 seconds, I think, was the lowest, and between these periods I have seen them more frequently above 60 seconds than under.
4538. (The Commissioner.) That is to say between 60 seconds and 70 seconds?—Yes.
4539. (Mr. Trayner.) Give us an idea of the number of times you may have timed the train in the high girders?—That is very difficult, not having a list. Two or three dozen times I should think.
4540. Did you notice any vibration or oscillation?—No; nothing more than I observed on any other line.
4541. There was nothing particular in the motion of one kind or other to call your attention to it?—No; I never observed anything.
4542. Did you notice whether trains going south went at a higher rate than those which came north?—Those coming north went at a higher rate than those going south.
4543. Did you time them both ways?—No; I rather think it was only those coming north that I timed.
4544. But the highest rate of speed which you have spoken to passing through the high girders in 50 seconds was, as I understand, coming from south to north?—Yes.

(Dr. Ralfour stated that he had no questions to put to this witness.)

DAVID PRICE sworn.

Examined by Mr. TRAYNER.

4545. You are a painter in Dundee?—Yes.
4546. And I believe you went over the bridge with a view to offer for the contract to paint it?—Yes.
4547. Was your examination of the bridge on that occasion a careful one?—Oh, yes, it was pretty careful.
4548. Your primary object of course was to examine the extent and character of the work for which you proposed to contract?—Yes, and how to stage the bridge.
4549. And especially with regard to the staging I suppose you had to pay attention to the structure of the bridge?—Yes, to a certain extent.
4550. I suppose that your observation would relate chiefly, at any rate in so far as the staging was concerned, to that part of the bridge which was above the footway or the level?—Well, it was more underneath.
4551. You were to paint it all, or at least that was what you were proposing to contract for, both above and below?—Yes.
4552. When did you make your examination?—It was either about the last of May or the end of June, I am not very certain whether it was the 28th of May.
4553. In what year?—1879.
4554. Did you observe any bolts or screws lying loose?—I saw a good number of bolts and screws lying upon the upper portion of the boom, but they were just what had been left over in the construction of the bridge I presume.
4555. You thought so?—Yes.
4556. Bolts or screws that had been required by the workmen and had been just let lying?—Yes.
4557. Did you notice whether any bolt was out of its place?—No; if I never observed that.
4558. Or any of the bolts without the screws or heads on them?—No; I never observed any.
4559. Might such a thing have escaped your notice?—Quite so, it might have done so.
4560. Did you get the contract?—No.
4561. How long did your examination take you; did it extend over more than one day?—Yes; I was three different days upon the bridge, I believe.
4562. And was the bridge at that time being used?—Yes.
4563. I suppose several trains would pass while you were on the bridge in each of the days for the purpose you have mentioned?—Yes.
4564. Did you notice any vibration in the bridge where the trains were passing?—Oh, I always did so.
4565. Was it slight or violent?—We felt the vibration as soon as the train entered the bridge, I believe.
4566. Do you mean that you would feel the vibration of the train from the one end of the bridge to the other?—My principal position was on the bridge on the north end of the fallen girders.
4567. Outside or inside of the fallen girders, to the north or to the south of the commencement of the fallen girders?—My position would be very likely upon the north where it is fallen.
4568. Do you mean that your position would be on a part of the bridge that is still standing?—No; that is down.
4569. Rather to the south of what is now standing?—Yes.
4570. And therefore to some extent inside the high girders?—Yes.
4571. But near the north end of the high girders?—Yes.
4572. And at that point you say you could feel the vibration of the bridge when the train came upon it at the south end?—Yes.
4573. Would you describe whether the vibration you felt was a slight vibration or a violent vibration?—It was slight as the train entered the bridge, and it gradually increased until it came with a waving vibration until it passed.
4574. You felt a wavy motion of the bridge before the train came up to you?—Yes.
4575. That wavy motion increasing as the train advanced?—Yes.
4576. As the train passed you was the vibration very great?—Yes; very great.
4577. Did you notice what the effect of the passing train was upon the girders or any part of the structure of the bridge above the way?—The latter work I presume you mean?—Yes; Yes; I observed that the lattice work vibrated very much.
4579. It vibrated very much every time the train went past?—Yes.
4580. Was it a vibration enough to shake off anything that had been simply placed upon the lattice work or any of the beams, for example a paint pot?—No, I do not think it could have done so.
4581. But you could see it quite distinctly?—Yes.
4582. And I suppose the vibration of the lattice work would be greatest just as the train came up to it, or when past it?—Yes, as the train came up to the position.
4583. Just as it was approaching?—Yes.
4584. Had the train, when it actually came up to the point, any effect in shaking the lattice work, or did it still shake as the train went actually past it?—Yes, as far as my recollection goes, it vibrated extremely as the train passed.
4585. Was that vibration not only visible to the eye but audible to the ear? Could you hear it?—Yes, both.
4586. Would you describe it as a violent vibration?—At times it was more so than others.
4587. How did you account for that—what was it that made it greater at times than at others?—It must have been the speed of the train.
4588. You thought so?—Yes.
4589. Did you notice whether the trains went through the girders at a great speed?—Yes, they went through at a great speed.
4590. Could you form any idea as to the rate of speed?—No, I could not.
4591. Were those passenger trains or goods trains, or both?—Both.
4592. Did you notice whether the upper part of the bridge, the beams, were affected by the vibration which you saw, or the lattice work?—No, it was the lattice work that I saw only.
4593. You could only observe the vibration of the lattice work within the girders?—Yes.
4594. Did you notice outside of the girders, either north or south of them, any motion or vibration in the bridge occasioned by the passing of the train?—No; I could not say that I did.
4595. Did you take notice of any train approaching one way or the other, except when you were within the high girders?—I have several times been off the high girders, and generally I came within the high girders, as it gave a little more shelter from the great draught.
4596. Does it come to this, then, that you never observed the vibration caused by the train except on occasions when you were standing within the high girders?—Yes.
4597. For that reason that if you were outside of the high girders when a train was approaching, you went within the girders to save the draught that the passing train occasioned?—Yes.
4598. Did you use the train as a passenger at all?—Oh, yes.
4599. Did you feel the vibration in it when you were passing over as a passenger?—No, I could not say that I was sensible of it.
4600. At any time?—I could not say that I ever observed it.
4601. Did you travel upon the Tay Bridge both ways?—Yes.
4602. Were you a frequent passenger?—No; I was not.

Cross-examined by Mr. BALFOUR.

4603. When you were within the girders and the train passing, you were necessarily very near the train?—Yes.
4604. How far off would you be?—I suppose about 4 feet.
4605. Not more than 4 feet I suppose, and perhaps less?—Yes; possibly less.
4606. The distance is just about 4 feet as it is not?—Yes.
4607. So that you must have been probably rather less than more than 4 feet?—Yes.
4608. I suppose you have not had much experience of being so near running trains as that?—Certainly not.
4609. It was a novel experience to you?—Yes.
4610. Have you had much to do with great iron railway-bridges?—No; I have not.
4611. This was the first you had had to do with?—Yes; of iron bridges.
4612. This was the first great iron railway-bridge you had had to do with?—Yes.
4613. So that you are not in a position to compare what vibration there was in this iron railway-bridge with the vibration in any other iron railway-bridge?—No.

The witness withdrew.

Examined by Mr. TRANTH.

4614. You are a painter and reside in Dundee?—Yes.
4615. Were you at the painting of the Tay Bridge?—I was.
4616. In whose employment?—In the employment of Mr. Bannett of Sunderland.
4617. He was the man who contracted to paint the bridge?—Yes.
4618. How long were you engaged painting on the Tay Bridge?—Between four or five weeks.
4619. On what part of the bridge were you engaged during that period?—On the high girders only.
4620. At the northernmost or the southernmost end?—From about the fifth pier on the south side northwards.
4621. About five piers from the south end?—Yes.
4622. And you went on from that point working northwards?—Yes.
4623. What part of the work were you to do?—Was it the lattice work and the high girders—the beams?—Every bit about it.

PETER ROBERTSON sworn.

4624. From the underneath to the top?—Yes; or from the top to the underneath.
4625. I suppose there were a great many men employed upon the job?—Yes; there were about thirty, I think.
4626. When you went there did you find a good many loose screws and screw nuts and bolts lying about?—Yes, latterly—that is, when we came to the boom underneath.
4627. How many were there? Can you give us any idea of their number or weight?—Well I should say there was two or three going to do with.—Yes.
4628. Where were those lying?—Yeside the lower booms.
4629. All along it?—All along each side.
4630. Were those cleared away before you began your work?—There was a man on each side of the bridge clearing out each boom, one on the west side and one on this side.
4631. Clearing away those bolts and things and any other rubbish that was there?—Yes.
4632. Was there a good deal of other rubbish on the boom besides the iron screws and bolts?—Yes;
there was a good deal of sand and pebbles, and one thing and another, that falls off the bridge into the boom.

4633. Sand and pebbles off the way?—Yes.
4634. Did you notice how the booms were screwed together? — The plates were screwed — riveted — I think, by bolts.
4635. Plates overlapping each other and bolted together? — Yes.
4636. With screws and bolts similar to those that you saw on the boom? — Yes; I think they were riveted with bolts.
4637. Were the bolts that were used to those plates similar in kind, so far as you could judge, to what were lying along the boom? — Yes, there were different kinds — both nuts and bolts.
4638. But the nuts and bolts that you saw lying on the boom were similar in character to those that had been used in the fixing of the plates? — Yes.
4639. Did you observe any of the bolts out of their holes? — No; I could not say that I did.
4640. You did not observe any bolt-hole that was empty? — No.
4641. Nor any bolt or bolt screw that seemed loose? — No; I never observed that such was the case; there was not many of them and we never took particular attention.
4642. In the course of your painting you did not come across anything of that kind? — No; I could not say.
4643. But if you had come across it you would have noticed it? — Very likely I would.
4643a. And you did not notice anything of that kind? — No.
4644. Of course there were a great many trains passing each day while you were at the work? — Yes.
4646. What effect had the passing of a train on the bridge? — We felt the bridge shake very much whenever a train passed.
4647. When you felt it shaking were you on the bridge itself or on scaffolding which had been put on the bridge? — Both.
4648. Did you feel the shaking equally whether you were on the bridge or on the scaffolding? — I think as near as possible just about equally.
4649. What kind of motion was it which the train in passing produced upon the bridge? — It just made us jump up and down whenever a train passed on the bridge.
4650. Did the bridge move up and down as the train passed, in your opinion? — Well, I should say so; it was bound to do that, for it made us go up and down.
4651. If you were upon the bridge it made you go up and down, and you naturally supposed that what made you go up and down was the thing you were standing upon going up and down? — Yes.
4652. Was that movement violent? — Very much so I think; at some times more so than others.
4653. Was there any other movement than the movement up and down? — Not that I am aware of.
4654. Did you not feel the bridge going from side to side? — No; I could not say that I did.
4655. The other motion was not only very observable, but you say very violent at times? — Yes.
4656. Did that happen every time a train went past? — Every time.
4657. Whether it was a goods train or a passenger train? — Yes.
4658. You did not, I suppose, take much notice of what kind of a train it was that was going past when this motion occurred, whether it was passenger or goods? — Yes; we always noticed which it was.
4659. Could you tell me which made the greatest motion, a passenger train or a goods train? — I could not say exactly. I know with the passenger trains the higher the speed was the greater the motion.
4660. You noticed that there was a higher speed at some times than at others? — Yes.
4661. Much higher? — Yes; a good deal higher.

4662. Could you have left anything standing on the boom without its being thrown off when the motion came unless it was fixed? — We never did so without making it fast.
4663. Your paint-peg and other things were fastened? — Yes, or else inside of the boom.
4664. Inside of the boom could they not be shaken off? — No.
4665. But you knew from experience that you had to fasten things unless they were inside of the boom, otherwise you would have lost them? — We were in the habit of doing so.
4666. From the fear that if you did not do that they would go? — Yes; or leave them in a place of safety.
4667. When you were actually painting, if you had not fixed your material in some way to prevent its being thrown off, that violent up and down motion would have done so? — I would think so, and especially on a scaffolding.
4668. And I suppose you and your fellow-workmen did in point of fact fix your things to prevent the chance of their going off? — Either that or lower them to the bridge.
4669. You would be sometimes below the bridge, and sometimes high up upon the girders? — Yes; the lower part of the bridge was done last, underneath the bridge.
4670. Did you feel the motion most when you were above the bridge, or on the level of the bridge, or below it? — Well, I think I felt it most on the level of the bridge.
4671. I suppose you did some work standing on the way of the bridge? — Yes.
4672. Had you felt that up and down motion while you were standing on the bridge as a train went past? — Yes.
4673. Was it then, as you have described, a violent motion? — Yes.
4674. I suppose you got more accustomed to it by and by? — Yes; we did not take so much notice of it latterly.
4675. You were not engaged at any part of the bridge except within the high girders? — No.
4676. And therefore what you have told us now is the result of your own observation within those girders? — Yes; within these girders.

Cross-examined by Mr. Balfour.

4677. You spoke about bolts and nuts; I suppose you mean by these bolts with a screw on the end of them, and by the nuts you mean the nuts for screwing on to those bolts? — Yes.
4678. Proper nuts and bolts? — Yes.
4679. Was any part of the bridge that you worked upon at the high girders fastened together with nuts and bolts, or was it not all riveted there? — Bolts riveted on the boom.
4680. It was all riveted was it not? — All riveted.
4681. Then it was not fastened together with the kind of things that you found there? — There was a deal of bolts lying on the boom, I expect the same as what the boom was riveted with, but I could not say whether they were the same or not.
4682. Were not all that you found used in keeping the bridge together riveted? — Yes.
4683. Was it not quite evident that these loose bolts and nuts had been the ones used for tacking the bridge together while they were actually working at it and which had been left there? — I do not know what they were for; I never noticed any screw or bolt loose.
4684. There was nothing like them in the bridge, and they were taken away? — With the exception of those bolts.
4685. You surely know the difference between a screw bolt and a rivet? — Yes.
4686. Were not all the things you found bolts with a screw on the end and the nuts for screwing to that bolt? — They were all screws and pieces of bolts.
A different kind of thing from a rivet? — Well, I could not say exactly.

Was it not quite evident to you that these had been used when they were making the bridge and were there to be taken away? — It was quite evident that they had been left there in some way.

You did not suppose that they had fallen off the bridge? — No, not at all.

And you did not mean to convey by anything you said that they had dropped off the structure of the bridge? — No.

And they were taken away? — In fact they could not have dropped off the structure of the bridge, the beams was covered.

Then they were simply taken away with other rubbish which had accumulated in the course of the work? — Yes.

You were asked about this movement of the bridge — was it a kind of trembling? — It was an up and down motion.

How much up and how much down? — I could not say that.

Would you describe it as a kind of dirl? — I would describe it as a sort of dance up and down.

But how much you danced up and how much you danced down you cannot tell? — No.

Have you been accustomed to work on big iron bridges before? — I never did.

It was quite new to you? — Yes.

And you got accustomed to it? — Yes.

Did I correctly understand you to say that you did not see any bolts out of their place? — No.

There were no bolt holes left without any bolts in them? — No.

The witness withdrew.

John Milne sworn.

Examined by Mr. Trayner.

What happened? — It shook.

Where was the shaking worst? — In the high girders.

Inside the high girders? — Yes.

And which was the worst of them, or were they pretty much the same, all the high girders? — Yes.

What kind of a shaking was it? — Up and down.

Have you been close by a train when it passed upon the ground, at any time? — Yes, often.

Was there a greater shaking on the bridge than you ever felt upon the ground? — Yes.

Was there a good shake up and down as the train went past? — Yes.

Something more than a dirl? — Yes.

A good sensible shake? — Yes.

Mr. Balfour stated that he had no questions to put to this witness.

The witness withdrew.

Peter Donegany sworn.

Examined by Mr. Trayner.

How old are you? — Nineteen.

Are you a painter? — Yes.

Are you a journeyman? — No.

Are you an apprentice? — Yes.

Were you at the painting of the Tay Bridge last year? — Yes.

How long were you there? — Two months.

What part of the bridge were you engaged on? — From the north side to the other end of the large girders.

Were you inside the high girders? — Yes.

What was the time? — Yes.

Beginning at the north of the high girders, and going southward? — No; I went southward and came northward.

Were you at the southernmost end, or did you begin inside of the south? — I began at the north end, and then I went to the south end.

You began to work at the north end, and then you were removed to the south end? — Yes.

You do not mean that you painted the whole way down? — Yes, I painted from the north side of the bridge to the large girders, and then went to the south side to the large girders, and then came north.

You were painting on the bridge to the mouth of the girders until you got the length of the girders? — Yes.

And then you were sent to the south side of the high girders and painted northward from that? — Yes.

Did you notice any bolts or screws or bolt heads lying about when you began your work? — Yes.
TAY BRIDGE DISASTER:

At these places where you saw the empty bolt holes did you notice if there were any lying as if they had come out?—No.

You could not say whether the bolt had ever been put in?—No.

But you are quite sure they were empty?—Yes.

Were those empty holes in a line altogether or at different places?—They were one here and there.

With holes of the same kind bored all round them or on each side of them?—Yes.

Did you notice any motion occasioned by a passing train?—Yes.

What was it?—Going up and down.

The bridge went up and down?—Yes.

Had you felt that when you were standing on the bridge?—Yes.

And also when you were on the scaffolding?—Yes.

And on the booms of the bridge and on the structure of the bridge itself?—Yes.

Was this movement up and down violent?—Yes; on the large girders it was more violent.

It was more noticeable there than elsewhere?—Yes.

Did you feel the same thing at every part of the bridge you were on when a train passed?—Yes; that was on the small girders and the large ones too.

But you felt it more distinctly inside the high girders than outside of them?—Yes.

Did you feel that motion before the train came up to where you were?—Yes.

Was it enough to upset your paint-pots unless you had secured them?—Yes.

And did you secure your paint-pots in consequence?—Yes.

Or if you did not secure them you held on by them while the train was passing?—Yes.

Was there any other motion beside the motion up and down that you felt when the train passed?—No, but when a train was coming on to the large girders at the south end we were on the north end, and we felt it shake before it came onto the large girders; it went back and forward—east and west.

You felt the bridge going eastward and westward from side to side?—Yes.

As the train was coming up?—Yes.

Which was the strongest movement, up and down, or from side to side, as the train went past you?—Up and down.

Was the movement from side to side a strong movement also?—Yes.

Did that happen every time a train went past?—Yes.

Cross-examined by Mr. Balfour.

How old are you?—Nineteen years of age.

You told us about some holes that you found in the top of the large girders?—Yes.

How many more?—About six or eight, I could not say how many.

Not more than that?—Not more.

Did you see more than two or three in the lower girders?—Yes.

How many more?—About six altogether, I think, but I could not say.

Was that in the lower boom of the high girders, or nearer to the north shore, or where about was it that you saw these holes?—It was underneath the bridge altogether.

Underneath what part of the bridge; where the high girders are?—No; where the lower girders are.

And there you saw about five or six?—Yes.

And in the high girders you saw two or three?—Yes.

The witness withdrew.

D. Dale.

Examined by Mr. Traisher.

You are a seaman, I believe?—Yes.

And residing in Dundee?—Yes.

But you were employed at the Tay Bridge painting last year?—Yes.

Are you a painter as well as a seaman?—No; I am a seaman.

How long were you there?—About three months.

That is about the whole time the job took is it not?—Yes; all but about a week or nine days.

You went there about a week or so after the job commenced and stayed on till the end?—Yes.

You assisted at painting the high girders, and the girders on each side north and south?—Yes.

Did you notice that the whole structure was fastened together with rivets and bolts?—Yes.

Did you notice a lot of bolts lying there that
MINUTES OF EVIDENCE.

1864. You told us about some bolts and nuts that you found; were they evidently stuff that had not been needed, and were there to be cleared away?—As to the bolts and nuts that I speak about, I painted one side of the lower boom myself on the east side, and there was another man cleaning it out, and there was a lot of gravel and stuff in the boom along with the bolts. Some bolts were thrown down with the gravel, and others were gathered up and put upon the top of the bridge.

1865. Was not all that just rubbish that had not been cleared away until the painters came?—It was just rubbish that was left in when they riveted it.

1866. And you saw that it had not fallen out of the bridge, because everything was in its place as regards bolts and nuts there?—I saw that it could not fall out of any part of the bridge because the top of the bridge overlapped the lower boom, so that it was impossible for anything to fall out.

1867. It would have been like getting in under a shelf?—Under a shelf.

1868. (The Commissioner.) You said you did not see any holes or any bolts loose in the girders; did you mean in any part of the bridge, or did you mean simply in the booms of the girders?—I did not see any part of the whole of the girders with any hole that there ought to have been a bolt in; nothing but holes in the lower boom about 12 feet apart from one another for letting the water out that were made for the purpose.

1869. You did not see any empty holes in the lattice work or anything of that kind?—No; nothing but those bolts.

1870. Nothing but those holes of which you have spoken at a distance of about 12 feet apart?—Yes, for letting the water out.

1871. Where were those?—In the lower booms.

1872. Were there any such holes in the upper booms?—Not that I was aware of or saw.

1873. You did not see them?—I did not see them.

The witness withdrew.

JOHN EVANS sworn.

Examined by Mr. TRAYNES.

1874. You are a mill overseer and you reside in Dundee?—Yes.

1875. I believe you were engaged at the painting of the Tay Bridge last summer?—I was.

1876. And you were present during the whole job?—During the whole job.

1877. The bridge is kept together by bolts and screws?—Bolts, screws, and rivets.

1878. Did you notice whether there were many bolt holes empty?—We came across one occasionally.

1879. Where did you find those bolt holes empty?—I could hardly give you that now.

1880. But you saw no bolts or anything of that kind on the girders themselves?—No.

1881. Did you notice in the course of your painting any hole that had no bolt in it?—No.

1882. Or any bolt that was unscrewed or had the head off it?—No; not in the girders, I did not see that.

1883. Do you mean in the high girders?—In any of the girders.

1884. Did you notice any emptiness in the high girders than outside of them?—It was more perceptible inside the high girders than outside of them.

1885. And you to hold on to your paint-pot, or did they all go as you painted?—It did not move.

1886. In what part did you feel it shake?—It just went from side to side, or both?—I never felt it shake up and down.

1887. Of the Tay Bridge last summer?—I was.

1888. Did you feel the movement that you have spoken of before the train came up to you?—Yes.

1889. And the movement would vary according to the speed at which the train was going?—Yes.

1890. Increasing as the speed increased?—Increasing as the speed increased.

1891. Did you feel the movement that you have spoken of before the train came up to you?—Yes.

1892. A good way off?—We felt the movement as soon as the train entered on the bridge at the south side, and passed those brick piers; it just began to shake gradually until it got alongside of it, and it just wore away in the same way.

1893. But when you were in the high girders you felt the vibration of the bridge or the movement that you have spoken to most as the train came north of the brick piers?—Yes.

Cross-examined by Mr. BALFOUR.

1894. You told us about some bolts and nuts that you found; were they evidently stuff that had not been needed, and were there to be cleared away?—As to the bolts and nuts that I speak about, I painted one side of the lower boom myself on the east side, and there was another man cleaning it out, and there was a lot of gravel and stuff in the boom along with the bolts. Some bolts were thrown down with the gravel, and others were gathered up and put upon the top of the bridge.

1895. Was not all that just rubbish that had not been cleared away until the painters came?—It was just rubbish that was left in when they riveted it.

1896. And you saw that it had not fallen out of the bridge, because everything was in its place as regards bolts and nuts there?—I saw that it could not fall out of any part of the bridge because the top of the bridge overlapped the lower boom, so that it was impossible for anything to fall out.

1897. It would have been like getting in under a shelf?—Under a shelf.

1898. (The Commissioner.) You said you did not see any holes or any bolts loose in the girders; did you mean in any part of the bridge, or did you mean simply in the booms of the girders?—I did not see any part of the whole of the girders with any hole that there ought to have been a bolt in; nothing but holes in the lower boom about 12 feet apart from one another for letting the water out that were made for the purpose.

1899. You did not see any empty holes in the lattice work or anything of that kind?—No; nothing but those bolts.

1900. Nothing but those holes of which you have spoken at a distance of about 12 feet apart?—Yes, for letting the water out.

1901. Where were those?—In the lower booms.

1902. Were there any such holes in the upper booms?—Not that I was aware of or saw.

1903. You did not see them?—I did not see them.

The witness withdrew.

J. Evans.

1904. I do not expect you to point them out within an inch, but were they in the bottom of the boom?—No; they were generally the angle irons outside of the boom.

1905. Those holes would not be left there to let water run through off the bridge?—The holes for the water were in the centre of the boom.

1906. It was not those holes?—No; not at all.

1907. You saw the holes that were left for the purpose of letting out the water?—Yes.

1908. And those holes that you saw were bolt holes?—Rivets missed out.

1909. Or came out, you do not know of course which it was?—No; I could not ascertain that.
J. Ewers.
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4876. But you saw that they were holes which had been intended to have rivets in them and which were empty—Quite so.

4877. Besides seeing those empty holes in the angle irons did you see them in any other part of the structure?—Well occasionally we missed a rivet here and there over the work, I did not see all the work.

4878. But over the work that you did yourself, you came occasionally across an empty rivet hole?—Yes.

4879. Could you give us any idea of how many rivet holes you saw empty altogether?—No; I could not answer that question.

4880. Did you ever find more than one rivet hole empty at the one place?—No; I do not think so.

4881. They were just occasional empty holes that you found in places, where the other rivets on each side of them had been put in and were still there?—Yes; I found a bolt occasionally here and there where a rivet ought to have been—it might have been quite as good.

4882. But you found bolts put in occasionally where rivets ought to have been?—They had been left in.

4883. Did you see any of the bolts or rivets without heads?—Yes.

4884. Here and there?—Yes; on the large girders.

4885. Were those places where you saw the empty rivet holes on the large girders?—They were generally on the smaller girders under the floor of the bridge; the small girders were all under the floor.

4886. What do you mean by the small girders?—Some of the bottom of the large girders.

4887. You found those empty bolt holes in the bottom of the bridge to the north and to the south of the large girders?—To the north.

4888–90. You also found rivets without their heads in the large girders?—In the large girders.

4889. Do you know the part of the high girders was it where you found them?—On the vertical posts.

4890. Running from the level of the way upwards?—The vertical post is the same as the box. The angle bars were outside, and those were wanting. That binds the vertical post together.

4891. And in those you found the rivets without the heads?—A great many heads were off altogether. I dare say they were sprung.

4892. Did it seem to you that they had been sprung?—Yes.

4893. Was that the opinion you formed at the time?—Yes.

4894. Can you give us any idea of how many of these rivets you found without heads?—A large number.

4895. Which had had heads at one time?—There could be no mistake about that; the remnant was left.

4896. Could you tell by looking at what was in the rivet hole that something that had been there originally was not there then?—Yes; had parted.

4897. Do you say that there were a great many of those?—A great many; some of those bars were hinged off altogether, hanging down, displaced altogether, all clear of it.

4898. In consequence of the want of those rivet heads?—In consequence of the want of the rivet heads.

4899. How many bars did you see in that condition?—Well, to the best of my knowledge I think I saw two hanging off in that way, two of these diagonal bars.

4900. As I understand you, two of the diagonal bars that were there for the purpose of supporting the vertical columns were off?—Yes.

4901. In the lower boom of the girders did you see a good many screws and bolts and rivets lying loose?—Yes; in the lower boom I did.

4902. These loose bolts and rivets and screws were what had been just left over by the workmen?—Well, I expected that they had been laid there during the construction of the bridge.

4903. You did not think they were bolts or screws that had been sprung out of their place?—Not for a moment.

4904. And those were different altogether from the other defects?—Yes.

4905. The rubbish that was left could not have been the result of the defects that you have been speaking of?—Not at all.

4906. What part of the work were you engaged in?—From the north cabin to No. 14 pier south, that is, the southernmost big girder.

4907. Then you have been on the work here and there from the north cabin to the south end of the high girders?—I was.

4908. Not continuously, I suppose, were you?—Yes.

4909. Did you go from one end straight on to the other?—Yes.

4910. Which side?—From the north side.

4911. On the east or west side of the bridge?—On the west side.

4912. Your employment lasted some months, I believe?—About four months, I think.

4913. In the course of your employment a good many trains passed every day?—A great many.

4914. Did the passing of the trains have any effect on the bridge?—Very much.

4915. What was its effect?—Oscillation, I would term it, first; side to side movement.

4916. Was there any other movement?—Yes.

4917. What?—Vertical movement.

4918. With regard to the oscillation or lateral movement, was that severe?—Yes, it was severe.

4919. Did you notice that the trains went at different rates of speed?—Yes.

4920. And which of them was it that produced the greatest lateral movement?—The fast trains.

4921. Could you give me any idea of the extent of this lateral movement?—No; I was going along with it, you know, and I could not ascertain that.

4922. Did you feel that lateral movement when you were on the level of the way as well as when you were up on the scaffolding?—Yes; more so, I imagine, when I was up.

4923. But I suppose it was a very distinct movement, even where you were standing on the bridge?—Very distinct.

4924. There is no mistake about it, I suppose, that the bridge did give from side to side as the train went past?—Before she approached you a long way.

4925. And it continued so until she went past you?—Yes.

4926. Increasing, I suppose, as she came near?—I do not know what you could tell as to the motion when she was on the same girder as yourself, it was an amalgamated movement.

4927. But keeping to the lateral movement it increased from the time you first perceived it as the train came nearer to you?—Yes.

4928. Did you feel that lateral movement when you had to cross over from the one part of the bridge to the other?—I did not feel it till she got past me.

4929. Did you ever find more than one rivet hole going up and down from the effect of the passing train?—There is no mistake in that.

4930. When were you first able to perceive the vertical movement?—Perhaps four or five girders distant; it took place then.

4931. It was noticeably distinct then?—Yes; it commenced to lift you.

4932. Then you were on the middle of the bridge?—The bridge.

4933. Did the motion also increase from the time you first felt it until the train passed you?—Yes.

4934. And it continued until she went past you?—Yes.

4935. What do you mean by she, the bridge or the train?—The bridge.

4936. When you first saw the bridge and the train, was it distinctive?—Yes.

4937. What was that vertical motion a distinct noticeable motion too?—Yes.

4938. Did you feel that when you were standing on the middle of the bridge?—Yes.

4939. And you have no doubt that the bridge was going up and down from the effect of the passing train?—I know it was going up and down.

4940. Was there any mistake in that?—That was violent motion.

4941. Was it also greater according to the speed of the train?—Yes.
4959. Did you notice whether the motion on the bridge corresponded with the crank of the engine?—Yes.
4960. When they were one.
4961. What effect did you see the motion thus produced have on anything that was placed on the bridge?—I have seen the spilling of a pail of water a long while before the train approached. You could feel the oscillation half a mile off.
4962. But you had not a pail of water upset?—No; merely the water oscillating and spilling over the side.

4963. Had it any effect upon the paint-pots?—We always secured them with every passing train.

4964. You made your paint-pots secure when you felt that there was a train approaching?—Yes.

4965. You had done so?—If they had been split?—It would have gone to the bottom, it would not have stopped upon the staging.

4966. If you had not secured it it would have gone over—is that what you mean?—That is what I mean.

4967. Did you secure them, I suppose, as a matter of practice?—Just took them in your hand and held on to them yourself.

4968. Did you ever do anything else besides holding?—Sometimes they were made fast; it would depend upon the job that you were on.

4969. But if you had not made them fast according to the necessity of the job, you made them fast in some way yourself, or otherwise they would have been in danger?—Yes, exactly.

4970. On one occasion I think you had your paint-pot secured by a lanyard?—Yes.

4971. What is it made of?—Spun yarn; three-ply spun yarn.

4972. What happened to the paint-pot on that occasion?—The lanyard parted and I lost it—it went down.

4973. What did you attribute the parting of the lanyard to?—To the vibration of the train.

4974. Was it not visible by any one going along the bridge?—I do not know.

4975. If the thing was off it was like that (describing the same); it had lost its top hold and swung round. Could anybody have failed to see it?—It is only about 18 inches long altogether.

4976. The thing that had got loose was only 18 inches long?—Yes.

4977. But still anyone going along, looking to see the state of the bridge, could not miss observing it?—Well, of course a sharp eye could find it.

4978. Would it only be a sharp eye?—I imagine so.

4979. How long were those two diagonal bars hanging in that state?—I could not say; I could not answer that.

4980. Where is he?—He is a diver.

4981. Where is he?—He is a diver.

4982. A week?—I found them loose, you know, and I left them loose.

4983. Were Mr. Noble's men still on the bridge?—Yes.

4984. Putting right anything that was wrong?—Not rivets, only bolts, putting on nuts or bolts, and driving up cutters.

4985. What were Mr. Noble's men doing there; did you understand that they were there to put anything right that was wrong?—Yes, by the use of rivets.

4986. But did you tell anybody that you had found those bars in that state that you describe?—Yes, but we speak among ourselves and do not report to headquarters.

4987. Did not you tell Mr. Noble's hands?—I did not.

4988. Did not you tell anybody about the rivet heads being off?—It was out of its place altogether, we had nothing to do with it.

4989. Had you no instructions to mention anything you found wrong?—No.

4990. Was it not right to do it?—Certainly it was.

4991. Was it an important thing those rivet heads being off?—Certainly.

4992. Why did you not mention that?—It was out of its place altogether.

4993. Why?—We had not got an overseer over us.

4994. Is it not the duty of a man if he finds anything wrong to tell his own superior or the men there to put things right?—Yes.

4995. Why did you not tell it?—The gaffer was there.

4996. Did you tell your gaffer; what was his name?—Edward Simpson.

4997. Where is he?—He is a diver I think of the Company yet.

4998. He was a man over you?—Yes, over the painters.

4999. You told him about anything wrong?—No, I did not tell him anything about it.

5000. Did not you tell your own gaffer when you found anything wrong?—No, we were not informed to do so.

5001. Were many of the rivet heads off?—Yes.

5002. How many?—I cannot say.
5003. Would you say 100?—I had no instructions. I had no idea this was coming. I paid little attention to it.

5004. Were there 10, or 100, or a 1000?—I cannot go into figures.

5005. Cannot you give me between 10 and 100?—There was a few tens.

5006. Were there 100?—I cannot say that. I won't say that.

5007. Were there a great many off?—Yes.

5008. Was it easy to be seen that they were off?—Working men would find it easy.

5009. Man who understood it?—Yes.

5010. No man accustomed to the kind of work, going along to look at the state of the bridge, could have missed seeing them, could he?—I do not know.

5011. Were those rivets heads just off so that the remaining part of the rivet was flush with the metal of the bridge?—Sometimes it was flush, and sometimes inside, the whole of it.

5012. Sometimes outside and sometimes inside?—Sometimes flush and sometimes inside.

5013. Were they smooth at the end, or how?—No.

5014. Always rough?—Like a break.

5015. Were they all of that appearance?—Yes.

5016. Were none of them smooth?—No.

5017. What other men were working with you at the time that you saw these things?—There were a number of jobs there.

5018. Can you name a few of the names of the men who saw the broken rivets and who had the opportunity that you had?—It is a hard case. I was one day working one party and another day working another party, and it is rather sharp to mind a name just now.

5019. If there were so many it would be easier to give one or two?—I cannot mind.

5020. Did you see all the broken rivets in one day?—No.

5021. Did you see them every day for four months?—No.

5022. Will you give me the name of one man who saw a broken rivet?—I do not remember the man who was working with me that day.

5023. It was all over and sometimes at intervals?—It was those bars.

5024. Give me the name of anyone who saw the swinging bars?—Frank McLaren, I think.

5025. Where is he?—At Temple Lane, I think he is.

5026. Who else?—I do not remember any one, just now.

5027. Do you not know any one who saw the broken rivets?—No.

5028. Did you find rivet heads lying below, where you saw the breaks; did you find a single rivet head on that bridge?—Yes.

5029. How many?—I cannot say.

5030. Where did you find them?—I cannot give you the number.

5031. Where there 100?—I cannot give you the number.

5032. Were there as many as there were broken ends?—At the big girder she is always perpendicular—I mean the heads come off they go over the side.

5033. About the ones that you saw which had not gone over the side, how many did you see?—I could not say.

5034. Anybody else going along would have seen the broken rivet heads, would he not?—Yes, if he went over the same work that I did.

5035. Where were the broken rivet heads lying?—Amongst the shingle.

5036. That is on the way?—Yes.

5037. How many did you see lying on the way?—I cannot give you the number.

5038. Where they lying about all the time that you were there, or were they taken away?—Not to my knowledge.

5039. When you left were they still lying there?—I cannot say whether they were still lying there or not.

5040. Why did you not mention to Mr. Noble's men that anything was wrong so that his men might get the use of your staging to put right anything that was wrong?—To put nuts on the sleeper bolts?

5041. Yes; or to do anything that needed to be done?—I speak of the small girders.

5042. When you might have had the men in that way who might have got the use of your staging, why did you not tell them that such a number of rivet heads were off the two swinging bars?—That was in the small girders, the swinging bars were on the large girders.

5043. Was that any reason for not speaking about them?—No; we were never told to do it. It did not lie in our way.

5044. I suppose all you have heard is in accordance with the facts about the finding of the bolt heads, and is true?—Yes.

5045. You have no interest one way or the other to misstate the fact?—No interest on either side.

5046. It would have been better if you had told your superiors about these things, but you did not at the time?—Yes; but we were not instructed anything of the sort.

5047. You did not want to talk about things?—We see it was better to hold our tongues.

5048. With regard to those swinging bars that you spoke of; there are vertical posts which go up from the side of the bridge?—At each girder, at the termination of each girder.

5049. There are one or two different columns?—One.

5050. What does that cross bar that you speak of do?—It attaches the column to what?—Have you got a photograph of the bridge?

(The Commissioner.) Let the photograph be produced.

5051. (Mr. Traynor.) Is there anything there which you can see (shown the official elevations and sections of the details of the Tay Bridge plate, spans 29 to 31).

(The Commissioner.) That is a portion of the high girders, is there anything there that you see?

5052. (Mr. Traynor.) Can you point out anything there?—It is there (pointing to the place).

(The Commissioner.) Now he wants a cross section (shown plate, No. 26).

5053. (Mr. Traynor.) Do you see anything in that—that is a cross section?—It is not on any part of that. Wait a moment, it is this here (pointing to the section).

5054. (The Commissioner.) It is one of those cross bars?—Yes.

5055. (Mr. Traynor.) It is the cross bars?—The diagonal bars.

5056. Shown upon the cross-section, sheet 25?—Yes.

5057. And the diagonal bars that run from the top of the column down to its base?—Yes.

5058. Were they the cast diagonal bars that you saw hanging out of place?—They were.

5059. I show you at the foot of the same plate a key to the details of the views of the girders, by which you observe that there are vertical strips coming down from the diagonal?—Yes.

5060. Were those what you saw, or the diagonal that you saw?—Those were them.

5061. The diagonals?—Yes.

5062. I think you said you saw two of them?—Yes.

5063. Were they both the top diagonal plate, or were they in either case the diagonals between the top and the base?—I cannot say exactly the spot they were upon the girders, but the top rivet was out and the bar was suspended.

5064. You have the top of the columns there, and you have the diagonals commencing to go round; and I want to know whether in each of those two cases it was the top diagonal bar that you saw displaced, or
whether it was one of the diagonals other than the top, between the top and the bottom?—I do not think it was the top altogether, but it was up like a ladder.

5065. One of the diagonals was displaced?—Yes; the last man at No. 1 bar came off with me.

5066. Who was he?—I do not remember the man's name.

5067. Do you remember the fact?—Yes; we were finished with the lower girder. We were coming up it this way (describing).

5068. (Mr. Balfour.) Were those what they call the distant pieces? Do you know what you call bars?—We call them diagonal bars.

5069. Were they between the two ends of the two girders?—No.

5070. Suppose that this is the end of one girder, and that it went away here (describing), and there is the beginning of another girder (describing), were they the bars which kept apart the ends of the two girders?—No. If you will give me a piece of paper I will show you (the witness explained by a piece of paper).

5071. Then it is exactly the distance pieces lying like that?—Yes.

5072. And each of them is held by one rivet?—Yes.

5073. Keeping the two things apart?—Yes.

5074. Apparently painters use them as a ladder?—Yes, going to the upper part.

5075. What brought out the rivets you cannot tell?—No.

5076. (Mr. Tragner.) Were the rivets simply broken, or were they out altogether at those places?—No, they had been broken.

5077. A bit was still there, and a bit was gone?—Yes.

5078. With the result that the bracing diagonal bar came down?—Yes.

5079. (The Commissioner.) Can you tell us exactly where it was that you saw those two hanging?—I cannot give you that exactly.

5080. Not the exact pier?—No; I had been over all the big girders from end to end; we started at the north side at the north cabin.

5081. But do you not remember where you saw it?—No, but it was on the big girders.

5082. Were two of them near together?—No, I think there was a day or two between my finding them.

5083. In different places?—Yes, there is one pier, No. 10, and there was not one fastening on that girder on the west end.

5084. (Mr. Tragner.) You mean those diagonal bars?—Yes.

5085. (The Commissioner.) You are speaking now of what you call No. 10 pier of the high girders?—Yes.

5086. Not one of them was fast?—Not one fast— they all shook in your hand going up, all slack in girder.

5087. Had any of them given way?—No, they were all on, all slackened.

5088. All counting from the north side?—No.

5089. No. 10 of the high girders, counting from the north side, there was not one of them that was fast?—No.

5090. You are sure it was No. 10 counting from the north side?—Yes.

5091. You are quite sure of that?—Yes, quite sure of it.

5092. Did you find those diagonals of which you speak over every pier?—There was very few of them.

5093. Were those diagonals over every one of those piers?—Yes.

5094. In every one of them?—Yes.

5095. But it was in No. 10 that you found them all loose?—Yes.

5096. Did you find any loose in any of the other piers?—Yes; occasionally.

5097. But in No. 10 they were particularly loose?—Yes; they were all loose.

The witness withdrew.

John Nelson sworn.

Examined by Mr. Tragner.

5098. You are a mechanic, and reside in Dundee?—Yes.

5099. Were you engaged in painting the Tay Bridge last summer?—Yes.

5100. For how long a time?—From the beginning to the end of the painting.

5101. What part of the bridge were you engaged on?—Just from the south end to the north end of the big girders. I was partly over it all.

5102. You were engaged for some time in the high girders?—Yes.

5103. On what side of the bridge were you most employed?—Both sides.

5104. Did you notice any bolt loose or any bolt hole or rivet holes empty?—Yes; you came across them occasionally.

5105. Did you notice any bolt loose or any bolt hole empty?—I do not remember any.

5106. Did you come across any that were loose in their holes?—Loose nuts?

5107. Yes.—Yes.

5108. That is, they screwed on the head?—Yes.

5109. Did you come across any bolts that were loose in the hole?—I cannot say for that as I did not try the holes.

5110. You did not see any that were obviously in where the holes were too large for the bolts?—No.

5111. How many nuts did you find loose?—I cannot say to one or two in a rough calculation, but about a couple of dozen all over the job.

5112. Did you notice any of the screws on the bolts that fastened down the sleepers to the bridge?—It was those that were loose.

5113. Did you see any nut heads loose at any place else?—None that I remember.

5114. Did you notice anything wrong with any of the columns?—Yes.

5115. How many?—One.

5116. Where was it?—I do not know which pier exactly, but it was about the south end of the big girders, or some of the piers about there.

5117. It was part of the high girder work?—Yes; close by the high girders.

5118. Can you say where it was?—I do not remember, but it was actually in the high girders.

5119. What column did you observe—the bottom column on the west side of the north tier—there are two tiers of columns, but what pier or span it was connected with you do not remember?—No.

5120. What was wrong with it?—It was rent.

5121. Was the rent a great one?—I did not so closely inspect it; but the remark that was made by some one who was at the bottom of the pier was that it was rent from top to bottom.

5122. Did you see anything about it that led you to adopt that view as your own?—I did.

5123. You thought it was rent from top to bottom?—Yes.

5124. Why did you think so?—Because there were four hands upon it.

5125. Or hoops upon it?—Yes.

5126. Iron hoops?—Yes.

5127. Holding it up?—I took it to be so.

5128. What was that column supporting?—It was supporting a girder.
5129. Could you see the rent?—Not from where I was.

5130. Did you not see it at all?—No, I did not see it; but I saw there was something wrong with the four iron bands upon it.

5131. Your attention was called to it, and you saw four iron hoops upon it?—Yes.

5132. Did you see any other column bound with iron hoops but that one?—I did not.

5133. Whatever was the matter with it was it different in that respect from all the other columns that you saw?—Yes.

5134. Did you see one of the sole plates that had some thing peculiar about it?—No.

5135. Where was it?—As near as I can remember it was about No. 4 or No. 5 pier from the south side on the brickwork.

5136. Of what is still standing?—Yes.

5137. Was it in the high girders?—No; counting on the south side altogether it was the fourth or fifth pier.

5138. There was a sole plate on the top of one of the brick piers which you particularly noticed?—Yes.

5139. What was the matter with it?—It was cracked across the centre, right across the centre.

5140. From side to side?—Yes.

5141. Did you point that out to anybody?—Yes.

5142. To whom?—To Mr. Noble.

5143. When was it that you pointed it out to Mr. Noble?—Was it near the beginning or near the end of your job?—It was about nearly the latter end of July, from the 20th to the 25th of July, 1879.

5144. You would sometimes be engaged painting, I suppose, on the scaffolding, and sometimes standing on the way of the bridge?—Yes.

5145. Did you notice whether the passing trains had any effect upon the bridge?—Yes.

5146. What was it?—It made it shake very much.

5147. How did it shake?—Both ways, both vertically and laterally.

5148. Was it severe?—Sometimes.

5149. When was it most severe?—With a fast passenger train.

5150. And the movement was more severe in proportion to the speed of the train occasioning it?—Yes.

5151. Was it so severe as to alarm you at times? It was sometimes.

5152. Did you notice any particular train, or at any particular time of the day when a train was generally more rapid than at others?—Nobody was passing taking notes of that, but there was a fast train about 9 o'clock in the morning and another about 3 o'clock in the afternoon going south.

5153. Was the train that came into Dundee about 9 o'clock in the morning generally a fast train?—Yes.

5154. Noticeably faster than the others?—Yes, we took notice of it at any rate.

5155. Then it was there to be noticed?—Yes.

5156. Did it produce a very serious shaking?—Yes.

5157. Which was the greater movement, the vertical or the lateral?—The vertical.

5158. When you were within the high girders, at what distance from the train did you first perceive this vertical movement that it was occasioning?—We felt it well enough at the fifth or sixth girder, and as it came nearer then we felt it more so, especially when it was on the girder next to where you were standing; it caused very much shaking and the same when it was on the girder past you.

5159. There was a distinct ware motion several girders before it reached you?—Yes.

5160. Was the girder which was just left behind by the train the one that for the moment shook most in your experience?—When the train had gone past the girder that it had been standing upon the girder shook the most.

5161. What was it that you were alarmed at?—Different thoughts came into my head.

5162. What thoughts came into your head?—One thing that I was afraid of was being struck by anything.

5163. But the shaking of the bridge, how did that alarm you?—Just for the fear that that might happen what has happened.

5164. Was that constantly in your mind?—Yes; many times it was.

5165. The shaking was so great that you were afraid of the thing coming down?—Yes; exactly.

5166. Which of the movements gave you the most anxiety, the vertical or the lateral; or did one alarm you more than the other?—The vertical shook the most, but sometimes I was pretty frightened of the lateral too, especially if there was a heavy wind blowing at the time.

5167. Then the lateral motion must have been pretty severe that really alarmed you for your safety?—Yes, it was.

Cross-examined by Mr. BALFOUR.

5168. You said that you found an occasional nut slack in connexion with the fastening of a sleeper; just tell us precisely what the bolts hold by those nuts tied together; was it the fish plates or what?—It was the sleeper that the rails lie upon.

5169. Are not the chairs spiked to the sleepers?—Yes.

5170. Not with a bolt nut, but with a spike?—The sleepers themselves are bolted.

5171. What are they bolted to; are they bolted to the floor of the bridge?—Through the sleepers of the bridge.

5172. Is the sleeper on which the rails rest bolted to the floor of the bridge?—Yes; it is bolted to the sleeper of the bridge.

5173. Are you speaking of longitudinal sleepers?—Yes.

5174. Is it a sleeper under the length of the rail, or is it a sleeper that is across between the two rails?—I mean longitudinal ones.

5175. It was in the longitudinal sleepers that you found a nut loose occasionally?—Yes.

5176. Trains were running over them quickly at that time?—Yes.

5177. Did the surface move along the tiers and tighten up any of the nuts that were loose?—No; the surface men never went. Mr. Noble had men to look after them.

5178. Were they always going along tightening up nuts that got loose?—Yes.

5179. You do not mean to convey that there were loose nuts left uncared for among those sleepers?—Not at all.

5180. I suppose that in any railway where there are nuts and even fish plates they go along and see what are loose and tighten them up?—Yes.

5181. And this was just done in the same way?—Yes.

5182. Except those nuts did you find anything loose or anything broken in connexion with the work of the bridge?—Nothing that I remember except what has been stated.

5183. You did not find anything wrong with the bolts or the rivets?—Not that I remember.

5184. Or any loose holes that you remember?—No.

5185. If there had been a great many you could not have forgotten it surely?—It is not likely.

5186. Were you going along the bridge every day from end to end?—Yes, when the weather would permit us to go.

5187. From end to end?—Yes; I went on the south side and worked north.

5188. Were you living at Dundee?—No, we had to cross the bridge.

5189. In going to your work did you walk from the north end of the bridge every day and walk back home again?—Yes.
5190. Besides the bit of the bridge that you were working on yourself?—Yes.
5191. So that you had opportunities of observing the state of the bridge for the whole of its length, although you could observe more particularly the places that you were working at?—Yes.
5192. Did you see rivet heads lying along the shingle?—Yes, sometimes I did.
5193. Where were they?—Lying among the gravel.
5194. Where were they?—They were strewn all over the bridge.
5195. You did not see any place where they had come off?—No.
5196. Where they bolt heads or rivet bolts?—Both.
5197. They were laying about as though they had been left there by workmen apparently?—Yes, probably they had been let fall.
5198. By workmen?—Yes.
5199. They had not come off after the bridge had been put together, because otherwise you would have seen the places where they would have come from?—Not that I ever saw.
5200. You spoke about a broken sole plate?—Yes.
5201. That is one of the piers that is standing yet?—Yes.
5202. Is it there to be seen?—Yes.
5203. Was it the fourth pier from the south end?—I cannot say for a pier or two, but it is about there; it is to be seen there if it has not been removed since the end of July.
5204. It would not have been easy to have taken it below the bridge, would it?—It could be done.
5205. Have you any reason to think that it has been removed?—No.
5206. Mr. Noble's men were always going about upon the bridge, were they not?—Yes.
5207. If you had found anything wrong with the bridge, the structure of which they were in charge of, would you have told them?—I should think I might; anything that I thought seriously wanted attention.

Re-examined by Mr. Trayner.

5208. When you were going along the bridge and saw the rivet heads, I suppose you did not concern yourself where they came from?—No.
5209. Therefore the rivet heads that dropped off when they were riveted on might have been the rivet heads that had sprung, for anything you know?—Yes, it might have been so.
5210. (The Commissioner.) As I understand you, you said that you felt the motion of the train when it was about five or six girders from you?—Yes.
5211. It increased until the engine, I suppose, got to the girders just before that upon which you were standing?—Yes.
5212. When it got on to the girders on which you were standing you did not feel it so much?—No; it is a sort of steadied the girder.
5213. When it passed along to the next girder you felt it move again?—Yes, exactly.
5214. How far was the column below you that you said you saw those bands round?—I think it was the seventh column on the piers; there were seven columns in tiers.
5215. Were you at the top?—I was on the top.
5216. Quite on the top?—Yes.
5217. And this was quite at the bottom?—Yes.
5218. And you could see the bands distinctly from there?—Yes; I was along about 100 feet or so from the top of the pier.
5219. Then you were a long way from it?—Yes.
5220. Were you up on the pier when there was a very high wind blowing?—Yes.
5221. Did the bridge seem to shake on those occasions?—Very much.
5222. Even when there was no train on the bridge?—Yes, even when there was no train; it was not perceptible by the eye, but you felt it well enough.
5223. When there was a strong wind you felt it?—Yes.
5224. (Mr. Burton.) Can you tell us which of the piers it was in which you found that broken column; was it one of the piers which has now fallen down?—I am sure I cannot say for a certainty, but it was not under those big girders; it is immediately on the north side.
5225. South of the large girders?—Yes.
5226. Is it one of the piers now standing?—I do not quite remember if it is.
5227. Do you remember of those columns that you saw there on that model which of them it was that you saw broken; was it the one that was standing out at the corner, or was it in the middle part?—(The witness points it out on the model.) I think it was one of the piers that is out of this column altogether; it was the bottom column. If this was the north side pier, it was this bottom column (pointing to the model).
5228. (Colonel Yolland.) Was it the pier with six columns on it, or three?—I do not remember, but I think there are four on each end of the pier.
5229. Was it one with three, four, or six?—I cannot recollect that, but it was there, at any rate.

The witness withdrew.

Examine by Mr. Trayner.

5231. Are you a painter, and reside in Dundee?—Yes.
5232. And you were engaged in painting the Tay Bridge last year?—Yes.
5233. For how long?—Three or four or five weeks.
5234. What part of the bridge were you engaged upon?—On the north side.
5235. You first commenced at the north end and then you were sent to the south; were you working at any time about the high girders?—Yes.
5236. Did you notice where you were working anything wrong; were any of the bolt holes empty?—I did not notice any of the bolt holes empty.
5237. Did you notice any bolt where the nut was loose?—I noticed one that was loose.

5288. Where was that?—I think it was before we entered the large girders, on the north side of the large girders.
5239. Just before you entered them?—Yes.
5240. Was it that on the floor of the railway, or where was it?—It was down underneath the floor—underneath the footway.
5241. You saw it when you were painting below?—Yes.
5242. Was that the only bolt that you saw with the head loose?—Yes, the nut loose; that was the only one I noticed.
5243. Did you see anything wrong with anything—any part of the bridge?—Yes; I remember some bars that were broken.
5244. What kind of bars were they?—I think diagonal bars, we call them.
5245. (Mr. Trayner.) Is that—(pointing to the model)—a diagonal bar like that?—Yes.
5245. Where were those cross bars that you saw placed?—On the large girders.
5246. There are the columns supporting the high girders (pointing to the model); can you point out on the model whereabouts in the high girders those diagonal bars were that you saw displaced?—They are not there.
5247. (The Commissioner.) Is it shown on the inside of that model?—Yes. (To the witness.) How many of those diagonal bars did you see displaced?—I do not know whether it was two or three; but I know there were two,—I am certain of that.
5248. How had they got displaced; were they hanging, or what was their condition?—Yes, they were hanging.
5249. They should originally have had a rivet at each end; there was just one?—Just one.
5250. The other end had swung over?—Yes, I was warned when climbing up not to take hold of them for fear that the other rivet should give way.
5251. That was the only holder that you had to get up by?—Yes.
5252. Did you notice in any other places than those where you found the diagonal bars loose that the whole of the diagonal bars in one particular place were getting shaky?—There was several of them shaky.
5253. At several different places?—Yes.
5254. Did you notice anything else about the construction of the bridge that was particular?—There was a column.
5255. What was wrong with the column?—There was a crack in it.
5256. Did you see it?—Yes, I saw it; it was up the bridge a good piece when I saw it.
5257. Did you see a crack in the column?—Yes, I did.
5258. Where was that column?—It was on the north side of the large girders.
5259. Was it within the large girders?—Yes.
5260. On the north side?—Yes.
5261. It was near the north end, was it?—Yes.
5262. Was there anything about the column different, apart from this rent, from the other columns?—Not that I noticed.
5263. Did you see anything round the column?—No.
5264. You did not see that it was bound?—No; I believe the painting was put upon it after I left the bridge.
5265. Did you feel the motion that the train produced in passing over the bridge?—Yes.
5266. What kind of motion was it?—When the train first entered the bridge it went up and down gently until the train came on the top, and then you could feel it go up and down in this way (describing), shaking. The two got amalgamated together, and you could scarcely tell one from the other.
5267. You speak now from what you experienced when you were on the scaffolding of the bridge pointing at the bottom of it?—Yes.
5268. When the train was at a distance you felt the vertical movement slightly; which increased as the train came near you?—Yes.
5269. Did it distinctly move you up and down with it?—Yes.
5270. Of course the bridge must have been going up and down, or your scaffold would not have been moved up and down, gently?—No, it would not.
5271. As the train came over, then the movement up and down was mixed up with the movement from side to side?—Yes.
5272. Was the movement up and down as the train coming the very strong?—Yes.
5273. Were you standing upon transverse planks?—Yes.
5274. Which were hanging from the bridge?—Yes, by ropes.
5275. Did your stand both go up and down, and away from side to side?—I did.
5276. Was it sufficient to make you anxious or alarmed about yourself?—At first it did, when I went on the bridge to work there, it was a new kind of work to you?—Yes.
5277. You got accustomed to it after?—Yes.
5278. Did you work in that manner below the bridge, both under the high girders and outside of them, or, were you only at work under the high girders?—I was at work inside the high girders.
5279. Below the bridge you were working under the high girders, were you not?—No.
5280. Where was it that you were working when you felt this motion that you have described when you were standing on the transverse planks hanging from the bridge?—On the end of the big girders, where we entered.
5281. Which end?—The north end.
5282. Then you got into the high girder and painted it?—Yes.
5283. Of course you were painting sometimes standing on the way of the railway?—Yes.
5284. Did you feel the same motion when you were standing there that you experienced when you were standing under the bridge?—Yes.
5285. Both before the train came to you and as it passed you?—Yes.
5286. Did you feel it increasing in violence as the train came near you when you were standing on the way of the bridge?—I did.
5287. Did you feel so severe a motion when you were standing on the bridge?—Yes.
5288. Did you feel so severe a motion when you were standing on the bridge?—Yes.
5289. Did you also feel a lateral movement when you were standing on the bridge?—Yes.
5290. Where did you feel it the worst, when you were standing on the bridge, or when you were standing below the bridge?—I think I felt it most when I was standing below the bridge on the plank.
5291. You felt most when you were below the bridge on the suspended plank, than when you were standing on the way of the bridge itself?—Yes.
5292. Were you underneath the flooring of the bridge painting the ironwork, of which it is composed?—Yes.
5293. Was the motion greater inside the high girders or outside the high girders?—Inside the high girders.

Cross-examined by Mr. Balfour.
5294. You said I think that you were somewhat anxious at first when you went to work there, was it a new kind of work to you?—Yes.
5295. Having from a big bridge?—Yes.
5296. Did you never have anything to do with work on a bridge like that before?—No on bridges.
5297. I suppose it takes a little time to stand on a scaffold hugging from ropes swinging?—Very little.
5298. You told us about finding two diagonal bars loose; were they at the end of the same girder, or were they in different girders?—I think I got two on one girder, and one on another.
5299. Had the painters been climbing up before your attention was called to them?—A man was going to climb up and I was behind him, and he wanted me not to take hold of them; he was just going up.
5300. For the first time?—Yes; to get on the top pier.
5301. He found them loose and told you so?—Yes.
5302. Those were small pieces of iron about 18 inches long and about 3 inches broad?—About that.
5303. Like the rungs of a ladder?—Yes.
5304. They were not bearing any weight?—No.
5305. Did you mention to anybody that they were loose?—No.
5306. At the time you were there, they were only loose, were they?—Yes, that was all.
5307. Were the rivet holes in them slightly loose at each end, or was any of the rivet away from either end?—It was away from one end.
5308. Had the bar swung round out of its place, and did it appear to be hanging down when you were there?—Yes.
You would not have thought of putting your foot on it then?—No.

That was the state it was in when you saw it?—Yes; I might have taken hold of it, and another rivet might have given way.

Were there, three hanging with their heads down?—No; one of them was a little from the hole, a little out of its place, but not much.

Were Mr. Noble’s men going about and putting anything right that was wrong at that time?—Yes; I think so.

Did you mention anything to anybody about them?—Not unless it was to the men who were working there.

Did you tell Mr. Noble’s men?—No; I did not know many of them to tell them, there was only one man I knew.

You have said that you found some others shaky?—Yes.

And that the painters were going up them and using them as ladders at that time?—Yes; they would be going up them at the time that I found them.

(The Commissioner.) Did you say that this column which you saw left was the lowest portion of the pier?—I am not sure whether it was the lower portion or not. I remember a man telling me that he put his knife in after we came up.

Did you see that done?—No; I did not see the knife put in, but I saw a rent in it, a hole.

Was it from the top to the bottom of that column?—Yes, I think so.

You could have put your knife in, could you?—I do not know; I generally carry a pretty thick knife.

While a thick knife would not go in, still it was cracked from the top to the bottom, was it?—Yes, I think so.

This you say was one of the columns supporting the high girders, was it?—Yes, I think it was.

But you are not quite sure?—No; I cannot be quite sure.

You said something about a binding having been put on afterwards. Did you see it afterwards put on?—No, I did not see it; I left the bridge.

At any rate you did not see it put on?—No; I did not see it put on.

(Colonel Yolland.) And you did not see it on?—No; I did not notice it on.

(Mr. Barlow.) Can you further tell me in which part of the pier that broken column stood; was it at the angles, or in the middle?—I think it was about this part of the bridge here (pointing to the model), inside about here.

At the time that you were painting the bridge was it in a heavy gale of wind?—Yes.

Did you feel any shaking in the bridge?—Yes.

Much?—A good deal. I remember going up one day and had to come down again; I could not work for the blow there was; there was too great a blow.

Not because the bridge shook too much, but because the wind was so high?—Yes, for fear of being blown off.

(Colonel Yolland.) Was the bridge shaking you very much?—Yes, it was.

(Colonel Yolland.) Can you say whether that column which you allude to was on the western side of the bridge or on the eastern side, or up-stream or down-stream?—I think it was on the easternmost side, but I cannot be positive.

The witness withdrew.

ALEXANDER STEWART sworn.

Examined by Mr. Trayner.

You are a joiner in Dundee?—Yes.

Had you the contract for the wooden casing of the Newport waterpipe that ran across the Tay Bridge?—Yes.

And you did the work necessary for the casing of that pipe from end to end?—Yes.

How long did the job last?—Well, it lasted a good long time; it was commenced in May month, and we finished about the end of October, or the beginning of November.

Were you about the job seemingly some five months or so?—Yes.

Were you frequently on the bridge while your workmen were proceeding with your contract?—Yes.

Were you there daily?—Yes, I was there daily the time that they were on the work.

But they did not work continually all that five months?—No.

They were off at times?—They were off at times.

How long did the actual work cover?—About three months, I would say.

So that for a period of three months you were on the bridge daily?—Yes; there might be a day occasionally when I might not be there.

But that was very occasionally, I suppose?—Yes.

And you were superintending the job yourself?—Yes.

Were you there sometimes for a whole day?—Yes.

Often?—Yes; pretty steady, about half a day.

Were you pretty steady in giving half a day’s attendance?—Yes.

And frequently a whole day?—And frequently a whole day.
A. Stenart.

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much support, but that they would be for steadying the structure.

5365. Supposing that that was the purpose for which they were there—did the cutting of them through lessen their capacity for steadying the structure, keeping in mind that there was a body put into the-H. would not say so as to the strength of them after the hole was cut, but of course there was the body of the plate taken out, but then there was a piece of metal 3 or 4 inches left whole all round; and it was a question whether that would weaken them or not—I have no opinion as to that.

5367. Did you when you were on the bridge notice the effect of a passing train upon it?—Yes.

5368. You must have noticed that often?—Yes.

5369. Did you notice the effect of a train both when you were within the high girders and outside of them?—Yes.

5370. Where was the movement most noticeable; within or without the high girders?—The greatest movement of all was where the high girders and the low girders joined.

5371. At which end?—At both ends; but, if anything, I will say the southernmost end. At both ends it was visible.

5372. It was as great at the joining of the high girders and the low girders as it was anywhere else?—Greater.

5373. And if there was a difference between the two ends of the high girders, the movement was greatest at the south end?—Yes.

5374. What was the movement?—When you were standing at the pillars it was a distinct side movement, when you would be standing say here (pointing to the model).

5375. Besides being distinct was it strong or was it slight?—Yes, I would say it was strong.

5376. When you were not standing above a pier, but standing between piers, what was the movement that you felt?—Well, it was a strong trembling movement.

5377. While you call it a trembling movement, was it a different movement from the lateral movement?—I would consider the two movements as combined.

5378. What movement was combined with the lateral movement?—Well, I should say the vertical movement.

5379. Then there was at times a distinct vertical movement perceptible?—Yes, in the high girders.

5380. If a train was coming towards you, you would feel this vertical movement before it came up; was that so?—Well, slightly, not very much.

5381. As it came near you, did it not increase?—Yes, but then it was always mixed with the other movement.

5382. When it got close to you?—Yes.

5383. When the two movements got combined was there a severe movement of the particular place at which you were standing?—Yes, it would make an unaccustomed man feel a little strange.

5384. Not steady on his legs you mean?—Yes, that is the feeling; you felt the under part shaking under you.

5385. And you felt it shaking from side to side?—Yes.

5386. At the place where the movement was greatest, at the joining of the high and the low girders, was it enough to produce alarm?—Well, I considered that it was weak there.

5387. What was weak?—That it was alarming.

5388. What was alarming?—The side movement.

5389. What did you think was weak at that place?—Well, I thought from the side movement that the columns must have given way.

5390. You mean that the bridge was weak?—Yes, exactly.

5391. At that particular point you thought the bridge was weak because the movement was so strong?—Yes.

5392. Was the movement greater as the train went faster?—Yes.

5393. Did you notice anything about the speed of the trains that passed?—Well, the passenger trains went faster than the goods trains.

5394. But, did some passenger trains go quicker than other passenger trains?—Well, some trains went faster at times than others.

5395. About what time of the day did the fastest train go past that you noticed?—Well, I could not say that I marked the trains.

5396. Was it a morning train or an evening train that went faster?—Well, I did not form an opinion upon that.

5397. But you have an opinion that some passenger trains did go noticeably faster than others?—Yes, I have an opinion upon that.

Cross-examined by Mr. Balfour.

5398. You told us about a plate that was cut for a pipe that was a thin plate, as I understand, which merely filled up the triangle between the struct and the corner of the base and uprights?—Yes.

5399. Had that plate really any weight to bear?—Well, I do not consider it had any weight to bear.

5400. Then have you the slightest idea that boring a hole in it, and putting your pipe in, in any degree diminished the stability of the bridge? (The Commissioner.) He did not do that; be only put the casing.

5401. (Mr. Balfour.) Had you any idea that the pipe having been put in in any degree diminished the stability of the bridge?—The only opinion that I had was that there was a bearing from each side of the hole to the outer struct, and it is just a question.

5402. It is not a question you would undertake to answer?—No, I would not.

5403. Thero were inches of metal left between the struct on the one side and the base and the upright, on the other?—Yes.

5404. You could give no opinion on the matter?—No; I would not; I could not say.

5405. You say you found a certain side movement?—Yes.

5406. Did you attempt in your own mind to turn that into inches in one way?—Yes, I did.

5407. Did you make any observation?—Yes; but I could not measure it.

5408. Why could not you measure lateral motion?—Because I moved along with it myself.

5409. You had no fixed point at all?—No; that was it; I attempted it.

5410. So that you had no means of getting a reliable estimate of the extent of it?—No.

5411. I suppose one mode of getting an estimate of it would be to observe through a theodolite from a fixed point?—Yes; but I did not have a fixed point.

5412. I am not complaining; only if such a thing was done that would be the right way to do it?—Well, I suppose so.

5413. Then the vertical motion I think you described rather more as a tremble, did you?—Yes; I did not think it alarming; it was the lateral motion.

5414. That gave you some uneasiness?—Yes.

5415. You were quite new, I suppose, to having anything to do with such a large bridge, or a bridge of that structure?—Yes, of the length of that.

5416. Did you get accustomed to it?—I did not feel alarmed myself. I felt alarmed at the side movement. I thought it was weakness in the bridge.

5417. But you were not alarmed?—Oh, no.

5418. And after you had been going on it for months you got quite accustomed to it?—Yes; there was one gentleman on the bridge who was quite alarmed at it.

5419. He was a more timid man than yourself?—He was not accustomed to it.

5420. But you were not alarmed at it yourself?—I was not alarmed at it so far as the movement of it was concerned.
Re-examined by Mr. Trayner.

5421. I suppose joiners, like slaters, have in the course of their trade to go into a good many positions that most men would consider alarming?—Yes.

5421a. (The Commissioner.) You are quite clear that although you cannot measure the lateral movement it was perfectly distinct?—Yes.

5422. You have no doubt at all about that?—I have no doubt about it.

5423. And although you were not alarmed, you thought it showed some weakness, as I understand?—Yes.

5424. Which would be alarming to some persons who might be on the bridge?—Yes, I considered that it was weak.

5425. Were you ever on the bridge at the time when there was a very heavy gale blowing?—Yes.

5426. Did you observe this lateral motion at that time?—Well, I did not observe it much at that time.

5427. You only observed it when the train was going on—was that it?—Not nearly to the same extent. The wind always blew yourself along with the bridge, so that you did not feel it.

5428. But it was when the train was going over the bridge that you felt this?—Yes.

The witness withdrew.

Adjournd till to-morrow at 10 o'clock.

SIXTH DAY.

Saturday, 28th February 1880.

RICHARD BAINES sworn.

Examined by Mr. Trayner.

5436. You are a moulder and reside in Hawkhill, Dundee?—Yes.

5437. Did you go to the foundry which the builders of the Tay Bridge set up on the south side of the river?—Yes.

5438. At a place called Wormit?—Yes.

5439. When did you go to that employment?—It was about the latter end of September or the beginning of October 1879.

5440. How long were you there engaged?—I was engaged upwards of 19 months—or up to the closing of the foundry there.

5441. What was the work you were engaged in doing?—I was engaged in casting the columns for the bridge principally.

5442. Look at this model which is here (pointing to the same). Those are the columns that you refer to, are they?—Yes.

5443. (The Commissioner.) The upright columns?

5444. (Mr. Trayner.) How were they cast, horizontally or vertically?—Horizontally.

5445. What kind of iron did you have to cast the columns?—The metal was from the Cleveland district.

5446. Was it of good quality?—No; compared with the Scotch metal, I consider it was of inferior quality.

5447. How did that show itself?—By being sluggish in its nature when in a molten state.

5448. And when cold in the ladle, what did it give off?—A dross rose to the surface, which might have been lifted out in greater quantities the more you stirred amongst it.

5449. With good Scotch metal that would not have happened?—No.

5450. The dross would have risen to the surface, and have been skimmed away, and left the metal pure?—Yes.

5451. You found, in the case of this metal, that the more it was stirred the more the dross rose?—Yes.

5452. Were you sure that you had got it free from the dross?—I could not say that I ever got it free from the dross.

5453. But I suppose you had to pour it out very hot in order to get a good sharp casting?—Yes; it requires that.

5454. More so than Scotch metal?—More so than Scotch metal.

5455. Good metal, I suppose, is livelier and thinner in its flow than that which you used?—That is right.

5456. What kind of core did you use for the castings in your mould?—Loose core.

5457. Is that a good kind of core?—Yes.

5458. While you were at the foundry did you see any columns that were unequaly thick?—Yes.

5459. Many of them?—Not many.

5460. What was the difference in thickness of one side from the other?—The one side measured somewhere between three-eighths of an inch and half an inch.

5461. And the other half measured what?—And the other side measured somewhere about an inch and a quarter, or an inch and three-eighths; between an inch and three-eighths and an inch and a quarter.

5462. What was the specified diameter of the pipe?—15 inches, I think, was the specified diameter of the one which we were making.

5463. And what was the specified thickness of the pipe?—Inch metal.

5464. What was the specified thickness of the columns?—An inch.
(The Commissioner.) There are two sizes of columns—15 inch and 18 inch columns. You speak simply of 15 inch columns?—

The Witness. Yes, that is so. (To the witness.) Was all the columns that you cast 15 inches in diameter?—Yes; I think they were.

The Commissioner. Those columns, you have said, were not uniform in their thickness in the sides of the columns? Were they made by you, or were they made before you went there?—Before I went there, I fully expect.

The Witness. How did you see them?—When they came away from the river, when the two girder fell in February 1877.

The Commissioner. Were those part of the supporting columns that gave way?—Yes.

The Witness. Just tell me, if you please, how you proceeded to cast those columns; had you an under flask?—Yes; that column that I was engaged on was what is termed a lifting column, a piece cast on the side of it.

The Commissioner. Lifting columns that were used temporarily for getting up the high girder on the top of the column?—Yes; those were made in the full box, two boxes, as it were, put together forming one when the casting was finished.

The Witness. Do you call those pieces of the box the under flask and the upper one?—The under one is the drag, or the bottom part, and the upper one is the flask, or top part.

The Commissioner. You have mentioned the lifting columns; were you engaged in casting any other columns than the lifting columns?—I may have been, to begin with, on the other columns, but that was of very short duration.

The Commissioner. The lifting column, I suppose, were removed when they had served their purpose?—No; I cannot tell you that.

The Witness. In the case of those columns that you cast, had they flanges?—Yes.

The Commissioner. What are called flanges?—Yes.

The Witness. Were the flanges and the lug parts of the original casting? were they on the tube when they came out of the casting?—Yes.

The Commissioner. They were intended to come out of the casting, the flange and the lug, as part of the column?—Yes.

The Commissioner. Did you find in taking out your casting in any case that either the flanges or the lugs were wanting?—I find that the lugs were wanting in some cases.

The Witness. Can you explain to us what it was that occasioned that?—It might arise from the portion of the mould that formed the lug being too hard, preventing the metal lying close to it.

The Commissioner. Close to the core?—Yes; close to the core from the lug.

The Commissioner. Those lugs were necessary parts of the structure, I suppose?—Yes.

The Commissioner. So that when the casting came out without the lug, the lug had to be added to it?—Yes.

The Witness. How was the lug added in those cases where it was wanting?—It was in general burnt on—what is termed so—a new burnt on.

The Commissioner. Will you explain what the process is of burring in the lug?—I will try; that part of the column which wants a lug is heated up to cause the column to expand first, and then a portion of the mould is removed, and a narrow place is left in the mould, and metal is poured over the column that is wanting the new lug, until it is properly softened and becomes amalgamated with the metal going on.

The Commissioner. In short, you applied the mould to the side of the column, after the column had been heated, and poured in metal into the new mould with the view of its attaching itself to the column?—Yes.

The Commissioner. Was it possible, in your opinion, to burn on the lug so as to be as strong as if it had formed part of the original casting?—From the peculiar position of the lug on the column being attached to the body of the column and the flange as well, I consider it was almost impossible with the material used that it could be solidly burnt on.

The Commissioner. Of course when the metal which is to form the lug is poured on, it has a greater heat than the body of the column?—Yes.

The Commissioner. Or of the flange?—Or of the flange.

The Commissioner. Did you find that in cooling the lugs came away from the flange altogether and adhered only to the column?—That was the case, the contraction of the metal forming the lug; you pulled it away, as it were, from the flange, and left a rent between the flange and the lug, that is wherein the unsoundness arose.

The Commissioner. Then I suppose that could not be as strong as a casting of which the lug had formed an original part?—No.

The Commissioner. Was that want of the lugs in the original casting and the burning of them on a thing that took place frequently?—Frequently.

The Commissioner. Who was in charge of the work superintending it?—That was the foreman's place.

The Commissioner. What was his name?—Fergus Ferguson.

The Commissioner. A foreman appointed by the contractors, of course?—Yes.

The Commissioner. Was he aware of these lugs requiring to be frequently burnt on?—Yes.

The Commissioner. He must have been?—He must have been. He ordered the party to do it whenever did it.

The Commissioner. You are aware from your own observation that it was being frequently done?—Yes.

The Commissioner. What is known in the trade as scabbing in the column?—That is the rising of the sand from the under-surface of the mould during the time that the molten metal is running into it.

The Commissioner. The sand of the mould in some places was washed away by the running metal?—Yes.

The Commissioner. What effect has that on the column when it happens?—The sand would float on the top of the column, after the column had been heated, and that might be thicker in the bottom, but it would not cause it to be thinner on the top than its original thickness.

The Commissioner. It would be thinner metal mixed with the sand?—Mixed with the sand.

The Commissioner. Of course when the metal which is to form the column, after the column had been heated, and poured in metal into the new mould with the view of its attaching itself to the column?—Yes.

The Commissioner. Did that take place in the columns that you were working at?—Not at the columns I was working at.

The Commissioner. Not in the lifting columns?—No.

The Commissioner. Do you know whether that took place in the ordinary columns?—It did take place in some of the ordinary columns.

The Commissioner. How did you avoid it in the lifting column?—From the fact of having the two parts of the box to make the lifting column in, we got better at that.

The Commissioner. In what mode were the ordinary columns cast—were they not cast in the same kind of box?—No.

The Commissioner. What kind of mould did they use for the ordinary columns?—The floor of the moulding shop formed the one-half of the columns, and the other half, when what are termed "flasks" or "tubes," to cover the top part—they had only one part of the box to make it in.

The Commissioner. That upper flask, was it barred across the top?—Yes.

The Commissioner. After you had placed the upper flask upon the lower half through those bars you rammed in the sand over the core, and pressed in the sand which was to form the mould?—The pattern of course was
on in its place when the top flask went on. The sand is filled in through the bars of the box and rammed in. It is taken summer then.

5513. Was that part between the sand on the lower part and the sand that you rammed in thinner so as afterwards to let one out and leave the other free?—Yes.

5514. What sand was it?—Sand found on the seashore, or what is termed separating sand, or parting sand.

5515. So that after you had rammed in the sand into the upper flask in the top of the pattern and thus produced the mould that you were to fill, the upper flask was taken off?—Yes.

5516. And the pattern then taken out and the core put in?—When the mould was finished.

5517. Having got the core put in, the upper flask is again replaced, and the metal is poured in?—Yes.

5518. Is it essential, in making a good casting, that the upper flask should be put on a second time over the core, exactly in the position that it occupied when it was over the pattern?—Most decidedly it must be.

5519. Can you tell me what means were taken at the Woorit Foundry to secure that the upper flask, when placed over the core, should occupy exactly the same position as it occupation for the pattern?—On the sides of the box that the core is moulded in are cast pieces, square ours, or what are termed “lugs,” and by the side of those there are pins driven into the floor, so as properly to form them and steady them, and when the box is lifted out those pins are left in their position, and when it is put on again it just slips down by those pins into its place?—Yes.

5520. Was that course followed at Woorit with all the columns that you saw?—Yes; all the columns moulded on the bed of the moulding shop.

5521. Were there any other moulded except on the bed of the moulding shop, or that were not moulded there?—They were not all moulded in the same form; some pieces, square ones, or what are termed “lugs,” and by the side of those there are pins driven into the floor, so as properly to form them and steady them, and when the box is lifted out those pins are left in their position, and when it is put on again it just slips down by those pins into its place?—Yes.

5522. Was that course followed at Woorit with all the columns that you saw?—Yes; all the columns moulded on the bed of the moulding shop.

5523. Were there any other moulded except on the bed of the moulding shop, or that were not moulded there?—They were not all moulded in the same form; some pieces, square ones, or what are termed “lugs,” and by the side of those there are pins driven into the floor, so as properly to form them and steady them, and when the box is lifted out those pins are left in their position, and when it is put on again it just slips down by those pins into its place?—Yes.

5524. It would not have been round?—Just so.

5525. Cast out of the round towards an oval?—Yes.

5526. Did you see any castings at all at Woorit for the bridge that presented that appearance?—No.

5527. Seeing that the castings were coming away without the lugs did you call the foreman’s attention to that matter?—He might have spoken to me of it, and I suggested to him that instead of casting the third lug (there were three on each end of the columns) on the top of the columns, he ought to turn it round and cast it on the bottom side of the column where he would be sure to find it sound, and not require to burn it afterwards.

5528. Did he take that suggestion?—Yes.

5529. After that, so far as you know, there were none of the castings came away without their lugs?—No.

5530. Those castings were sent down from the foundry to the jetty?—Yes.

5531. Are you aware that the columns which were sent down from the shop to the jetty with the lugs on them sometimes got the lugs knocked off them?—Yes.

5532. And did those come back to the shop to have the lugs replaced?—Yes.

5533. When they were replaced, how was it done?—In the same form as has already been described—by ramming.

5534. You burnt a lug on the last column that went out, I think?—The last that was burnt at the Tay Bridge Foundry.

5535. The last that was burnt at Woorit?—Yes.

5536. Did you do your best to get it firmly attached to the column and the flange?—I did.

5537. Did you succeed?—No.

5538. Was the result the same that you had previously described, the lug attaching to the column, but away from the flange?—Away from the flange, but not to such a large extent; a flaw was discernible, but no more.

5539. You did your very best with that, one?—Yes, under the circumstances.

5540. And you could not get it firmly united?—Just so.

Cross-examined by Mr. Ballochon.

5541. Were your employers Messrs. Hopkin, Gilkes, & Co., the contractors?—I never inquired who were the contractors; I was taken on by the foreman.

5542. By Mr. Fergus Ferguson?—Yes.

5543. You do not know whom your employer were?—Messrs. Hopkin, Gilkes, & Co., I suspect.

5544. Mr. Fergus Ferguson was the foreman of the foundry?—Yes.

5545. During all the nineteen months that you were there?—Yes.

5546. Was he always looking after the moulding, was that his business?—Yes; that was his business.

5547. How many moulders were working at that temporary foundry?—I cannot exactly answer that question. There were somewhere about ten or eleven.

5548. Had it been going on some time before you went there?—Yes.

5549. And continued to go on for some time after?—Yes.

5550. Had you been engaged in casting with Cleveland metal before, or only with Scotch metal?—I had cast with Cleveland metal before.

5551. Where?—In Douglas Foundry in Dundee, and in the Blackness Foundry, Dundee.

5552. That appears to have been the kind of metal which had been in Dundee otherwise than in connexion with the bridge?—Yes, but generally mixed with Scotch metal.

5553. Had you ever been accustomed to casting with it alone before with Cleveland metal alone?—I have cast such things as girders for houses with Cleveland metal alone.

5554. Is what you have said to us all the experience that you had had before of Cleveland metal?—Yes; I had had a number of pins.

5555. How many years had you been casting before?—With Cleveland metal I should say five or six years before.

5556. It was a thing commonly used in Dundee for other work than the bridge?—Yes; for mixing with Scotch metal.

5557. Was there anyone else beside Mr. Fergus Ferguson in charge, or anyone over him?—Yes.

5558. Who was that?—Mr. Camphuys.

5559. Was he in charge during the whole nineteen months that you were there?—Yes.

5560. Did he look in and see what was going on in the moulding process?—I have seen him often.

5561. Did he examine the columns after they were turned out?—I cannot say.

5562. Do you know who examined the columns after they were turned out of the moulding shop, and before they were built into the bridge, or did anyone do so?—I do not know who did, or whether anyone did so.

5563. Your work was, I suppose, inside?—Yes.

5564. Was Mr. Fergus Ferguson always inside?—Yes; he had perhaps business outside that I did not know of.

5565. But that was his place, he was usually there?—Yes.

5566. Supervising the moulding?—Yes.

5567. You told us, I think, that you had seen some
of the columns that came in broken at the fall of
1877 ?— Yes.
5558. And that you had found that some were of
unequal thickness?—Yes.
5559. Was that the first time you knew that any of
those had been of unequal thickness?—Yes.
5560. If they had not been broken would you have
known that they were of unequal thickness?—I should
not have known.
5571. In speaking of the columns being of unequal
thickness, did you know that that was the case with
regard to any except those that came in broken in
1877?—Yes.
5572. What others?—I saw a portion of the
columns that had been made lying behind the foundry.
5573. Broken?—No; they were stacked up behind
the foundry. They had been made of the wrong
length, or something of that sort; they were not of
the usual length, and they were broken up.
5574. It comes to this, does it not? Were the
only columns that you knew to have been of unequal
thickness on the two sides the columns that were
broken up, either broken by the fall of 1877, or broken
because they were of unequal lengths?—Since they
came ashore from the river they were broken up—
thick and thin on one side.
5575. The ones that you saw stacked up which
were short, were also broken up, and some of them
were of unequal lengths?—Yes.
5576. And it was those batches alone that you
knew to have been of unequal thickness?—Yes.
5577. Were there many of them of unequal thick-
ess, or was it a rare thing?—That batch that was
broken up were nearly all unequally thick.
5578. And was that the reason why they were
broken up?—No; they were broken up because they were
short, were also broken up, and some of them
were of unequal lengths.
5579. You cannot say whether the columns that
were built into the bridge and remained there were of
unequal thickness?—No.
5580. Who gave the directions for the short
columns being broken up?—I cannot tell you.
5581. Who could tell us that?—Mr. Champn:is
would be a likely person to tell you.
5582. He will be a person able to tell us about the
columns that were brought in after the fall?—Some
part of them.
5583. I understand you to say that the only columns
that you were personally engaged in casting were the
lug columns. Is that so?—Principally so.
5584. Those were all 15 inches diameter?—So far
as I know they were; it was an approximation to it.
5585. I did not measure the columns exactly.
5586. They were not 18 inch columns?—No.
5587. Who had charge of the casting of them?—
Those were different parties on them; I cannot give
the names.
5588. With regard to the lugs, the lugs were pieces
outside the columns?—Yes.
5589. Pieces not intended, as I understand, to bear
a strain resting upon the column, but to attach other
parts to the columns?—Yes.
5590. To attach the tie-rods which were to cross
between the different columns?—Yes.
5591. What was the size of the lugs?—I cannot
give you any size.
5592. They will be seen there yet?—Yes.
5593. Do you know whether the columns that you
cast in those nineteen months went into the part of
the bridge that is now down, or whether they went
into the part of the bridge standing, or partly one and
partly the other?—Into the part of the bridge that is
now down.
5594. All of them?—I think so. I do not know
easily.
5595. Who can tell us?—Mr. Champn:iis is the
likeliest person that I know of.
5595. You did not follow them to the bridge?—
No.
5596. With regard to the lugs that were burnt on,
did you see any of the columns which came out of
the mould with the lugs imperfect and broken up?—
No.
5597. Did Mr. Ferguson not direct the moulders to
break up those that came out with the lugs
imperfect?—No; never that I heard of.
5598. Were there any columns that had lugs burnt
on to them except those the lugs of which had been
broken off in transit?—Yes.
5599. How many?—I cannot tell the number.
5600. Was Mr. Ferguson present, and did he
direct that the lugs should be burnt on that were
originally imperfect?—Yes.
5601. And saw it done?—Yes.
5602. In all cases?—In all cases, so far as I know.
5603. It was all done under his superintendence?—
Yes.
5604. How were the moulders paid; were they
paid by the piece or by the hour?—They were paid
by the hour.
5605. It did not matter to them whether they were
replacing and remoulding or casting the original work?—
No.
5606. They had no inducement to put out had
work?—No.
5607. Can you give me any idea how many lugs
were burnt on?—I cannot give you that. It was a
very frequent occurrence.
5608. Should you say twenty?—More.
5609. Thirty?—Yes.
5610. I understand you to say that in the case of
the column which you say had come out originally a
bad casting, the lug did not burn in so close as not to
leave an interval between it and the column. There
was a space between, you said?—That only arose
after the lug was burnt on.
5611. When it cooled?—Yes.
5612. I mean before, instead of the metal uniting
together, when it cooled it contracted and left a
space?—The metal was united together, but when it
contracted it broke itself from the flange.
5613. When the metal was cool there was a space
left between the lug and the original column?—Yes.
5614. How large?—About the thirty-second of an
inch.
5615. Along the whole length of the lug or the
breadth of it?—The breadth of the lug.
5616. What was the breadth?—Somewhere about
2 1/2 or 2 1/2 inches up and down the flange.
5617. So that any person looking at the columns,
that is, looking at them with care, any person in charge
would himself see that interval of about a thirty-second
of an inch. It was quite visible?—Yes; it was quite
visible.
5618. You said, I think, that where a lug had been
burnt on, there was some interval also but of less
extent?—Yes; it might be to the same extent or to a
less extent in the case of the one that was burnt on
last, when I attempted to do it without any interval,
but it could be done.
5619. Is it true of all the columns that anyone
looking at them carefully could not fail to see this
interval between the original column and the lug?—
Anyone looking carefully at them ought to have seen it.
5620. Anyone examining them as a person would
to pass the columns?—Yes.
5621. He must have seen it?—Yes.
5622. Did the columns go away out to the bridge
with this thing visible to any careful observer?—I
cannot tell you.
5623. They went out of the moulding shop in that
way, and that was the last you saw of them?—Yes.
5624. Where did they go to then?—They generally
went down to the jetty.
5625. On their way to the bridge?—Yes.
5626. You have no reason to doubt that they went
to the bridge. Was this crack visible as they left the
moulding shop?—I could not tell.
5627. You spoke about sand seeping; is that one
of the ordinary risks of moulding?—Yes.
5628. You also spoke of the sand which is used
in moulding; where was it got from; I did not speak of the sand that was used.

(Mr. Trayer.) He talked of separating sand being grasped from the sea-shore.

(Mr. Balfour.) Let me understand what sand you did mean by separating sand?—The sand that separates one half of the mould from the other.

5630. You were not speaking of the sand constituting the mould into which the metal is run ?—No.

5631. You have no criticism to make upon that sand?—No.

5632. It was all right?—So far as I saw it.

5633. Was it not sand from the river Earn?—I cannot tell you.

5634. Have you nothing to say against it?—It was mixed with salt water.

5635. The separating sand, I understand you, was mixed with salt water, but I am asking you with regard to this sand in which the castings were made: was that mixed with salt water?—Yes.

5636. How?—Because, when the metal is run into the sand, it dries the sand in the morning, and when the casting is taken out, the sand has to be wetted again before it can be worked with, and it was wetted with salt water.

5637. With salt water thrown over it?—Yes.

5638. By whom?—By everyone who worked it.

5639. Did Mr. Fergus Ferguson see that?—Yes.

5640. Was that after the mould was made?—No.

5641. I mean after the casting was made?—Yes.

5642. How long had the casting been made before salt water was thrown over it?—It had been made the night before.

5643. Twelve hours?—Yes.

5644. So that that was after the metal was solid, but not?—Yes; it was to prepare the sand to begin to make other ones.

5645. Was there not a well close by, out of which the water was thrown, used for that purpose?—No.

5646. Was there no well near?—Yes.

5647. What was the water from it used for?—To make the men’s coffee. It was drinking water, not for moistening.

5648. Are you sure of it?—I am very sure of it. There may have been water taken out of and thrown over the sand when there was plenty of it, but there was seldom very much in the well.

5649. Mr. Fergus Ferguson knew of it. Did Mr. Camphish know of it?—I cannot say that he knew of it.

5650. Did the men get any direction as to where the water was to be taken from?—Yes.

5651. From whom?—From the foundry.

5652. That was Mr. Fergus Ferguson?—Yes.

5653. Were the pipes or columns all turned after they left the moulding shop?—Yes; all turned in the ends.

5654. Put on a lathe and the ends turned?—Yes.

5655. Were you in that shop?—No; it was all under one roof.

5656. You had nothing to do with that?—Yes.

5657. Each column had to go on the lathe and be turned so as to smooth at the ends?—Yes.

5658. It passed through bands after yours?—Yes.

5659. Was that after the lugs had been burnt on as you say they were?—Yes.

Re-examined by Mr. Trayer.

5660. You said that there might have been 30 lugs burnt on; did you mean to limit it to 30 over the nineteen months that you were there?—No; it was only because I could not give a definite number.

5661. You have said before, and I suppose you say now, that the burning out of the lugs was of very frequent occurrence?—Yes.

5662. If the columns were of unequal thickness in any part not at the ends of the columns, that would not be visible of course from the outside?—No.

5663. You judge of the columns that were sent out as being possibly liable to the same defects as those that you saw, the short lengths that were being brought back broken?—Yes.

5664. There was nothing in the founding of the ordinary columns different or more careful so far as you saw, than the mode adopted for moulding the columns that were broken up and found to be deficient when they were broken up?—No.

5665. The scabbing, you say, was the common risk of moulding, and therefore a risk against which all careful moulders provide?—Yes.

5666. It is a thing that is known to happen and to produce an inequality in thickness, and therefore a risk of want of strength?—Yes, a risk of want of strength.

(Mr. Balfour.) I think he said “not,” your own witness.

5667. (Mr. Trayer.) I think not. (To the witness.) Do not let me misunderstand you. The scabbing you said produced an inequality of strength in the different sides of the column?—Yes.

5668. If that column has to support a weight the place where it is mixed with the sand is more likely to give?—Yes; it is most likely to give under a crushing strain.

5669. Was there any chaplet used for the purpose of letting the sand, or the scum, or the air, come off when you were moulding?—No; they are not used for those purposes.

5670. Not in those castings?—They are not used for that purpose. They used a chaplet to begin with, to keep the core straight in the column before I went there.

5671. Is there not something used by moulders, or some place left by them through which or into which the scum and the scum will rise?—No; not in cases of that kind.

5672. In the case of those columns there was nothing of that kind?—No.

5673. Tell me, if you please, were any of these columns (pointing to the same) supporting the high girders that you call lifting girders?—Yes; these columns with pieces on the side.

5674. Those columns with bits on the side were the columns that you were talking of as lifting columns?—Yes.

5675. And those, I suppose, were in the bridge under the high girders?—I think so.

5676. The sand required for the purposes of moulding requires to be moistened, does it not?—Yes.

5677. And after the casting had been taken that of course had dried up all the moisture?—Yes.

5678. Before you used the mould again it was dampened?—Yes.

5679. And as a rule, I understand you to say, that it was dampened with salt water?—Or water pumped from the river.

5680. The river, I suppose, is never perfectly fresh at that point?—No.

5681. At high water it is perfectly salt?—Yes.

5682. Was there any supply of water sufficient for the purpose of the foundry except what was got from the river?—There was a supply of water at Wormit Bay.

5683. But that was just by the River Tay?—No; water running into the River Tay.

5684. Is it a branch of the natural stream?—Yes.

5685. How far was that from the foundry?—I should say about a mile.

5686. Was there any apparatus used to convey that water towards the foundry for the purposes of the foundry?—No further than the men going down for some of it to drink sometimes.

5687. When your well was low or dry?—Yes.

5688. Then there was, as a rule, no water used for dampening the moulds except salt water?—As a rule, that was the case.

5689. Is that the kind of water that workmen like to work with in mouldings?—It is very seldom used that I could not say whether they would like to
work with it. If I gave my opinion of that I should say that I should not like to work with it.

5690. Did you hear the men at Wormit complaining of it?—Yes.

5691. Did they complain of it to their foreman, or was it talk among themselves?—Talk among themselves.

5692. What is it that makes salt water less agreeable to work with than fresh water?—As a matter of course salt water will carry with it more ingredients than fresh water, and when the molten iron goes into the mould gases generate there which come off, and that causes an acid to float through the shop which they could scarcely stop in the shop with.

5693. (The Commissioner.) Do you mean that the well you had ordinarily only contained sufficient water to supply the men for drinking purposes?—Yes.

5694. And no more?—It might have done more at times, and when it did so it was taken advantage of.

5695. But generally it did not supply more than was required by the men for drinking purposes?—Generally it did not.

5696. With regard to this lifting column that you speak of, you have seen it there; assuming that to be a model of the construction, it is still there?—Yes.

5697. They had got pin-holes in order to support the girder as it was raised?—Yes.

5698. Those are the ones you refer to?—Yes.

5699. You have stated that you could not ever completely get the scum from off the top of it; what would be the effect of leaving the scum in the iron?—I can scarcely speak to that, as I have never seen it tested to give any effects.

5700. Would it produce an imperfection in the iron?—I cannot say that.

5701. You say that scabbing is an ordinary defect which the workmen would always try and avoid?—Yes.

5702. How would they try and avoid it?—The means they take to avoid it is to let the gases away from the sand while the metal is going on as much as possible.

5703. Do you mean to say that with salt water there would be more of those gases?—Yes.

5704. Therefore there would be a greater tendency to scabbing when you used salt water than when you used fresh water?—Yes.

5705. (Mr. Barlow.) You mentioned one of those columns from which the lug broke off, and which you afterwards tried to put on by the process of burning on, and that the job was not satisfactorily done?—Yes.

The witness withdrew.

JAMES MCGOWAN SWORE.

Examined by Mr. TRAINE.
6745. Was there a bad scum on this iron?—There was a bad scum on the iron. When we puddled it a scum rose up to the top; the more we puddled the more scum was.

6746. With good Scotch metal proper puddling brings all the scum to the top, and when that is taken away it is clear?—Yes.

6747. So far as you saw was that condition ever brought about in the iron that was used at Wormit Foundry?—Yes.

6748. I mean, was it made perfectly clear with Cleveland iron. You say that in the case of Scotch metal, when it is thoroughly puddled and cleared out and skimmed away, it leaves it clear?—Yes.

6749. Did you ever get that condition of iron in the English iron that was used at Wormit Foundry?—No.

6750. There was always more or less scum left?—Yes.

6751. I suppose you could not have cleared it unless you had cleared out the iron?—We could not have cleared out the iron.

6752. Did you see the mark of the cold shut on any of the columns that were not broken up, but sent out to the jetty?—No.

6753. Where all the columns that showed this cold shut, so far as you are aware, destroyed?—They were destroyed when I saw the cold shut, but I did not notice the cold shut until they were broken.

6754. Is that cold shut a thing that may exist without being seen on the column until it is broken up?—Yes, or turned.

6755. You might see it through the ends of the columns when they are being turned?—No, you could hardly see it then; you can see it more readily on the body.

6756. Were these columns sent out to the Tay Bridge all turned?—Yes; all that I saw.

6757. After being cast?—Yes.

6758. Did you not see any columns with cold shut visible upon those that went out to the jetty?—No.

6759. What columns were you engaged in casting?—The 16-inch columns.

6760. Where those the ordinary columns that were going out to the bridge?—Yes.

6761. Had they flanges on them?—They had flanges in each end.

6762. Are lugs?—Yes, and lugs.

6763. For the two rods?—Yes.

6764. Was the lug a part of the original moulding?—Yes.

6765. And did you always get your column out of the mould with the lug on?—They always came out of the mould with the lug on. I have seen a small piece of the lug broken off after it was out.

6766. Was that of frequent occurrence or of rare occurrence?—Of frequent occurrence.

6767. Then when the lug came out of the mould defective, as you have described it, bow did you proceed to remedy that defect?—We burnt on a part of a lug.

6768. In some cases had you to burn, on a whole one?—No; I never burnt on a whole lug.

6769. When you did burn on a part of a lug, was it, general speaking, a large part or a small part, considering what the size of the lug was altogether?—A small part.

6770. Was it principally in one position, or did it take different places in lug?—It was always in one position—at the top of the lug.

6771. Was it of so constant occurrence, or frequent occurrence, that the same defect indicated to you what was occasions it?—Yes.

6772. What was it?—I thought it was the bad blows at times.

6773. If the mould at the core had been complete and sharp you think it would not have occurred?—Yes; I think it would not have occurred.

6774. How did you burn on a part of a lug?—By pouring two or three ladles of metal upon it.

6775. Applying a new mould to the defective place, pouring in two or three ladles of metal?—Yes.
5808. The lump that had filled up the place where the sand had been washed away—Yes, where the sand had been washed out.

5809. I suppose that again would be removed by the turning?—No; they did not turn the body of the lump; they chipped that piece off generally.

5810. Chipped it off with a chisel?—Chipped it off with a chisel.

5811. You saw that done more than once, I suppose?—Yes.

5812. And that showed to a skilled workman that there had been scabbing?—Yes.

5813. Now, what became of those columns where the scabbing had taken place, and where the lump was taken off, with the chisel?—They went out to the jetty, as far as I know.

5814. You had nothing to do with them when they left the moulding shop?—No.

5815. But so far as you know they went with other columns down to the bridge?—Yes; I have seen them going down the incline of the jetty.

5816. You said that the specified diameter of the columns was 15 inches; what was the specified thickness?—An inch.

5817. Did you see any of the columns brought back to the shop that came down with the two big girders in 1877?—No.

5818. You left before that happened?—Yes.

5819. What water did you use for damping the moulds?—Salt water.

5820. Was there any other water available to use for damping those moulds except salt water?—In the winter there was generally a well of surface water; it dried up sometimes in the summer time, and then we always use the salt water.

5821. During the time that you were there did you mostly use salt or fresh water for your damping?—Mostly salt water.

5822. Had you ever used salt water for damping before?—No.

5823. Did the moulders like to work with moulds damped with salt water?—No, I believe most of them preferred to use fresh water.

5824. What did you prefer?—Fresh.

5825. Why?—The salt water makes a harder skin on the mould, I thought.

5826. Did it throw off disagreeable smells more than fresh water did?—It threw off a very disagreeable smell. I have seen the whole of the men in the shop have to go and leave it at times.

5827. Do you know as a matter of fact that salt water throws off more gases than fresh water?—I could not answer for that; but I never felt a disagreeable smell with the fresh water.

5828. You have spoken of the defective lugs being remedied by burning on; did you ever see columns that had gone down to the jetty and which had been sent back to have a lug burned on where a lug had been accidentally knocked off?—I saw one.

5829. And that was burned on in the same way as you have described?—It was not sent down to the jetty; it was before it went down to the jetty, after it was turned.

5830. Had the lug been knocked off in the turning?—No; it was putting it outside the shop. It got smashed somehow or other, and part of a lug was burned on.

5831. Could those lugs when burnt on, or could part of a lug when burnt on, ever have the same strength as if they had been part of the original moulding?—Not with that sort of iron.

5832. And it always left a crack?—It always left a crack.

5833. Do you remember some bases that came for the bridge that were made at Bathgate?—I remember some bases about three and a half or four feet in diameter.

5834. Base plates?—Base plates. I think they were made at Bathgate; I am not certain.

5835. Wherever they were made they came to Wormit for the use of the bridge?—Yes.

5836. Were they used on the bridge?—No; they were not used.

5837. Why?—The plan was altered.

5838. The plan of the bridge?—The plan of the bridge was altered.

5839. And then those were not required?—They were not required.

5840. What iron did those bases appear to you to be made of?—They appeared to be made of Scotch iron.

5841. Superior to the iron you were using?—Superior to the iron we were using.

5842. You saw them lying there apparently useless?—They were laid down close to the cupola apparently useless, as though they were to be melted over again.

5843. Did you say anything to your men about them?—I told the furnace man after Strachan was paid off.

5844. And who was the man that came in his place?—Fergus Ferguson.

5845. Was he there when you spoke to the men?—No; it was during the time before Ferguson came.

5846. After Strachan had been paid off, and before anyone had come to take his place?—Yes.

5847. Then you had charge of the moulding shop?—I had charge of the moulding shop.

5848. Did you see your men do what you told them?—They did not see my men do what I told them.

5849. For the purpose of being used in the making of the columns?—For the purpose of improving the iron of the columns.

5850. But it was iron that was to be applied for moulding columns?—Yes.

5851. What extent of base plates would there be altogether?—I think ten or twelve tons altogether.

5852. Did your men do what you told them?—They melted some of them.

5853. How many?—About 10 cwt.

5854. Why did they not go on melting them all as you had told them?—They were stopped by the manager.

5855. Who was he?—Mr. Beattie.

5856. Do you know that he stopped them?—Yes.

5857. Did he say anything to you why?—I was standing beside the furnace man when he told us not to break them up; not to use them, but rather to send to Middlesborough for pig, and we should get a better price for these when the bridge was finished.

Cross-examined by Mr. Ballou.

5858. I think you told us that you were eighteen months at the job. Could you try and tell us the year and the month, if possible, in which you went to the job?—I am a very bad hand at dates.

5859. Was it in 1874?—It was at the commencement of the foundry.

5860. That is to say, did you work at the foundry at Wormit from the very first that there was any work done there?—From the very first casting for the bridge.

5861. At that time was the man you named first, Hercules Strachan, the foreman moulder?—No.

5862. How long was he the foreman moulder?—About eighteen months.

5863. Then he had been foreman all the time you were there?—All the time I was there except a short time I was there after Ferguson came.

5864. How did Strachan come to leave?—He was paid off.

5865. Why?—He was the worse for drink.

5866. Who else was in charge of the foundry, or came about it, besides Strachan?—Mr. Beattie was over Strachan.

5867. All the time?—All the time.

5868. Do you know where he is now?—I do not.

5869. Was he ever Strachan from the time you went until the time you left?—Yes.

5870. Then you left before Mr. Cambell came?—
MINUTES OF EVIDENCE.

I did, Mr. Cameron was there, but Mr. Beattie had the charge.

3871. How long was Ferguson there while you were working?—About six weeks.

3872. What place had Mr. Cameron at that time?—I could not say exactly.

3873. Was he coming about the foundry?—Very seldom, and then he did not come about it.

3874. Were you casting columns all those eighteen months?—Columns and bases.

3875. What part of the bridge were the columns that were cast when you were there put into?—Part on the south side, and part on the north side.

3876. Parts that are still standing?—Parts that are still standing.

3877. Then all the columns that you helped to cast are still standing, and can be seen there yet?—Yes.

3878. You told us about the iron: was there no Scotch scrap put into iron that was cast in those columns?—No, except that twice; it was only twice put in.

3879. How much was put in all these twice?—About 5 cwt. each time.

3880. Was that all?—That was all.

3881. Are you sure that those were the only times that you saw Scotch scrap put in?—That is the only time that I have seen it.

3882. (Mr. Trayner.) That is the occasion when it was done under your orders?—Yes.

3883. (Mr. Balfour.) You told us about the columns that you saw broken up where the cold shut was; what led to those columns being broken up; why were they broken up?—There were some of them made the wrong length.

3884. Were those columns that were piled up behind the foundry?—No.

3885. Was Richard Baird there when you were there?—No.

3886. Then you had left before he came?—I had left before he came.

3887. How many columns did you see broken up which had the cold shut on them?—About eight or nine.

3888. Was the cold shut quite visible to any person accustomed to these things?—After the column was broken up.

3889. Anybody could see it?—Anybody could see it.

3890. Who else saw those columns broken?—The foundry men.

3891. And the people in charge, I suppose?—And the people in charge.

3892. When there is a cold shut upon the column do you not see it on the outside of the column before it is broken up?—Sometimes.

3893. It makes a sort of inequality, does it not?—Two places come together with a sort of thin skin over them.

3894. It is caused by the two quantities of metal gradually rising up over the core, and then when they are not quite hot they do not unite, but form a thing like that (describing the same) —Yes.

3895. So that the cold shut is visible on the outside also, isn't it?—When the column is broken.

3896. But before the column is broken?—No; it is not visible then.

3897. Then it could not have been a very cold shut if the metal amalgamated so close that you could not see it on the outside?—There is a thin skin goes over the top of the cold shut, and you cannot see for it generally.

3898. It cannot have been a very bad cold shut if it made a quite even column on the outside?—I have seen some of them very bad.

3899. Even in the case of the bad cores, did you not see it outside?—I could not see it outside.

3900. If you could not see the cold shut where the column was broken across, it must have gone from end to end?—Part of the column where the metal was run in, that was properly moulded.

3901. At all events, it would be visible at each end?—Yes.

3902. And of course if both ends were turned in the lathe, any one looking at the turned end must have seen the cold shut?—No; the flange kept you from seeing it.

3903. Was there no cold shut in the flange?—No; there was a flaw, and the metal rose up through the column of the flange.

3904. Then do you say that the cold shut could not be seen upon the turned end?—No; it could not be seen upon the turned end.

3905. Then were the kind of cold shuts that you had to do with at that foundry the ones that could not be seen at all except the column was broken. Does it come to that?—They could not be seen until the column was broken.

3906. You never saw a column come out without a lug in it?—No.

3907. What was it that broke the lugs after they came out?—Some of the lugs were not solid when they came out, and they broke off then.

3908. Were they not complete?—They were not complete.

3909. How much of them broke off?—Right off by the top of the hole.

3910. Leaving part of the hole on one side and part on the other?—Yes.

3911. So that it broke across the hole?—Yes.

3912. And what did you do to put the column into the mould again and cast on the bit that remained?—Yes.

3913. Passing through about the middle of the hole?—Passing through about the middle of the hole.

3914. Was the place where the crack was between the part of the original lug that remained and the new part cast on?—No; it was done at the flange.

3915. But it could only be at the part of the flange which was outside which was added on?—Yes.

3916. It would not extend along the part of the flange which remained solid with the old lug?—Some of them did, and some of them extended along the body of the column.

3917. Up and down?—Up and down.

3918. You saw cracks extending up and down close to the column?—Yes.

3919. How many?—Five or six.

3920. And how many did you see with the crack along the flange?—I saw about a dozen.

3921. So that you saw about a dozen and a half altogether?—Altogether, to do with the column.

3922. Were they quite easy to be seen?—Quite easy to be seen.

3923. What would be the size of a crack?—About the thirty-second part of an inch.

3924. So that any one looking with an ordinary eye could not fail to see it?—Any one who looked at it closely could see it.

3925. You said there were bad cores; what was wrong with the cores that were used?—I thought they were too hard.

3926. In what respect?—The sand was too hard, and it was too strong sand.

3927. Did you mention to your foreman that you thought they were too hard?—I mentioned it to the man that made the cores.

3928. Who was he?—There were several at that job.

3929. Could you give the name of any one?—There was one named James Burns, Thomas Christie, and Peter Macaroe.

3930. Did they give you softer cores?—Yes.

3931. Whenever you complained?—Whenever I complained.

3932. And I suppose you did not go on with work with bad cores without complaining, did you?—Yes.

3933. Had you only just the one bad core of which you complained?—There was a lot of them.

3934. All at once?—All at once.

3935. But you had just one lot of hard cores?—No, there were two or three lots.
In the eighteen months?—Yes.

And you immediately complained, and then you got the right kind of cores?—No, we did not get exactly the right kind of core at once.

You got better cores?—Yes.

Did you not complain again?—Yes.

And did you not get them right again after all?—They tried to make them better; they tried to put softer sand in them—more free sand.

Do you know where the sand for the core was got from?—It was got, part of it, from the river Thames, and part of it was what we call London sand, from the river Thames.

Where was it got from the river Thames?—About Newburgh.

Was it not all sand from the Erne?—No; they brought it in sloops.

You are only speaking about the sand from what you heard. I suppose?—Yes.

Did you not go for it, I suppose?—No.

The people who brought it will know better.

Did you not do that?—We had just to put up a tank and a pump to pump river water from the commencement of the foundry to the use of salt water?—Too much water amongst the sand will make it hard for one thing.

What is it that makes the cores during, I suppose, if you had bad the lug there as a fink to the shop?—The moulds?

Did you not get them right after all?—They were done in the shop.—They were bored.

Was the time when Strachan was over you?—Yes.

But you never spoke to him or to anybody else about it?—No.

Re-examined by Mr. Trayner.

There was, you say, a tank fitted up with pumping apparatus to bring the water up from the river to the foundry for the purposes of the foundry?

Did you not complain to any of your superiors about only getting salt water?—No.

Did you think it of much importance?—I thought it was of much importance, but I knew well enough that they would not send all that distance for fresh water.

Did you try?—I only tried once for one particular job.

That was the time when Strachan was over you?—Yes.

But you never spoke to him or to anybody else about it?—No.

I am talking now of the wall?—The wall was close beside the shop.

I think you said that the wall was about a mile away. The wall was close by the shop?—The wall was close by the shop.

Was there enough water in that well to supply the men for their cooking purposes, and also to supply them for moulding purposes?—There was not.

And therefore you had got your water from the river Tay pumped up in the way you described or to have it conveyed from the stream a mile off?—Yes.

And when the foundry was built they had provided apparatus for bringing water from the river Tay, and they had not provided apparatus for bringing water from that stream?—Yes.

Did you say that some of the lugs showed a crack between the lug and the column?—Yes.

But between the lug and the column itself?—No, I never meant to say that.

The crack which you have described was a crack between the lug and the flange?—A crack between the lug and the flange and a crack on the body of the column away from the lug.

A crack in the column itself?—A crack in the column itself.

The other crack was the crack produced by the drawing off or contracting away from the flange?—Yes.

Can you tell me to what cause you attributed the crack in the column itself?—I expected or I thought it was the cooling of the column, one part of it, quicker than the other.

Cooling in the mould?—No; after it was taken off.

How would you, as a workman, account for one part of the column cooling quicker than the other?—The column all cooled alike; it was only when we were boring on the lugs that it cracked.

To burn on the lugs you had to heat the columns to a certain extent?—Yes.

And then you poured the molten metal into the mould that you had placed against it?—Yes.

And you thought it was after that process that the column had unequally cooled?—Yes.

Producing the crack you have described?—Yes.

Then the crack would not have been produced, I suppose, if you had had the lug there as a part of the original casting?—No, I think not.

(Thc Comrissioiler). Those columns that you cast had a flange at each end, had they not?—Yes.

And it was merely the face of the flange that was plane?—No.

Consequently the cold shut would not be visible after planing, would it?—No.

Were the holes cast in the lugs?—The holes were cast in the lugs.

Were the holes cast in the flanges?—No.

How were they made in the flanges?—They were bored.

Were they done in the shop?—They were done in the shop.

Where you saw it?—Yes.

Then it was merely the holes in the lugs that were cast?—In the lugs.

What is it that makes the core too hard, as you call it?—Too much water amongst the sand will make it hard for one thing.

Would salt water being used make it harder?—Yes.

Do you attribute the hardness to the use of salt water?—To the use of salt water—too much water of any kind will make it hard.

But salt water, even in the ordinary quantities, would make it hard, as I understand you—is that so?

I have used salt water to harden moulds at times.

When were they too soft?—When there was
a great rush of metal I have used salt water to harden the mould there.

6001. Then, as I understand you, what you say is that this cold shut would not be visible after planning, but that it was due to their using inferior iron?—It would not be visible unless you broke the skin of the column.

6002. And it would be due to your using bad iron?—Yes.

6003. (Colonel Vollard.) What length were the cracks that you speak of as existing in the columns themselves after the burning process had gone on?—I have seen some of them from ½ inch in length up to 14 inches or thereabouts.

6004. Can you tell whether those cracks passed through the metal to the inside of the column?—The cracks passed through the metal to the inside of the column.

6005. Was anything done to them afterwards—were they stopped in any way?—They were painted and puttied.

6006. (The Commissioner.) Did you see them painted and puttied?—Yes.

6007. Before they left the shop?—Before they left the top of the hill, before they went down to the jetty.

6008. Was that done in the shop?—Outside the shop.

6009. Then this crack was painted and puttied (I suppose first) by the workmen in the shop, or by whom?—By the workmen in the yard.

6010. Employed for that purpose?—Employed for that purpose.

6011. (Mr. Barlow.) You were there from the beginning of this work, were you not?—I was there from very near the commencement. I was there from the first casting of the bridge.

6012. Were the whole of the castings made there?—The whole of the castings on the new plan were made there as far as I know.

6013. Were the 18-inch columns cast there as well as the 15-inch columns?—The 15-inch columns were. I was away before they commenced to make the 18-inch columns.

6014. Was the foundry a new one erected for these works?—The foundry was erected for these works.

6015. Do you consider the quality of the ironworks turned out there of that foundry equal to that you had been accustomed to deal with on former occasions?—No, I did not.

6016. You thought it inferior?—I thought it inferior.

6017. In what way?—I thought it inferior. For one thing, because it was very easily broken, and it was very sluggish when it was melted, and cooled very quickly, and there was a nasty scum on it.

6018. I think you said that the holes in the columns were drilled?—The holes in the flanges were drilled.

6019. But not in the lugs?—Not in the lugs.

6020. And there was machinery fixed up at this place, was there, for the drilling of the holes?—Yes.

6021. Was that used in all the columns?—All the columns that I saw.

6022. You do not know of any of the columns in which the holes were cast?—No.

6023. (Mr. Trayner.) The foundry was built for the purpose of these works?—Yes.

6024. And it was knocked down when the bridge was finished?—It was taken down just after the bridge was finished.

6025. (The Commissioner.) It was for the purpose of this work, of course.

6026. (Mr. Trayner.) Solely.

The witness withdrew.

ALEXANDER HAMPTON (sworn).

6027. Examine by Mr. Trayner.

6028. You are a moulder, and reside in Dundee?—Yes.

6029. You were engaged at the Wormit Foundry while the works at the Tay Bridge were going on?—Yes.

6030. You were engaged at two different times, I believe?—Yes.

6031. And altogether your work there extended over what length of time?—Five or six weeks altogether.

6032. Can you tell me about the date of your first employment?—No, I scarcely could.

6033. In what year was it?—It was soon after it commenced.—No, it was well on.

6034. How long were you there the first time?—About a fortnight.

6035. And what interval was there between that and your going on again?—It may be a year, but I could not say exactly.

6036. And then you only stayed for about three or four weeks, I suppose?—Yes.

6037. When you were there what was the work you were engaged upon?—Casting columns.

6038. Casting columns?—Yes.

6039. Nothing else?—No.

6040. What kind of iron was it which was used?—English iron.

6041. And what was the quality?—It was very bad iron, the worst that I ever saw.

6042. How long have you been a moulder?—Twenty-seven years come the 5th of March, if I am right.

6043. How did it show its bad qualities?—By a nasty scum coming upon it at the top the more you puddled it. You might have puddled the ladle toom (empty).

6044. In short you could not get rid of the scum?—No.

6045. In the case of good Scotch metal, by puddling you bring the scum to the top, and when it is skimmed off it is left clear?—Yes.

6046. There was nothing like that in the Wormit Foundry?—No.

6047. Suppose that would make it run thick and sluggish?—Yes.

6048. Good Scotch metal flows readily and thinly?—Yes.

6049. Is it the case that lively metal fills the mould all the quicker, and then you have a more gradual cooling all round?—Yes.

6050. With sluggish metal rising up the sides of the core, it has more time to cool, and is more apt to produce what is called a cold shut?—Yes.

6051. Did you see any signs of a cold shut in any of the columns that you cast?—No. I never paid any attention to that.

6052. Did you see any signs of scabbing?—Plenty.

6053. From the inequalities of the surface on the outside?—Yes.

6054. How were these inequalities taken off?—By chipping by a chisel.

6055. If there was a scab on one side of the column what effect would it have on the opposite side of the column?—It would make it thin of course.

6056. The metal that should have gone to the top of the core was detained at the bottom just in so far as the scab would return it?—Yes.

6057. And the sand that was scooped out to make the scab float on the top of the metal and either made the metal thinner there, or mixed with the metal, which did it do?—It mixed with the metal, it mixed with it like a dander (a kind of impurities cinder).

6058. Of course that would not be as strong to resist pressure or weight as pure metal?—No.

6059. Scabbing is a well-known risk in moulding; it is a thing that you provide against?—Yes.

6060. What was done with these scab columns?
which were chiselled in the way which you have described?—Just the same as with any other moulds.

6058. But what use were they put to after the chiselling?—For the bridge.

6059. Did you see them sent away with the others for the bridge?—No, it is not my business to see that, but I know they were going there; they would not have been chipped if they had not been for that.

6060. They were chipped and put out of the moulding shop for the purpose of going to the bridge?—Yes.

6061. And for anything you know they went to the bridge?—Yes, for anything I know.

6062. Were there a great many columns scabbed that you saw?—They were of frequent occurrence.

6063. If all those had been broken up, or put aside, I suppose you would have been aware of that?—Decidedly.

6064. And so far as you know, was anything of that kind done with them?—I never saw our broken up.

6065. Nor laid aside?—No.

6066. But they were put out of the shop as part of the columns that were to go to the bridge to form the structure?—So far as I know.

6067. Now those columns had flanges and lugs?—Yes.

6068. And according to the original mould the flanges and the lugs should have come out as part of the original casting?—Yes.

6069. Did you always get out your casting with the lug on?—So far as I know.

6070. Did you ever see any lug burnt on?—Not that I know of.

6071. You know the process of burning a lug?—Yes.

6072. If a lug was burnt on would it be able to stand the same strain as a lug that had formed a part of the original casting?—No.

6073. You require to damp your mould?—Yes.

6074. What water had you for damping your mould at Wormit?—Salt water, water out of the river.

6075. There was a large tank with a pumping apparatus to bring the water of the Tay up for the purpose of the foundry?—Yes.

6076. And that was the only appliance I understand that there was there for bringing water in large quantities to the foundry?—It was the only water that I used, except for drinking.

6077. And that water that you got from a well near by?—Yes.

6078. Would the well have supplied sufficient water for the purpose of the moulding shop?—No, I do not think so.

6079. But in point of fact you used the water from the river Tay, which was pumped up for that purpose?—Yes.

6080. I suppose you were told to get your water there?—Decidedly.

6081. By whom?—By the foreman.

6082. Had you ever used salt water for damping your moulds before?—Never.

6083. Was it as good as fresh water?—I do not think so.

6084. What was peculiar as a result from the use of salt water?—It would make the mould hard.

6085. And it would make the core hard?—I had nothing to do with the core, you know, I had only to do with the moulding.

6086. And making it hard, the gases that rise from the contact of the molten metal with the damp sand would not escape so readily?—Not so readily.

6087. And if those did not escape, would they produce what you know as air bubbles and scabbing?—Yes, and they might produce blow holes too; the mould will not lie upon it.

6088. Did you see anything on the columns that you cast which indicated that salt water was having that effect upon them?—That scabbing.

6089. Did you see anything beyond the scabbing?—No.

6090. What did you do for the purpose of letting the air or the gases escape?—By using something as we call a pricker, and putting it through below the mould.

6091. I suppose the pricker would not go as freely through a mould made damp with salt water as through a mould damped with fresh?—According to the time it was in; if it was in as long it would go as freely, but after a little it goes hard.

6092. I suppose if you left it in a long time you would have a distinct channel?—Yes.

6093. But if you merely pushed it in, and withdrew it again, it was not so likely to leave a free exit for the gas as in softer material?—No.

6094. Was any bad smell perceptible from the use of the salt water?—A very bad. We had to go about, some of us, with both our mouth and our nose tied up with a napkin to keep it out; in fact, when first I started I had to leave the shop for it.

6095. Were the holes in the lugs moulded or drilled?—Moulded.

6096. And in the flanges?—They were bored so far as I know.

6097. There was a drilling apparatus in the shop?—Yes.

Cross-examined by Mr. Balfour.

6098. You told us you were unable to mention the time that you went there first. Who was the foundry moulder when you went there first?—Mr. Ferguson.

6099. Was he the foundry moulder on the second occasion you were there also?—Yes.

6100. So that both of these times were after Strachan had left?—Yes.

6101. Apparently you do not know into what part of the bridge the columns that you cast were built?—No, I paid no attention.

6102. You being there only about six weeks altogether?—Yes.

6103. How many columns may have been cast in these six weeks?—I could not say; there were two cast every day, but you can count for yourself; I have not made the calculation.

6104. Do you mean in the shop altogether?—No, by the squad that I was working with.

6105. How many were there in your squad?—Three, I think it was.

6106. How many were there in others?—I could not say. I did not pay any attention to any but my own business.

6107. So that you do not know, and would rather not give any opinion, as to how many were cast during your time?—No.

6108. You spoke about this nasty seam; was that quite visible to anyone who was going about the shop and seeing the casting?—To anybody.

6109. You spoke also about the cold shut; did I rightly understand you to say that you did not see any signs of a cold shut in any of the columns that you cast?—I never spoke about that—I said "not observe it."

6110. Did you see a cold shut in any of the columns that you cast?—No.

6111. Can you ever see the signs of a cold shut on the outside of a column?—Sometimes.

6112. That is an imperfect junction which could be seen on the outside?—Yes.

6113. But you saw nothing of that kind in the ones that you cast?—No.

6114. Did you ever ask for fresh water to cast with when you were only getting salt?—Never.

6115. Or did you make any complaint?—Never, we used the stuff that was given to us. We had no right to complain.

6116. (The Commissioner.) You have been a moulder for a long time?—Yes.

6117. A cold shut might exist in a column without its being seen on the outside, might it not?—Perfectly.
6118. And was there a flange at each end of the column?—Yes.

6119. Would that prevent the cold shot being seen or not from each end?—Yes, at the end by the flaws it would not have been seen so readily.

The witness withdrew.

Mr. Trayner stated that Thomas Laird, of No. 2, Hunter Street, Dundee, had been summoned to attend, but that in consequence of his having received a severe burn he was confined to his bed and unable to be present.

(The Commissioner.) If there is anything to be made of that it will be desirable to have a medical certificate.

(On Mr. Balfour.) What Mr. Trayner says quite agrees with our information, that this man is suffering from such an injury.

Andrew Foreman sworn.

Examined by Mr. Trayner.

6120. You a moulder residing in Lochne?—I am a cupola man.

6121. You went to the Wormit Foundry shortly after it commenced, did you not?—Very shortly. They were beginning the first base; it was in the cast. But I have to state that I went there as a dresser at that time, not as a cupola man. I occupied both positions occasionally.

6122. After you did go, and in whatever capacity you were there, how long were you there?—About two years.

6123. You sometimes worked at the cupola and sometimes at the dressing of the columns after they were cast?—When I went there first I went there as a dresser to dress the columns. After that I went to the cupola.

6124. Dressing is doing what?—Taking the sand off, and what we call the fins (that is to say, the rough places on the castings), preparatory to their going into the lathe to be turned.

6125. The cupola is the furnace in which you melt the iron for the purpose of casting?—Decidedly.

6126. Before I come to the cupola work tell me this, in your drawing of the column did you include as if the base planed?—Yes.

6127. Frequently?—Very frequently.

6128. And how did you remove the fin or scab?—We chiselled them off and supplied the place with putty or such as that, or perhaps cement.

6129. You chiselled off what was an excrescence, and then if there was any hole made you filled that up with cement or putty?—Yes.

6130. Was that frequently done?—Very frequently, in fact there was cement there for the express purpose of doing that.

6131. A supply of cement?—Yes.

6132. What kind of cement?—Roman cement.

6133. Who was the foreman at that time?—I was under both Strachan and Ferguson.

6134. While you were dressing?—Strachan was gaffer or foreman there first, and then he left and Ferguson came in his place, and James McGowan, who was examined here to-day, was in the interval between the two.

6135. He had charge of the moulders until the new foreman was appointed?—Decidedly.

6136. I suppose the foreman knew that cement was there?—Oh yes.

6137. And for what purpose it was being used?—Decidedly.

6138. Do you know anything about moulding yourself?—No, I cannot say that I do. I have never been engaged in that capacity.

6139. Were you principally engaged as a dresser, or in the cupola?—Well, I have been at them both very often, but my principal job was a cupola man.

6140. I understand that into the cupola you put manufactured iron with combustible material, so as to reduce it to a molten state?—Yes.

6141. But you do not put any iron into it except manufactured iron?—Manufactured iron.

6142. (The Commissioner.) Do you mean pig iron?—Yes.

6143. Not worked iron?

6144. (Mr. Trayner.) Not worked iron and not ironstone, but pig iron. What kind of iron was melted in the cupola while you were there?—Middleboro' iron, so far as I know.

6145. What was its quality?—Very bad, I consider.

6146. How did that show itself?—It showed itself in this form, to my mind, that after it was melted there was a terrible lot of refuse into the top of the ladle, and we could never get done with that. I have tried to melt that refuse again and I could not do it, it was full of rubbish.

6147. When that refuse rose to the top of the iron was scraped off, could you by puddling or any other way get rid of it?—The more you puddled the worse it was.

6148. So that this rubbish, as you call it, was all through the iron, and could not be got separate from it?—No, not so far as we could do it.

6149. I suppose you have seen good Scotch metal united?—Oh yes.

6150. Did the metal that you melted at the cupola differ from good Scotch metal with reference to the scum?—Greatly.

6151. In good Scotch metal the scum rises to the surface, and when ladled away leaves the metal behind clear and lively?—Yes.

6152. With the iron used at the Wormit Foundry the scum never got clear away, and remained sluggish?—Yes, always sluggish.

6153. Do you remember, when McGowan was superintendent between Strachan's dismissed and Ferguson coming on, his speaking to you about some base plates?—I do.

6154. They were lying near the cupola?—Yes, nearly opposite the cupola.

6155. And what kind of iron were they?—We considered it good iron. We could not say whether it was Scotch or not, because you cannot determine that very easily after it is in the scrap form.

6156. But you thought it was Scotch?—Yes.

6157. What quantity of it was there?—Well, I could not say exactly the quantity. There were some tons of it lying on the head of the brace.

6158. Did you get any orders from McGowan about it?—Yes.

6159. What were they?—To mix a lot of that scrap amongst the English pigs to improve it.

6160. Did you do so?—We did a little. I would say 10 or 12 cwt.

6161. You did not put it in all at once, I suppose?—No; just with different charges.

6162. Did it, so far as you can judge, improve the quality of the iron?—We considered so.

6163. Did it show more life and less scum than when it was unmixed?—It had a sharper tendency, and was a better class of iron, we thought.

6164. Why did you not go on to fulfil McGowan's instructions, and use, up the whole of that iron?—Because we were stopped.

6165. Who stopped you?—Mr. Beattie.

6166. Who was Mr. Beattie?—He was manager over that department at that time.

6167. Why did Mr. Beattie stop you?—Well, the only reason that I heard him assign not to melt that was this, that he would bring iron from Middleboro',
and that would sell better after the bridge was finished.

6218. And accordingly you did not melt any more of it, but left it there?—Yes.

6219. And left it there, I suppose, when you left the works?—It was lying there when I left.

6220. And it had lain there, without being put to any use, for how long a time?—Well, I could not say exactly, but as far as I understand—

6221. But how long were you there?—I was there nearly two years.

6222. And was it lying there all the time?—Yes.

6223. With regard to these columns which were defective through striking, could you form an opinion as to what led to that?—That was not my capacity.

6224. You do not know whether it was the fault of the mould or of the coke?—No; I am not a moulder.

6225. I suppose it was coke you used in the cupola?—Yes.

6226. What kind of coke was it?—Well, I consider it inferior.

6227. Inferior to coke that you had used at other places?—Yes, it was sulphur.

6228. In what did its inferiority consist?—In the sulphur.

6229. Was it more charged with sulphur than coke that you had used in other cupolas?—Yes, generally speaking.

6230. I suppose most coke has some sulphur in it?—Yes, there is sulphur in all coke.

6231. But did this seem heavily charged with sulphur?—Yes.

6232. From the fumes that it gave off?—Yes.

6233. Could you see that by the flame that came from it?—The flame is the only thing that you can tell it by.

6234. But you did detect it by the smell?—Yes.

6235. What water was there for the moulder to use?—There was the Tay water.

6236. There was a large tank there?—Yes.

6237. With appliances for pumping the water from the river into it?—Decidedly.

6238. There was also a well near at hand?—Yes, not far distant.

6239. What supply of water did that yield?—It was not a large supply.

6240. Anything like enough for the moulders?—I would not think so.

6241. I suppose it was used chiefly for cooking purposes or drinking purposes?—Yes, generally.

6242. Did you know that it sometimes ran dry?—I have seen it nearly dry.

6243. But the tank and pumping apparatus was part of the original construction of the foundry?—Yes.

6244. And I suppose you judged from seeing that it had been put up there originally, from its appearance, for the purpose of supplying the necessary water from the river?—Yes, the tank was there for that very purpose, I believe.

6245. And was it used for that purpose?—Yes.

6246. All the time you were there?—Yes.

6247. The Tay water is salt water?—Salt water.

6248. At Wormit it is always the more or less salt?—I would say so.

6249. And at high water it is very salt?—Yes; very pregnant with salt.

6250. Not distinguishable from sea water?—No.

Cross-examined by Mr. B Alyvout.

6251. Were you at the foundry both in Strachan's time and Ferguson's time?—I was.

6252. How long were you there in Strachan's time?—Well, I would be there nearly eighteen months.

6253. And how long were you there in Ferguson's time?—Not so very long; I would say about six months.

6254. You cannot give the particular year, but that enables us to get it?—Yes.

6255. Were you chiefly working at the cupula, or were you chiefly dressing the columns in Ferguson's time?—I was on the cupula all the time with Ferguson.

6256. You were doing nothing else in his time except working at the cupula?—No.

6257. Ferguson was the man over you—your superior—was he not?—Yes, he was.

6258. Had you any instructions from Ferguson as to putting in a certain proportion of scrap iron with the Middlesboro' pig?—Not that I remember.

6259. Was there any scrap iron lying about?—Yes.

6260. Plenty?—Yes, plenty.

6261. The plan of the bridge had been changed, had it not?—So far as I heard, it was.

6262. Did you not find there the caissons which were intended to have lined the pillars?—Yes.

6263. And that was broken up into scrap?—Yes.

6264. Scotch scrap?—I could not say what it was.

6265. Scrap iron?—Yes, scrap iron.

6266. Did you not receive instructions from Ferguson to put in two of pig and one of scrap?—No.

6267. At any time?—No.

6268. On any other proportions?—No other proportions.

6269. Did you say that at no time did Ferguson ever instruct you to put any proportion of scrap iron into the pig?—I never got any instructions of the kind from him.

6270. Did you ever put any scrap up with the pig except on the occasions that you have spoken to?—Yes, I have.

6271. Did you do that at your own hand?—Yes; it was lying there, and we just did it to our own minds.

6272. Did you not know it was there intended to be melted and used?—We understood that.

6273. Then during the time that you were working at the cupula did you regularly put in a proportion of that scrap with the pig?—Generally we did.

6274. What proportion?—Generally about one-third.

6275. Was it not rather more?—No.

6276. Then you did that merely at your own hand, and did it regularly all the two years?—Well, I could not say for the whole two years; there was a while that we had no scrap.

6277. When was it that you had no scrap?—That was in Strachan's time.

6278. How long had you run out of scrap in Strachan's time?—I could not say exactly.

6279. How long had you been using scrap before you ran out of it?—I could not tell.

6280. Was the reason that you ran out of it because you had used it all up in melting for the columns?—There was none to be got at that time.

6281. I know that; but you said that you had it at first, and that then you ran out of it, was the reason why you ran out of it for a time because you had used it all up in melting for the columns all that was there at first?—After Ferguson came the scrap came from the jetty. After the orders were given by Mr. Beattie to drop it, Ferguson broke it up that scrap, and then we commenced to melt it again.

6282. See if I rightly understand you. I thought you said that during Strachan's time you had used scrap for a certain period, and you ran out of scrap, there being no more to use?—Not in Strachan's time; there was no scrap at all in Strachan's time, or very little. At the time that McGowan came he wanted to introduce this scrap among the pig, and he was stopped by Mr. Beattie.

6283. Except the time that you were proposing to use it, when Mr. Beattie stopped your using it, did you use no scrap in Strachan's time?—Very little.

6284. Did you then use some during the whole of Ferguson's time?—Yes, all his time.

6285. In the proportion of about one-third?—In the proportion of about one-third.

6286. What part of the bridge were the columns
put into that you made in Strachan's time?—They were commenced with the centre portion before I left.

6236. That was in Ferguson's time, was it not?—Yes.

6237. What part of the bridge were you putting the columns into that were cast in Strachan's time?—It was the small columns, not the large columns.

6238. Is not that the columns that are standing yet?—Yes.

6239. So that all that were cast in Strachan's time are standing yet to be seen?—I would say so.

6240. And is it the columns that were cast in Ferguson's time with one third of scrap that were put below the big girders that have gone down?—Both kinds were cast in Ferguson's time, both the big and the small columns.

6241. At all events they had always in Ferguson's time one third of scrap?—Yes.

6242. And that was the scrap that was brought up from the changed plan of the bridge?—Yes.

6243. Do you recollect in Ferguson's time any defective castings coming out which you were told to break up?—Yes; I broke up some defective castings in his time.

6244. By Ferguson's order?—Yes.

6245. Was it not Ferguson's custom whenever any casting came out defective to direct it to be broken up?—Generally.

6246. And you did it accordingly, and put it through the furnace again?—Yes.

6247. You say generally?—Yes.

6248. What defective casting did you ever see in Ferguson's time that he did not direct to be broken up?—I have seen, as I have already stated, the blistered columns filled up with cement.

6249. Was that in Ferguson's time?—Oh yes.

6250. You were not a dresser at that time, were you?—No; but I have seen it done.

6251. Let us understand about this cement; what place was cement put into?—Well, I have seen it put into about the centre of the column generally.

6252. Was that where there had been a scabbing?—That is what we call a blow, or a blister.

6253. Did Ferguson see it done?—Yes.

6254. Did he give any directions on the subject?—I could not say, but it was done, and he was there as gaffer.

6255. And saw it?—And saw it.

6256. How often was it done?—Well, I could not tell how often.

6257. Who did it?—Them that was working at the columns.

6258. Not you?—I have not done it under him, but I have done it under Strachan.

6259. When you were acting as dresser?—Yes.

6260. Can you give the names of any of those whom you have seen filling up a blister with cement?—I can give you one, John Tasker.

6261. Where is he?—I could not say where he is working just now; he is about Dundee somewhere.

6262. Can you give me any other name?—No, that is the only one I can remember just now.

Re-examined by Mr. Trayner.

6263. Was the iron still sluggish and full of scum after you had mixed it with the scrap?—Not so bad.

6264. But was it even then at its best equal to good Scotch metal?—No, nothing like.

6265. What scrap had you in Strachan's time?—It was generally from the jetty.

6266. Do you wish to break up columns?—No, I mean broken base plates.

6267. What iron had they been made of?—They were said to be of Scotch iron, but I could not tell.

6268. Had you much of that in Strachan's time?—A good deal.

6269. Did you use it in his time?—Yes.

6270. Was any part of the scrap that you used for mixing composed of the broken up columns?—When we broke up bad columns we had to do them over again.

6271. Then you mixed it with Cleveland iron to go into the new castings?—Yes.

6272. Was that done often?—It was done as often as we had bad ones.

6273. As often as you had broken columns which you were told to use as scrap you mixed them with Cleveland iron in the cupola?—Yes, we melted them over again.

6274. Was the iron used in those columns at its best, what you would call lively?—No, I could not say that it was not lively.

6275. Was it so sluggish as to make scabbing probable, or cold shots probable?—I could not say—the effect was whatever effect the mould might have upon it.

6276. Can you tell me why Mr. Beattie ordered you to refrain from mixing up the base plates lying at the cupola and none lying at the jetty?—I cannot tell.

6277. Do you know why you were not allowed to use the base plates nearest at hand?—I do not. I expect it was by his instructions; they were used after Mr. McGowan got in power between Mr. Ferguson and Mr. Strachan; he used them until he was stopped in doing it.

6278. You said that some of the scrap mixed with the Cleveland iron was the plates that had come up from the jetty?—Yes.

6279. If you were to mix base plates with Cleveland iron, do you know why it was that you were forbidden to use base plates of the same kind that were lying near the cupola, and allowed or ordered to use base plates that had to be brought from a distance?—I do not know what was his reason. I cannot tell.

6280. As far as you saw, was there any reason for not using the base plates nearest at hand if the base plates to be raised up at all?—No reason.

6281. You were asked if this scrap that you used were Scotch scrap, could you tell that?—I could not tell.

6282. For anything you knew it might have been Cleveland scrap?—For anything I knew.

6283. (Mr. Balfour.) Is there so little difference between the two that you cannot tell one from the other, even when they are broken up?—No; you cannot tell very easily.

6284. (The Commissioner.) As I understand the whole scrap that you used during Mr. Strachan's time was from base plates broken up, was that so or not?—Yes, it was.

6285. That was the only scrap you did use there?—Yes.

6286. Nothing else?—Nothing else.

6287. Then it was all used before Mr. Strachan left, was it?—No.

6288. It was not all used up?—No.

6289. Was there any time when you had no scrap?—Yes, there was awhile we had none.

6290. When was that?—In Mr. Strachan's time generally.

6291. Not towards the end of his time?—No, there was none forthcoming from the jetty.

6292. After Mr. Ferguson came there you always used scrap?—Yes.

6293. And not those base plates that were used during Mr. McGowan's time?—I do not know whether they were the same or not.

6294. At any rate that which Mr. McGowan was using remained there after you had left?—Yes.

6295. (Mr. Harlowe.) Were you employed by Messrs. Gilkes & Co.?—It was from Mr. Strachan that I got the job.

6296. For them?—Yes, under Strachan.

6297. Perhaps those base plates that you speak of as being broken up had been cast in the same foundry?—No.

6298. Where did they come from?—I cannot tell.

6299. Had there been anybody at work there before
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who had made those base plates?—They were not cast in the foundry over there.

6300. Were they cast by Mr. de Barge, who had the first contract?—I cannot tell you where they were cast. I don’t know.

6301. You do not know whether they were

considered better metal than what you cast?—I could not say.

6302. (The Commissioner.) Was there any other supply of scrap iron from any other place, except the jetty brought to the foundry?—No.

6303. Only from the jetty?—Just the jetty.

The witness withdrew.

After a short adjournment:

David Hutton sworn.

Examined by Mr. Trattner.

6304. You are a moulder?—Yes.

6305. And reside in Dundee?—In Lochee.

6306. Were you at the Wormit Foundry when the bridge was being built?—Yes.

6307. How long were you engaged there?—Between two and three years.

6308. Were you there at the beginning of the castings?—No.

6309. They had commenced before you went there?—Yes.

6310. Were you there at about the end?—Yes. I was there till the end.

6311. Were you engaged in casting the columns?—Yes.

6312. What kind of iron was used?—It was very bad iron, I thought.

6313. What induced you to think that; what showed its bad qualities?—The bad scum it raised on it.

6314. Did you get rid of that?—No, we did not; we simply brought it off, and when we turned up the iron it gathered again.

6315. Pudding it only brought up more scum?—Yes.

6316. You never could get rid of it entirely?—No.

6317. It was sluggish?—Yes.

6318. I suppose it was affected by the scum that was always in it?—Yes.

6319. Scotch metal gets clear sometimes, and then it is lively and flows rapidly?—Yes; Scotch metal after it has been once skimmed and cleaned off remains clear.

6320. The columns that you helped to cast, had they flanges at both ends?—Yes.

6321. Had they lugs on them for the rods?—Yes.

6322. Did those lugs always come out of the mould on the columns?—Yes.

6323. Have you never taken a column from the mould when the lug was not on it?—We have taken out columns with the lug blown, or blown hollow in the lug.

6324. What was done with the lugs?—They were burnt, and another was burnt on. If a bit of it went, it was burnt on.

6325. If a lug or a bit of a lug was burnt on, would it be as strong as if it had been part of the original casting?—It would have been as strong as the original casting, but then it generally cracked at the side.

6326. Could you hold the original casting without — No, it generally cracked at the side.

6327. Did you see any cracks like that?—Yes, there was never a column with a bit of lug burnt on, but what was cracked.

6328. Had you ever to put in these bits of lugs?—I could not say how often.

6329. Will you tell me whether it was frequent or rare?—It was very frequent.

6330. Are you aware that sometimes the lugs that were on the columns got knocked off?—Yes.

6331. Accidentally?—Yes.

6332. Were new lugs burnt on in the same way, as you had put on to those columns?—Yes.

6333. In these cases also, did you see a crack between the lug and the flange?—Yes.

6334. Was the burning on done very carefully so far as you saw?—Yes.

6335. Still they could not make it as close as the original casting?—No, I do not think they did.

6336. So far as you saw, they never did?—They never did. If they made it as secure as the lug itself, the column was generally cracked.

6337. If the lug was secure, the column got cracked. What cracked it?—I suppose it was the hot iron going on the cold body of the column.

6338. Was the column heated at all before this new metal was poured in?—Yes, it got heated.

6339. But it was nothing like the heat of the new metal that you poured on?—No, it was not heated as it ought to have been.

6340. It was not very carefully heated?—No, I do not think so.

6341. The column could have been made hotter than it was?—Yes.

6342. The hotter it was made the more likely the new metal was to adhere?—Yes, exactly.

6343. And the less likely to crack the column?—Yes, exactly.

6344. Did those columns with the lugs burnt on them go down to the bridge?—I expect so, I cannot tell; but I expect they went there.

6345. They went out of the shop, so far as you know, to be used at the bridge?—Yes.

6346. You do not know of their being used for anything else?—No.

6347. They were not broken up?—No, they were not broken up.

6348. Do you know what scabbing is?—Yes.

6349. Did you see any column cast in your shop that was scabbed?—Yes, very frequently.

6350. How did you get rid of the scab on the columns?—Chipped it off with a hammer and chisel.

6351. I suppose that would sometimes leave a hole;—The sand would float on the top side.

6352. I quite understand that, but what I mean is this, after you had chipped away the scab from the outside, did that leave any hole?—No, it left no hole.

6353. The sand that was floated off the scab inside the mould would rise on the molten metal to the top side of the column, would it not?—Yes.

6354. And would there mix with the metal?—Yes.

6355. And reduce its strength for resisting pressure?—It is bound to do so.

6356. Did you see any Roman cement about the foundry when you were there?—Yes; a great deal.

6357. What was it there for?—I have seen them fill up a hole in the column with it, and the like of that.

6358. What holes?—Those were the scabs from the sand rising to the top of the column; it was part of the sand lodged.

6359. In the scab or place where the sand rose to the top of the column when it came out of the mould, did it show any holes?—Yes; it showed a space where the sand lodged at all.

6360. And that showed on the top surface of the column?—Yes.

6361. Those holes were filled up with cement that was taken for the purpose?—Yes; piles of cement and piles of putty.

6362. Were those painted over?—Yes.

6363. Did you see that done often?—Yes; it was very frequent.
6364. I suppose the foreman must have known it was going on?—Yes.
6365. Everybody knew it in the shop?—Yes; everybody knew it.
6366. What was the size of the diameter of the pipes that you cast?—Both sizes. There were only two sizes, and I cast a part of both—both the 15 and 18 inches diameter.
6367. What was the thickness of the sides?—An inch.
6368. Both of them?—Yes.
6369. An inch thick?—Yes.
6370. Do you remember two big girder girders falling in 1877?—Yes, I do.
6371. Some of the columns that fell were brought back to the foundry, were they not?—Yes.
6372. Did you see them?—Yes.
6373. What was their thickness?—There was some of them of different thicknesses—they varied on the one side from the other.
6375. What did that arise from?—They were thin on one side.
6376. What was the thickest side?—The top side.
6377. What was its thickness?—I think somewhere about five-eighths.
6378. Where it was five-eighths of an inch thick on the top what was the thickness on the corresponding outside?—There was a corresponding thickness of the bottom side—it may be an inch and three-eighths or an inch and three-quarters.
6379. In short, the iron was more on one side than it should have been, and less on the other side than it should have been?—Yes.
6380. That is the result of scabbing, is it?—No, that is not the result of the scabbing—it was the core rising through the centre of the column.
6381. In good moulding should not the core have been kept down firmly by pins?—Chaplets.
6382. Were those used in the casting which you have been upon?—There were no chaplets used at all.
6383. Was there anything to prevent the core being displaced or floated?—We wedged in the core from the ends.
6384. How did you wedge them down from the ends?—The boxes were screwed with bolts, and then we wedged the cores to the boxes, and so we raised the boxes and all.
6385. When you were there, although you did not use chaplets, you used means to secure the steadiness of the cores?—Yes.
6386. So far as you know, was there any defect in any of the columns that you cast from the floating of the core?—No, we could not tell before it was broken up.
6387. Did you do your best to secure the core?—We did.
6388. Were there many of the columns that fell in 1877 unequal in their thickness?—Yes, there was a good few.
6389. Were you in the works at the time that those columns were cast?—I cannot say.
6390. Was that fall in 1877?—I cannot say.
6391. Was the same general system of casting carried on from the time you went until the time you left?—Yes; the pattern was sent from Middlesborough, and we just made them as we had orders to do it.

Cross-examined by Mr. Balfour.

6392. Had you anything to do with putting the metal into the cupola?—Nothing.
6393. Perhaps therefore you do not know what was put into it?—No; I cannot tell.
6394. You do not know whether there was Scotch scrap put in along with the Cleveland or not?—No; I do not know.
6395. You spoke about the lugs being burnt on; when they were burnt on in that way were the cracks quite visible?—Yes.
6396. To anyone looking?—Yes.

6397. Were you casting there in Mr. Strachan’s time; and in Mr. Ferguson’s time also?—No, it was not in Mr. Strachan’s time; it was all in Mr. Ferguson’s.
6398. How long did you come after Mr. Ferguson?—I went there about the time that Mr. Ferguson went, and I remained up to the end.
6399. Mr. Strachan had gone also before?—Yes; I was about a fortnight with Mr. Strachan, but the time I was with him is not worth speaking of. There was no casting at the time I was with him, and I left and came back again when Mr. Ferguson started.
6400. I think you have told us about this scabbing, that the scabbing does not create an inequality in the thickness; it is where the core rises that it happens?—Yes.
6401. When you dressed off the butt which had been made unequal by the scab, did you simply dress it down so as to be of the thickness it had been intended to be?—I expect we did, but I had nothing to do with dressing the columns, but I expect that they did that.
6402. Then you did not dress them?—No.
6403. Did you see them after they were dressed, after they were painted?—Yes.
6404. You did not see them after they were dressed and before they were painted?—I might begin to look at them, but I paid no particular attention.
6405. You spoke about the ones rising; there were no chaplets used in your time?—No.
6406. Do you know whether the core bars were thickened in consequence of the chaplets having been found to be attended with some mischief?—Mr. Ferguson made thicker core bars when he went there.
6407. Why did he do that?—I expect it was from the former ones yielding.
6408. Was it not because the chaplets had made blow holes in the bad metal?—Yes.
6409. It had been tried and given up, had it?—I cannot tell you that.
6410. What was the effect of thickening the core bars?—Just to keep it from heading and from rising.
6411. And to keep it stiff and in its right place?—Yes.
6412. Did that thickening of the core bars not keep them stiff and in their right place?—I cannot tell for that.
6413. Do you not know whether they were stopped in the right place or not?—No.
6414. They may have stopped in the right place?—Yes; or they may have risen.
6415. You cannot say that the pipes or columns that you cast were not equal in thickness all round?—No.
6416. They may have been?—Yes.
6417. Your answer about the inequality in the thickness applied only to the broken columns brought in from the jetty?—Yes; I could not see anything but what was broken up.
6418. Do you know whether the ones that had been broken up had been cast before the core bars had been thickened?—I could not tell.
6419. Was Mr. Ferguson overlooking all that, you were doing?—Yes.
6420. You said something about Roman cement; where did you get it?—There was a lot lying about the engine house and there was plenty about the jetty, it was easily gotten.
6421. What was it at the jetty for?—For building the pier with.
6422. Not to fill up the holes in the pipes?—No, there was not sufficient for that.
6423. Did you moulders just go and help yourselves to a little?—We filled up the holes—the dressers did that.
6424. Did the dressers help themselves to a little?—Yes, exactly.
6425. Then just tell us the names of some of the dressers who took this cement?—I cannot exactly say, but there was two or three of the dressers there.
6426. Did you see any of them take the cement?—I have seen cement put into the holes.
Examined by Mr. Trayner.

6483. You are a boiler maker in Dundee, I believe?—Yes, I am.

6484. You worked at the making of the Tay Bridge for some months before the opening of it?—Yes, I did.

6485. For how long?—About six months.

6486. What was your particular work during those...
six months? — General work; sometimes we were just putting on the bolts or junctions connecting two girders together.

6487. You were putting together the work that came from Worgan in sections? — Yes.

6488. How did you fasten them together? — By plates put on.

6489. What were you fastening together by plates? — The girders.

6490. How did you fasten the plates and the girders together? — They were put on to the top heme (pointing to the model).

6491. Were you bolting them or rivetting them? — Bolting them.

6492. Were the bolt holes drilled? — They were all made before they came to us.

6494. How did you fasten the bolt when you put it in? — They were screwed, but they were afterwards rivetted; they were only just put on for service bolts.

6495. And you removed them and rivetted the plates on the girders? — Yes.

6496. Where was this done? — On the beach; on the bridge.

6497. The rivetting? — Yes.

6498. You had bolted them on the beach, had you? — No.

6499. Was the whole of the rivetting that you saw well done? — I have seen bad rivets; as a matter of course, in every job there are bad ones, but they are afterwards repaired.

6500. What was bad about the rivettng? — A little slack it sounded by the hammer.

6501. Was that from careless rivetting, or from what cause? — Most from careless work.

6502. Where those rivets had been carelessly put in, was it way and were slack. I suppose the strength of that part of the work was all the less? — Most decidedly.

6503. Can you say that every one of those defective rivets was put right as far as you saw? — Yes, as far as I saw; the inspector went over it with me.

6504. What inspector? — Mr. Macbeath, for the North British Company.

6505. You were under him? — Yes; Mr. Campbills was the manager, and Mr. Loudon was under Mr. Campbills.

6506. Mr. Campbills was head man of that department, but Mr. Macbeath was the man over you from whom you took your orders? — Yes.

6507. When did Mr. Macbeath come there as inspector? — I think about the June month, if I remember rightly.

6508. It, what year? — In 1877.

6509. Was that before or after the high girders fell? — It was after that.

6510. Do you know whether that had anything to do with his being brought there and put on as inspector? — I don't know anything about that.

6511. Was the work more carefully done after he came? — He seemed to have a check upon the men; he was very particular in looking after the work; it seemed to be a check upon the men; they seemed to talk about the inspector and that.

6512. The men seemed from their talk to be more careful of their work, because the inspector was there to find them out if anything was wrong? — Yes.

6513. Were the men paid by the piece or by the hour? — Some part of the men were paid for the piece and some by the hour.

6514. How were the rivetters paid? — The rivetters were sometimes working piece work and sometimes time work.

6515. As far as you saw, was there any plate used on the bridge, or any rivetting done on the bridge, that was not efficient? — None that I saw or heard of were not efficient.

6516. What you had noticed before as being carelessly done was put right after Mr. Macbeath came? — Just so.

6517. How did you remedy a loose rivet? — By taking it out and replacing it.

6518. I suppose, as you were only there six months, you can only speak to a comparatively small part of the work. — We went after we were done with our work generally over the whole of the bolts of the columns from the south to the north end of the high girder, taking out any bolt that had been put in as a service bolt and forgotten to be taken out, replaced it, and caulked all the nuts and stopped them from working off the bolts.

6519. Did you leave any bolts in bolt places? — Any bolt that was used in that way was taken to the surface of the bridge and left there.

6520. Did you in your inspection find some service bolts that had been left there where a rivet should have been put? — No.

6521. I thought you said that you did find such bolts? — In bolt places.

6522. Did you tighten up the whole of the nuts on those bolts? — Yes.

6523. As far as you could see, the bolting and the rivetting were efficiently done? — Yes.

Cross-examined by Mr. BALFOUR.

6524. In putting together the girders were they screwed together for a time with bolts and nuts until they could be permanently fastened with rivets? — Yes.

6525. Then when they had to put in a certain number of rivets did they take out the service bolts and put rivets into the holes where the service bolts had been? — Yes, just so.

6526. So that when the girder was completed it was held together by rivets only? — Yes.

6527. In the case of the columns again, were bolts permanently used? — Yes.

6528. So that when you had done with the girders, they were all rivetted? — Yes.

6529. When the service bolts had done their work they were just left about? — Yes, sometimes they were left about until when they had a sufficient number to take to the south side.

6530. When the rivetters were going on taking out the service bolts and putting in rivets, did they just fling them down on to the bridge? — Just into the booms.

6531. Was it your duty as foreman of the rivetters to go over their work and check it? — Yes.

6532. And you did so? — Yes.

6533. And wherever a rivetter had left a loose rivet you made him put it right? — Yes.

6534. Was that just the kind of thing that you find rivetters are apt to do in any case—are you always apt to find that the rivetters leave occasionally a loose rivet which the inspectors require to be put right? — Yes; when a rivet is not closely screwed tight when it is put in, and one rivet is not exactly tight, the next rivet closes altogether a little loose.

6535. What then should be done is to come back upon the last rivet which is a little loose and tighten it up? — Yes.

6536. You saw that it was done? — All that was under me.

6537. After the last had gone over the work, did Mr. Campbills or Mr. Loudon, your superiors, go over it again? — Yes, they were always very careful and telling me to do so.

6538. Mr. Campbills and Mr. Loudon—were you in the employment of Messrs. Hopkins, Gilkes, and Co., the contractors? — Yes.

6539. After the contractors or their officials, Mr. Campbills and Mr. Louden and you, had done the work, did Mr. Macbeath check it for the company? — Yes.

6540. To see whether they would take it out of your hands? — Yes.

6541. Then anything that Mr. Macbeath found wrong, did he call your attention to it and get it put right? — Yes.
6542. And he also went to the manager about it?—Yes.
6543. So that the work appears to have been gone over after it was out of the rivetters’ hands at least three times?—Yes.
6544. Had you any doubt that when all of you had done with it, it was quite right after it had been gone over three times?—I had no doubt about it.
6545. Did you go over the part of the bridge where the high girders were?—Not on the high girders but on the columns.
6546. Was there any one officially going over the high girders in the same way that you did over the columns?—Yes.
6547. Who was he?—William Dixon.
6548. You were on one part of the bridge and William Dixon on another?—Yes, latterly when finishing up, we were both on the columns putting the bolts right.
6549. Was the whole of the bridge checked by the same foreman rivetter in the same way as you checked the bolts you have told us about?—Yes, as far as I can see.
6550. After the foreman rivetter had checked it, was all of it checked by Mr. Campbuis and Mr. Loudon and then by Mr. Macbeth?—Yes.
6551. (The Commissioner.) What was specially under your charge, the columns under the high girders?—Yes, from the south of the columns to the north end of the high girders, putting the bolts to rights.
6552. From the south end of the bridge, or from the south part of the high girders?—From the south end of the columns where the columns commenced.
6553. Did you attend to anything else besides rivetting?—Sometimes putting on plates on those junctions.
6554. Did you examine the condition of any of the columns themselves?—Yes.
6555. You did?—Yes.
6556. Did you see any of them at all damaged in any way?—I saw two I think with the lug broken, and it was replaced with malleable iron put on in its place.
6557. Did you see any columns cracked?—No.
6558. Did you see any bands round any of the columns?—No.
6559. (Colonel Yolland.) Were all the columns truly vertical, or any on the slope?—They were perpendicular, with the exception of the wrecker girder on the outside of some of the piers.
6560. Had they no inclination to the north or to the south?—I could not say that.
6561. You are not aware of any?—No.
6562. Did you look at the bolts and nuts that passed through the flanges of the columns?—Yes.
6563. Was it part of your duty to do so?—Yes.
6564. Those were all left securely screwed up?—They were all left securely screwed up and then caulked, so that they could not work off the bolts. I believe they would break before the nut would come off.
6565. Were there any cases where one column was not truly placed upon the top of the column below it?—I did not see it.
6566. You did not observe any such case?—No.
6567. (Mr. Barlow.) You said that there were one or two cases of a lug being broken off and put on by malleable iron; how was that malleable iron lug put on?—By screw bolts; what we call pincing screws. The holes were bored into the column, that lug was broken off and the holes were tapped, and the bolts screwed in through them and fastened on the lug in that way.
6568. Whereabout is that to be seen?—I do not mind where it was; I cannot say which pier.
6569. Was it upon any part of the work that had fallen down?—I cannot say. I remember it being replaced, but I cannot say at what spot it was on.

The witness withdrew.

GEORGE GOWAN.

Examined by Mr. Trayner.

6570. You are a moulder in Dundee?—Yes.
6571. And you were engaged at the foundry at Worriit, where the columns were cast for the Tay Bridge?—Yes.
6572. How long were you engaged there?—It would be about five or six months.
6573. Were you engaged all the time on the columns?—No, I was making some of the bottom bases: the tops of the piers. 6574. How long were you engaged on the columns?—I was not very long on the columns, but I saw a good many of them cast.
6575. Of what kind of iron were they cast?—Not very good.
6576. How did it show that?—It showed that in the last.
6577. The scum?—Yes, the scum on the top of it.
6578. Could you get rid of that by scraping away, or did it come back again?—It came back again.
6579. It was sluggish and slow in its flowing?—Yes; I have seen it about two inches thick.
6580. Did you see any columns that showed signs of scabbing?—No.
6581. Did you see any columns that were not of equal thickness?—No; there was none of the columns broken up; there was nothing wrong when I was there.

Cross-examined by Mr. Balfour.

6582. During the time that you were there, was the moulding done in the ordinary way, and well done?—Yes, it was well done.
6583. (The Commissioner.) How long were you engaged on the moulding?—About five months.
6584. But how long were you engaged on the columns?—I was not long on the columns; I was more on the foundation of the bases.
6585. How long were you engaged on the columns?—I just could not tell you to a day.
6586. Were you engaged a month on the columns?—About a month.
6587. And during that time were none of the columns broken up at all?—No.
6588. Not one?—Not one.
6589. Not even of those that had been cast before?—No.
6590. Nor of those that you helped to cast?—No.
6591. So that you never were able to see whether or not they were equally cast?—The columns that I was making I put chaplets on them.
6592. Had not chaplets been put before them then?—Those were the first that were made.
6593. Then you made chaplets specially for your columns, did you?—Yes.
6594. Were there other men casting columns at the same time with you?—Yes.
6595. Did they use chaplets?—Yes.
6596. Then did you make chaplets for all of them, or what?—I put chaplets on the columns that I was working on; there was two or three sizes, and I put chaplets on them all.
6597. Then there were no chaplets before that?—That was the first start on making the columns.
6598. Then you were there quite at the beginning, were you?—Yes; I was there quite at the very beginning.
6599. (Mr. Barlow.) Had you any columns with defective lugs?—No.
6600. There were none in your time?—No.
Examined by Mr. Taeurn.

6601. You were formerly examined?—Yes.

6602. And you have made up a report of the result of all your dips from the 30th of December down to the 23rd of January last?—Yes.

6603. You made up that partly before your last examination, I suppose, and partly since?—Yes; but there was one part of that that was answered in the last examination, and the remainder since.

6604. That is the report that you made up (producing a report)?—That is the report.

6605. And it contains an accurate statement of what you did, and the results?—Yes.

6606. You gave it to the railway company's agent?—That had it as well. (The report was handed in.)

6607. You remember at the last examination another diver, named Tait, having been examined?—Yes.

6608. He spoke to what he found had been the state of the girders at the first space, that is to say, between the last standing pillar on the south and the first fallen pillar?—Yes.

6609. Did you go down after Tait's examination to the place that he had described?—I went down to the end of that girder to find out the distance and give the measurement from the end post of the girders to the point of the pier.

6610. Did you find whether or not the lattice work was twisted in the way he described?—Well, it was twisted to a good extent and broken too.

6611. Did you satisfy yourself that Tait's examination had been represented by him with reasonable accuracy?—Yes.

6612. The result of your examination was to corroborate what Tait had stated?—Well, it was partly that and partly to get the position of the girder from the pier.

6613. The purpose that you went down for was to find out whether your examination would result in the same things that Tait said he found?—Yes.

6614. And also to get certain measurements?—Yes.

6615. Did your examination enable you to say that Tait had properly represented what was the state of matters at that place?—I believe it did, because at that time the water was quite dark, and the man could not see—he had to do everything by feeling—and when I went down the water was clear and I could see.

6616. But the result of your seeing and feeling was that Mr. Tait's evidence was practically correct?—Practically correct.

(Mr. Trawner.) I have examined this witness in defense to some suggestion made by the Court at the end of the last day, the 6th of January, at pages 54 and 55, and also, I am bound to say, in consequence of what seemed to be an idea on the part of one of the members of the Court that Tait's examination could scarcely be accurate; and, as the Court desired at that time to have more information upon the particular matter to which Tait had spoken, the witness Simpson was desired to go and make the examination, with the result, I am glad to say, of entirely corroborating the witness Tait.

Cross-examined by Mr. Balfour.

6617. I think you superintended or "gaffed" the painting of the bridge?—Yes.

6618. From the time when it began on the 24th of June of last year till it was over?—Yes; from the 23rd of June, I think it was, to the 4th of November.

6619. So that you went there before the first painter, and remained after the last painter?—I was there a fortnight, I may say, after the last.

6620. Did you hang all this staging for the painters to work upon?—Yes; I superintended and hung all the staging that the painters wrought upon.

6621. Besides doing that, had you any other duty on the bridge during that time?—Yes; I had to look after the varnishing of the girders, besides, I had to go three times over every girder as I went along.

6622. Did you go three times over every part of every girder of that bridge?—Yes; first I had to hang the staging; then I had to see to its being varnished, and examine the varnish work, and see that the whole of it was covered; and then I had to take down the staging—so that I had three times to go over every part.

6623. Did you make a point when doing that of looking to see whether there were any defects in the work?—Yes.

6624. Such as anything wrong with the rivets, or empty holes, or the like?—Anything of the like; and I was to report the circumstances to the inspector the very day, if I could find him. I generally met him three or four times in the week, and I reported whatever I came across. If it was ever so trifling, I thought it was my duty to do so for the benefit of the public.

6625. You had received instructions to report to Mr. Noble anything that was wrong, that it might be put right, and you did so?—Yes, I did.

6626. In going over the girders these three times did you find any empty rivet holes?—None.

6627. Did you find any holes in any of the girders which you knew to be left intentionally for any purpose?—Yes.

6628. What were those?—Holes in the lower boom to allow the water to run out.

6629. At what intervals or distances?—Well, I believe they would be about 27 feet apart.

6630. Were they just about the size of rivet holes?—Just about the size of the rivet holes.

6631. With the exception of those holes, were there any holes at all in the girders?—I came across none myself.

6632. Did you find any loose rivets?—No, I found no loose rivets.

6633a. Was Macbeath, the inspector, on the work when you were there?—Not at that time.

6634. Do you know that he had been there?—Yes.

6635. Do you know whether he had gone over the rivets and condemned a number?—Yes. I am quite well aware that he went over and condemned a great number.

6636. And that they were renewed?—They were renewed.

6637. Were the rivet heads that had been condemned and knocked off lying there?—Yes, lying there, rivet heads that had been cut off.

6638. You saw that they had been cut off?—I saw that they were cut.

6639. You saw the marks of the chisel?—Yes.

6640. And did you see sound rivets in their place?—Yes.

6641. You, being a man of skill, would have no difficulty, I suppose, in distinguishing where a rivet head had been cut off with the chisel, and where it had been shaken off by vibration?—None in the least.

6642. Did you see any of the rivet heads on the bridge which appeared to have been shaken off?—No, I did not.

6643. At the time when you were there at the painting, the bridge had been in use for more than a year?—Yes, for more than a year.

6644. And it continued in use for the six months or so that you were at work?—For four months.

6645. From June to November?—Yes.

6646. Then it had been subjected to the test of traffic for about 18 months before you left it?—Yes.

6647. Do you think that during that time any week work of this smaller kind would have been disclosed before you went over the girders?—Quite distinctly.

6648. If there had been any bad rivets or loose things shaken off?—You might quite easily see them.
TAY BRIDGE DISASTER.

6648. And there were none such — There were none such.

6649. Do you know the diagonal straps which were used in the high girders? — Yes; that is on the end posts.

6650. What were they there for? — Well, I do not know what they were there for, unless it was for strengthening or ornament.

6651. But you do not profess to know which? — I do not profess to know which.

6652. When you were there they went over to see whether any of them wanted shortening? — That is these straps here (pointing to the model).

6653. Were there small diagonal ones gone over? — Not that I am aware of. There were two that I drew Mr. Noble's attention to, and they were made fast; the rivets were out of them and he had them bolted up. I drew his attention to that.

6654. On what occasion was that? — While we were coming along with the staging.

6655. And were they put right? — They were put right the very day following.

6656. Then are you satisfied that when you took away the staging there was no loose diagonal piece? — There was no loose diagonal piece.

6657. Did those diagonal pieces carry any weight? — Not that I am aware of, unless when you climbed upon them.

6658. Did the painters use them for climbing up and down upon? — We always used them as a ladder.

6659. Were you on the bridge every day during working hours from June to November? — During working hours, and I had to go down there during a storm of wind to keep my staging right and make it fast.

6660. When it was hardly safe to paint? — The others would not go because the master would not pay them.

6661. Had you therefore an opportunity of observing the effect which passing trains produced? — Yes, I had.

6662. Will you describe what the effect was? — The only effect which ever I felt was a tremor upon the movement we in it, and it was scarcely perceptible.

6663. Was there any side to side motion? — I could find no side to side motion whatever. It was just perceptible to see the least movement backwards and forwards upon the rollers going from north to south.

6664. That is to say, at the expansion joints? — If I went to any pier and had a look at the lower boom fixed upon the roller.

6665. But there was no movement from side to side? — Not that I am aware of.

6666. Have you been there when trains of all weights passed? — Of all weights.

6667. And all speeds? — And all speeds.

6668. And wind and no wind? — Wind or not.

6669. Did you ever hear any complaints of paint pots or anything being shaken off the bridge, or off the stagings? — Never.

6670. Did the men put down their breakfast and their dinners on those things? — Yes; we have sat upon the nosing piece at the side of the bridge and taken our breakfast, and had our tin pots by our side with tea or coffee in them, or whatever it was, and when the train was passing we did not require to hold the pots, but we went on all the time.

6671. Neither you nor your tea were thrown over the bridge? — No.

6672. And the same with the victuals of your neighbours? — The same with the victuals of my neighbours.

Re-examined by Mr. Thaynh.

6673. I know you are a diver, but what were you bred to? — I was bred to be a soldier.

6674. I suppose you were only bred to be a soldier after you enlisted? — Yes, but I had fifteen years of it.

6675. What were you bred before you joined the army, had you any trade at all? — No.

6676. And you are neither a painter nor a rivetter? — Neither a painter nor a rivetter.

6677. You were over the painters for one part of the job? — Yes.

6678. On what side of the bridge? — From the north end of the bridge up to the high girders, and from the south end of the high girders to the north end.

6679. You had no charge of the men who were within the high girders? — Not over the men that were painting. I had charge of the men that were hanging the staging and varnishing.

6680. I am talking about the painters; you had no charge of the painters within the high girders? — Yes.

6681. I had partly charge of them.

6682. What part of them had you charge of? — I had charge of my own squad.

6683. How many were your squad? — I had 15 in my own squad.

6684. You told me a little while ago (perhaps it is not accurate, or perhaps I misunderstood you) that your charge extended from the north end of the bridge to the high girders, and then from the south end of the high girders to the south? — Yes.

6685. You are excluding the high girders from your own supervision in saying that? — No.

6686. Why did you come so far as the north end of the high girders, and then begin to take up your superintendence again at the south end of the high girders? — Because the two squads amalgamated at the south end of the high girders and worked north.

6687. Which side of the bridge, east or west, did you take charge of? — I had no particular side. I had to take charge of the whole.

6688. Was there no foreman there but you? — Yes.

6689. And who was he? — He belongs to Sunderland. I forget his name.

6690. Who was over you all? — Mr. Robert Bamlett of Sunderland.

6691. He was the contractor? — He was the contractor.

6692. How many more were there like you and the other foreman that you named? — Only the two.

6693. And had you equal authority? — Equal authority.

6694. When you were on the bridge from the 23rd of June to the 1st of November you were then under Mr. Bamlett for the purpose of seeing to the painting of the bridge? — Yes.

6695. And although in going over the bridge you had opportunities of seeing the state of the rivets, the painting was your chief concern — you were not there to look about the rivets? — I got instructions from Mr. Noble that if I saw any defects I was to report the case to him.

6696. But apart from what you might see in coming across a defect, in letting him know you had nothing to do with the rivets? — No.

6697. And even after you got that order or that request from Mr. Noble, you were still attending to the painting? — Yes.

6698. And reporting to him anything that you came across if you came across it? — Yes.

6699. But you were not looking for defects in the rivetting? — Well, I was looking in a sense for defects in that.

6700. Do you mean to say that from the one end of the high girders to the other you are in a position to say that you looked at every rivet in that bridge? — No.

6701. And there may have been rivet holes empty, or rivets loose that you did not see? — There might have been.

6702. I rather think you said that you did discover some defective rivets? — I found two, I said. There
were two or three in the diagonal bars and I reported those.

6703. Was it only in the case of those diagonal bars that you found defective rivets?—That was all.

6704. What did you say it was that you sat down upon your tea upon the bridge when the train was going past?—Upon the eating piece.

6705. Is it a transverse beam?—Yes, half round; it is longitudinal; it is what the hand rail is made fast to. We used to sit there and take our meal to be in shelter from the wind.

6706. Outside the high girders?—It was on the outer edge of the high girders, sitting here, as it were (pointing to the model).

6707. Outside the hand rail?—Yes, outside the hand rail.

6708. With your feet dangling over?—With our feet hanging over towards the lower beam.

6709. Did you observe there anything between your feet and the water?—No, nothing; we put our heels upon this flange here. (The witness described his position on the model to the Court.)

6710. What is the breadth of that place that you put down your tea upon?—I could not exactly say. I think it would be about nine inches.

6711. Did that happen often?—Very often, we sat there regularly, in fact, because it was out of the way of the wind.

6712. Who else sat there?—The whole of the men sat there, we put a barricade and sat there.

6713. The men took their breakfasts in the way that you have described?—We carried our meat out with us.

6714. You did observe a motion occasioned by the passing trains?—Yes.

6715. And a motion, if I understand you aright, that you could see after the train went past you?—Yes, I could see it to a slight extent.

6716. What was it that you saw after the train went past?—It was a shaking motion.

6717. But how did it shake?—Just a tremor, as I would call it.

6718. But how did the bridge move?—The bridge would move slightly north and south.

6719. Not up and down?—No.

6720. But just backwards and forwards?—Just backwards and forwards.

6721. You sitting upon the pier saw the longitudinal motion so to speak?—Yes, upon the rollers.

6722. To what extent?—I could not tell to what extent.

6723. Would the rollers be moved an inch backwards and forwards?—No.

6724. Half an inch?—No, not half an inch.

6725. How much, one-eighth, or one thirty-second, or what?—I am not very much versed in that.

6726. It seems to me rather a bold thing to say that with the naked eye, looking at that bridge, you could tell that the motion of the bridge was there, and yet that it did not exceed the eighth of an inch?—It may have exceeded more than one-eighth of an inch, but it did not go up to half an inch.

6727. Was it as much as half an inch?—I do not think it was.

6728. You think that, sitting on that pier and looking at that large structure, you could tell that the motion backwards and forwards occasioned by a passing train was not half an inch in extent?—I am certain of it on the top of the pier.

6729. But you could distinguish a motion clearly backwards and forwards?—Yes.

6730. Was there no movement from side to side at all?—Yes.

6731. You never felt any movement from side to side?—No.

6732. Some of the men were painting the bottom of the high girders on planks that were swung by ropes?—Yes.

6733. And a man standing upon that would feel very soon, would he not, the motion of the bridge if there was a motion at all?—Yes.
6761. And that you were over the men who were on the low girders, and not on the high girders at all?—Over both.
6762. Then where was the other man?—The other man was there too.

6763. But you said first that you were from the south end up to the high girders, and then from the north end of the high girders to the other shore?—From the north end out to the north of the high girders I had charge of the squad by myself, and there was another squad went from the south end of the small girders to the south end of the high girders.
6764. Over which you had no charge?—Over which I had no charge, and then the two squads were amalgamated and started at the south end of the high girders, and went to the north end.

6765. Then your time was chiefly spent, I suppose, upon the smaller girders as you had sole charge from the north end of the high girders up to the north end of the small girders, which is the longest part?—We finished up almost simultaneously together.
6766. And then you both worked on the high girders, did you?—We both worked upon the high girders then.
6767. [Mr. Barlow.] Were you ever engaged upon any other bridge but this?—No.

6768. Were you ever on a railway bridge at all made of iron, when the train passed?—Not that I can recollect.
6769. You do not know, then, how much this bridge might have shaken compared with any other railway bridge?—No.
6770. Now about this diving; you mentioned, I think, that you had been down, and found some broken lattice work. I did not understand whether that was in the first opening or in the second?—On the southernmost girder that has fallen.

6771. Between the first opening? 
[Mr. Trayner.] The first opening.
6772. There is a part of the girder opposite the second pier which is bare at low water.

6773. Then would this fracture of the lattice work that you saw have anything to do with the fact that the one girder fell on the other?—That is not near that place at all.
6774. I understand you to say that you found it fractured between the first standing pier and the first broken pier?—Yes.
6775. And that this piece of fallen girder is lying between the first pier and the second pier?—The first broken pier and the second broken pier.

6776. Can you show me on this model which part of the lattice work is broken?—This is all broken and twisted (pointing to the model); this is broken away entirely, and this is broken.
6777. But how about the upper one?—That is twisted.

6778. You see the size of it?—Yes; that is one of the straps, it is twisted.
6779. Is it at that end of the girder that it is twisted?—At the south end of the girder.
6780. Near to the pier that is standing?—Near to the pier that is standing.
6781. Which day was it that you went down there to see this?—On the 8th of January.

The witness withdrew.

Adjourned to Monday next at 10 o'clock.
Cross-examined by Mr. Traynhr.

6841. Who were your employers?—Messrs. Hopkins, Gilks, and Company, of Middlesborough.

6842. Who was your immediate superior?—Mr. Beatie, William Delpatt, and Mr. Camphius, during my stay at the bridge.

6843. Were all those gentlemen in equal positions as your superiors?—It is difficult for me to say as to that. They were my superiors.

6844. But their relative positions to each other did not know anything about?—I cannot say.

6845. Will you kindly tell me this; you said that you were foreman erecter of the large girders?—I was.

6846. But you had nothing to do with the foundry?—Nothing, only passing and repassing.

6847. You had nothing officially to do with it?—No.

6848. The girders and the columns as prepared elsewhere were given to you, and your duty was to see to their erection in situ?—I had nothing to do with the erection of the columns.

6849. Then the girders were sent to you prepared, and it was then your duty to put them in their place?—They were sent to me in sections, and I erected them and assisted in floating them out.

6850. You assisted in putting them on the columns?—They were lifted under the superintendence of Mr. William Delpatt, and after they were lifted I made the junctions of those large girders.

6851. You got them in sections put together on hand, when they were floated out and then put on the columns under the superintendence of Mr. Delpatt, and you attended then to the junctions of the girders when they were so placed?—Yes.

6852. Was it for the purpose of getting to the high girders that you ascended the columns, as you have stated, from three to five times a day?—Yes; I used to go out in a small boat.

6853. From the base of the columns you ascended to the top?—Yes; I had to mount it from a ladder.

6854. How did you ascend?—By means of a vertical ladder.

6855. I suppose when you were going from the base of the column to the top, you would not pay special attention to the columns as you went up?—Sometimes I did; many a time I had to take a rest, and I was only too glad to do it.

6856. Where you happened to rest?—It was upon the T-bars.

6857. Where you took a rest you had an opportunity, I suppose, of examining the columns at the particular place where you were resting?—I naturally looked round upon the works.

6858. Were you examining the columns or not?—I was looking at the iron work in general.

6859. Were you looking at the columns or not?—I was looking at them.

6860. But you were not examining them?—If I was looking at them I must have been taking notice of them.

6861. Were you or not examining them?—Yes.

6862. For what purpose?—Simply because it is in my profession.

6863. It was not part of your duty then to examine the columns. I understand that; and had nothing to do with them?—Certainly not.

6864. It was merely, I suppose, to satisfy your curiosity as you ascended?—Yes, simply for experience.

6865. What was it that you looked at it for?—To see how the bracing was fixed on.

6866. Point out on this model what it was that you examined?—To look at the iron work generally in connexion with the loading of the columns and seeing how the thing was braced in.

6867. That was for your instruction?—Just so.

6868. Can you tell me how the tie rods were fastened to the columns?—Yes.

Q 4
6866. How was that done?—By means of gibes and coppers, I suppose, in the lug; a gib and a coper.
6870. Did you notice rivets or bolts in the lugs?—I never noticed any in the lugs; there were bolts.
6871. Did you notice them particularly?—Yes.
6872. How many columns did you examine in that way?—I cannot say that I have been up and down every pier.
6873. Can you say that you paid attention to every column under the high girders?—No, not to every column.
6877. Do you know who was the man charged with the duty of seeing to the columns, as you were charged with the duty of seeing to the rivets?—Do you mean in the erection?
6875. Yes?—There were two or three different parties, but I cannot give their names, but one of the name of Gordon I can bring to mind.
6876. You were only there between February 1876 and September 1877?—That is all.
6881. At the junctions of the girders there were diagonal bars?—Yes.
6882. How were those fastened to the uprights?—By means of rivets.
6883. I presume then that you went over those rivets as well as over the rivets in the girders with the same care?—I did.
6884. So far as you could see they were all perfect too?—They were all good.
6885. I suppose you did not expect that the rivets in the diagonal bars would give way any more than any of the other rivets in the high girders?—No.
6886. If any of them did give way, how would you account for it?—I do not think they did give way.
6887. Assume that some of them did, can you account for it or not?—Not without the rivet had been left too hot and it had contracted, which had caused it to be the result of the being left; if that had been so, it would have been detected by the sound of the hammer before leaving it.
6888. Do you think that none of those rivets that held the diagonal bars could possibly have come away?—That is my opinion.
6890. That is to say at the particular moment that the train passed you?—Yes, just as it passed.
6892. It died out pretty quickly after the train passed?—Yes, as soon as she left the next pier.
6893. (The Commissioner.) Then you felt no more motion?—No, not after she had passed over the next pier.
6894. Your idea was that the motion up and down was confined to from pier to pier?—Just between the two piers.
6895. Did you ever happen to stand upon a pier when a train went past?—Yes.
6896. Did you feel a motion at all then?—I did.
6897. Still?—Yes, a slight jar, but no perceptible motion.
6898. Was that jar from side to side?—No.
6899. What kind of a jar was it?—I cannot exactly explain it, something similar to sitting in a railway carriage. You felt a sort of tremor in the bottom, but what it amounted to I cannot tell.
6900. There was a slight motion, but whether vertical or lateral you cannot tell?—It was a slight shake of the body, and what produced it I could not see, or say by the eye, it was so slight.
6901. Still?—Yes, a slight jar, but no perceptible motion.
6902. You went over the piers special for the high girders or not?—Yes, I went over and examined the piers, and I am a fitter of bridges, and I examined the piers.
6903. (The Commissioner.) Then you did not examine any of the columns except those that were under the high girders?—No; I had no business to do that.
6904. You did not climb any of the others?—I had nothing to do with them.
6905. Your evidence with reference to the work being so good and so on, relates to the columns under the high girders alone?—Yes, it does.
6906. Did you see, as a rule, not for every individual rivet, but did you see, as a rule, that the riveting throughout the high girders was complete?—I did.
6908. Was that jar from side to side?—No.
6909. What kind of a jar was it?—I cannot exactly explain it, something similar to sitting in a railway carriage. You felt a slight tremor in the bottom, but what it amounted to I cannot tell.
6910. There was a slight motion, but whether vertical or lateral you cannot tell?—It was a slight shake of the body, and what produced it I could not see or say by the eye, it was so slight.
6911. You saw many of the columns you said broken up?—Yes.
6912. When were those columns broken up?—I cannot mention the dates for that.
6913. Give it to me as nearly as you can?—It was my place to walk past the foundry to my work and from it, and I should be occasionally using a large hammer and beating them up, but I cannot mention the dates.
6914. When you saw the columns being broken up, was there anything that you observed in casual walks round the foundry?—Just in passing.

Re-examined by Mr. BALFOUR.

6915. Do you know whether Mr. Delpratt is now in Spain?—I cannot say.
6916. Do you know where Mr. Beattie is now?—I do not know, but I think he is in Birmingham.
6917. (The Commissioner.) You have not told us what you are—are you an engineer?—I am a fitter by trade. I have followed the occupation of bridge erecting and being in furness for the last eight years.
6918. Do you reside in Dundee?—No; I reside in Montrose. I am erecting the bridge piers on the North British Railway.
6919. You were taken on specially for the high girders?—No. I was sent from the firm to build the girders.
6920. You were employed by Messrs. Gilkes and Co.; by the same firm?—Yes.
6921. You were sent specially from them to put together the high girders?—Yes.
6922. You had nothing to do with the other girders?—Yes.
6923. As soon as you had raised the girders you ceased to work there, did you?—No; I made the junctions of them after they were lifted.
6924. And then you ceased, did you?—Yes.
6925. Have you left the firm now?—I went back to the firm again. I left the Tay Bridge.
6927. Were there any trains running before the girders were connected?—No; all the lower junctions were made, and the top ones all bolted up and secured; the service bolts had been there and they were allowed to run on trains as the thing was secure, and they ran over ballast trains and every hole was filled up with bolts.
6928. Trains were run over with ballast?—Yes.
6929. How long was that whilst you were there?—
I am sure I cannot speak to that.
6930. You left it after you had made the connections between the girders?—Yes, I was finishing the junctions during the time the ballast trains were running over.
6931. You had not finished them at one part and then went on before the other girders were raised, did you?—No, I worked on four or five junctions at a time.
6932. Did you not finish them while the other girders were being raised?—I did them during the time of the operation.
6933. Were all the girders raised before you effected the junctions?—Not all of them; two or three were up, and I was going on with those junctions during the intervals of raising the others.
6934. As soon as all the junctions were effected you left, did you?—Yes, as soon as my work was done.
6935. Are we to understand that when you were standing upon these girders, or upon the spans, you felt no motion of the train until it was close to you?—Not till it approached, while it was coming on at a high speed.
6936. You did not feel any motion until then?—I never noticed it.
6937. Did you ever try to notice it?—I had occasion to notice it. I was on the bridge sometimes 13 hours a day.
6938. Then you say there was no motion until the train had got on to the pier just before the span on which you were?—I never felt it myself.
6939. Do you say that there was no motion, or that you did not feel it?—If there was any it was not felt by me.
6940. Had you nothing to do with the piers?—No, except just climbing them.
6941. It was mere curiosity that induced you to look at them?—Yes, it just merely tempted me to look at them. I followed the profession, it is to my interest to do so.
6942. (Col. Pottland.) When you were climbing up the columns, did you in any case notice that the lugs were not quite close to the ends of the columns to the flanges, but removed some distance from them?—I cannot say that I ever noticed that.
6943. Did you notice any that were not tightly attached to the columns?—No, I never did.
6944. (The Commissioner.) Did you ever see any separation between the lugs and the flange?—I never saw it.
6945. (Mr. Barlow.) I suppose if there had been any small cracks there which had been puttled up and painted over you would not have seen them?—Not if they had been painted over.
6946. You spoke of two girders which fell in the process of erection, which two were they?—The two southernmost.
6947. That was between the pier that is now standing and the pier called No. 1, between No. 1 and No. 2?—The way the bridge was counted it was counted from the north end, between No. 1 and 2.
6948. It was the first and second spans?—Yes, from the south end of the large girder.
6949. When those girders fell did they do any injury to the pier?—Very slight, so far as I saw.
6950. Do you mean the bridge-work or the columns?—
6951. The columns?—They were all carried away, more or less.
6952. It carried away the first pier on the right and the first column on the pier, and it carried away the second pier also?—Yes.
6953. What became of the third?—Was it left standing?—Was what left standing?—
6954. What I call the piers are the piers, with their work—first pier—was that injured?—It was the first one on the south end, this would be the second one.
6955. Was the iron work of the south pier injured?—Yes, slightly.
6956. The second one, was that injured?—It was carried away.
6957. And the third one, was that injured?—It was carried away.
6958. The fourth one, was that carried away?—The greater part of it, the top of it.
6959. And the fifth?—The girder was on the brickwork there; it had not been fitted.
6960. In consequence of that fall the piers were injured from the pier now standing up to the fourth pier?—1, 2, and 3.
6961. Not the fourth?—Not that I am aware of; there was nothing there to be injured.
6962. Was it part of your duty to set out the line of girders, or did somebody else do that?—Mr. Campbells and Mr. Besant were the engineers for that.
6963. Did you notice in making the junctions that the parts fitted in a good line the one with the other?—Yes, very good.
6964. Did you notice that they fitted well in point of line as between the high girders and the low ones at that time?—I cannot say; I had nothing to do with the extreme ends of the high girders.
6965. Where were the girders made?—In Middlesborough.
6966. And brought here in pieces?—Yes.
6967. (Mr. Trapper, through the Court.) In whose employ were you building the bridge at Mornrose?—The North British Company.
6968. You are not in the employment of the North British Company?—No, I am in the employment of Messrs. Hopkins, Gilkes, and Company, of Middlesborough.

The witness withdrew.
W. Duns.

1 March 1860.

6981. Did you continue to work after he left?—Yes.

6982. Did you overhaul the small pier on the south side of the large girders?—Yes.

6983. Did you also overhaul the piers supporting the large girders?—Yes.

6984. All of them or part?—Part of them.

6985. Which did you overhaul?—I cannot exactly say. Mr. Oram overhaul four or five before I went there.

6986. And you overhauled the rest?—Yes.

6987. Had you anything to do with the small piers to the north of the high girders?—No.

6988. Were you at that time in the employment of Messrs. Hopkins, Gilkes, and Company?—Yes.

6989. Was Mr. Macbeth inspecting for the North British Company the whole of the time that you were there?—Yes.

6990. What was he doing?—He was inspector of the work in general I understand.

6991. When he found any fault with the work what did he do?—He rejected it and had it taken out and replaced by good work.

6992. When you became foreman rivetter had you the duty to see that there were no loose bolts or rivets left?—Yes.

6993. In going over the work did you sometimes find loose rivets or bolts?—Yes, in some cases.

6994. What did you do in those cases?—I had them taken out and good ones replaced.

6995. When Mr. Macbeth called attention to any defects were they remedied?—Yes.

6996. The girders were all rivetted, I understand?—Yes, at the junctions.

6997. And the piers were bolted?—Yes.

6998. What was the last job that you did upon the bridge, generally?—Overhauling the bolts and seeing that they all had a full nut and were properly caulked, and the brace bars and the channel bars properly tightened up.

6999. That was done on the piers after you had finished the girders?—Yes.

7000. What do, you mean by caulkling the nut?—After the bolt is screwed in, the art of screwing the nut so that the threads would not be damaged.

7001. Is that done with a blunt chisel?—No, a caulking tool.

7002. After that is done, could the bolt possibly unscrew itself off the nut?—No.

7003. Is it just slightly rivetted apparently?—Yes.

7004. After the bolt is caulked in that way, can it come out unless it is cut?—No, it cannot.

7005. Before you left, were the rivets and bolts all right?—Yes.

7006. Of course in going over the pier, you must have had an opportunity of examining the columns?—Yes.

7007. And of seeing them?—Yes.

7008. Did you see any broken or cracked?—No.

7009. With regard to the lugs, did you see any of them not tight to the flanges?—No.

7010. Or to the columns?—No.

7011. Or any of the cracks between the lug and the flanges?—No.

7012. Or between the lug and the column?—No.

7013. Had you occasion, in the course of your examination, to examine every lug?—Yes.

7014. In order to see about the bolts in it?—Yes.

7015. If there had been any important crack between the lug and the flange, or between the lug and the column, could you have seen it in the case of those that you examined?—No, I do not think so.

Cross-examined by Mr. Trayner.

7016. Will you tell me, if you please, what columns were under your supervision?—From the south side as far as No. 1 on the north side, No. 1 of the high girders.

7017. Then did you extend along the whole length of the high girders?—Yes, barring two or three or four that Oram did before I went.

7018. Where were those two or three situated?—I cannot exactly tell you.

7019. You can tell me whether they were at one of the ends or in the middle?—In the middle of the high girders.

7020. Were they continuous?—Yes.

7021. Did you pick out one here and one there?—No, about the centre of the high girders.

7022. And all together?—Yes.

7023. How did you know the particular piers that Oram had examined?—He told me before he left.

7024. Did he point them out to you?—Yes; I got a list of them before he left.

7025. You did not look at those columns at all?—No.

7026. How did you proceed to examine the columns; did you go up or mount them by ladder?—Yes, we had a ladder in many cases, but I did not use the ladder. The ladder was of no service to me. I had to go right round the pier and examine each flange.

7027. How?—I walked round on the channel bars.

7028. Inside the column?—Inside the pier.

7029. Did you do that at each different stage of the columns; from the top to the bottom?—Yes.

7030. Did you see any lug that was separate, however slightly, from the flange?—In one or two cases there was one or two broken off, and we replaced them by a wrought-iron lug.

7031. Was there any case in which you found the lug separated or cracked away from the flange?—No; not without being away altogether.

7032. Do you know anything about moulding?—No.

7033. Would you know the difference between a lug that had formed part of an original casting and a lug that had been burnt on to supply the place of a lug that had been broken off?—I think so.

7034. Were there any lugs that had been burnt on?—No, not that I saw.

7035. Then all the lugs that you examined were parts of the original casting, in your opinion?—Yes, barring one or two.

7036. Where were those?—On the small piers on the south side.

7037. Outside the high girders?—Yes.

7038. Had those lugs been part of the original casting when they were put in position?—Yes.

7039. In your opinion they were broken off after having been so placed?—Yes.

7040. What led you to think that?—The look of the iron told me so.

7041. I suppose they were not entirely broken off?—No; we had to clean them.

7042. They were just partially broken?—Yes.

7043. How did you remedy that?—By cleaning off the broken part and putting on wrought-iron; we drilled holes and put in taps.

7044. You drilled on a new bit to the old lug after you had cleared the surface?—Not the lug, the column.

7045. You found some of the lugs broken, did you?—Yes.

7046. Did you leave on the bit that was there?—No, we cleaned it off.

7047. Then you drilled on the new lug entirely to the standing column?—Yes.

7048. That was outside the high girders?—Yes.

7049. Then did you examine all the columns to the south of them?—Yes.

7050. As far as you could get to the shore?—Yes.

7051. Did you see any column with a crack in it?—No.

7052. Did you see any column with iron hoops round it?—No.

7053. You did not see anything of that kind from end to end as far as you went?—No.

7054. Did you see any column with any crack in it close to the place where the lug was?—No.

7055. Did you notice any column which had been seamed in the moulding?—No.
7056. You know what I mean well, do you not?—Yes, exactly.

7057. Did you see any signs of a blow-hole on any of the columns?—No.

7058. 

7059. I suppose you know quite well that is done sometimes by moulders?—I could not say; I know nothing at all about moulding.

7060. You never saw columns with blow-holes in them which had been mended in that way?—I have seen some columns with blow-holes on the outside, and I could see the inside of them.

7061. Outside you could see no signs, could you?—No.

7062. Or holes left by scabbing?—No.

7063. Did you examine the rivets of the high girders?—Yes, in the junctions.

7064. Only there?—Yes.

7065. Did you notice the diagonal bars at the junctions?—Yes.

7066. How were they fastened to the uprights?—By rivets.

7067. Did you notice in the course of your inspection any of those rivets loose, or insufficient?—No.

7068. Were they in as good a condition to all appearance as any other rivets in the whole structure?—Yes.

7069. No better and no worse?—No, we tried to make them all as good as possible.

7070. You said that Mr. Macbeath sometimes objected to the work and had it remedied?—Yes.

7071. Did he ever object to the work that you had passed?—No.

7072. Did he go before you in his inspection, or come after you in his inspection?—He came after they were rivetted in general.

7073. After you had seen to the rivetting?—Yes, but not tested it.

7074. Then that work that had been passed by you?—No, not tested.

7075. It was work that had been done under your supervision although not tested?—Yes.

7076. And work that satisfied you, I suppose?—No.

7077. But it would satisfy you so far as you could judge of it without specially testing it?—Exactly.

7078. That has been Mr. Macbeath came after you and tested it, I understand that he ordered the bad work to be taken out and new rivets to be put in?—Exactly.

7079. So you think that you examined every lug on the columns supporting the high girders?—Yes.

7080. With care?—Yes.

7081. How many lugs, if any, altogether in the high girders did you find defective?—None at all.

7082. All that you found defective were outside the high girders?—Yes.

7083. How many were there of these altogether?—Two or three.

7084. Throughout the whole bridge?—Yes.

7085. You left in December 1877?—Yes.

7086. What were you doing between September and December of that year?—I was overhauling the work generally.

7087. Was Newcombe over you when he was there?—Yes.

7088. Did you take his place in September?—No.

7089. Was not he there to overhaul the work?—Yes; the rivetting department in connexion with the large girders.

7090. Only?—Yes.

7091. That was done by September?—Yes.

7092. Then I suppose it was after September when you began at the rivetting of the high girders?—No, everything was done by that time.

7093. Just tell me this,—what were your duties from September 1877 until you left?—Overhauling the piers from the south side and along the high girders.

7094. From the south side of the river all through the high girders?—Yes, right throughout them.

7095. Did you go over the whole of that part of the bridge from the south side of the river to the north end of the high girders, in the time you have mentioned?—Yes; barring three or four which Mr. Oran did.

7096. Did you see any of the columns before they were placed in situ and put into their position?—Yes, I saw them lying about on the south side when they came out of the foundry.

7097. Did you inspect none before they were placed in the position which they were to occupy on the bridge?—No, I had no inspection.

7098. (The Commissioner.) When you were examining these columns, they were not?—Yes.

7099. From top to bottom?—Yes.

7100. So that if there had been any holes in them, or scabbing, or cracks, you would not have seen them?—No.

7101. They would have been filled up by the paint, would they not?—I could not say.

7102. Therefore you do not know whether there was scabbing on the outside of the columns, or whether there were cracks, or whether the holes had been filled up with putty?—No, it was a smooth surface, I could not tell.

7103. Painted over?—Yes.

7104. When you tell us that none of the lugs were separate from the flanges, you mean to say that you did not observe that they were separate from the flanges?—No.

7105. You do not know whether they were or not?—They were not separate.

7106. If they were filled up with paint, it would be just the same, would it not?—They could not fill up a lug with paint very well.

7107. Where there was a crack between the lug and the flange?—I did not observe it.

7108. I suppose paint would fill up a crack in a column?—I could not say.

7109. Do not you know that paint would fill up a crack in a column?—It might, but I cannot say about that. I am no judge of painting.

7110. Suppose there had been no hole at all in the columns, where there was a scab of that kind filled up with putty or with cement and painted over, I suppose you would not have perceived it, would you?—I did not notice it.

7111. (Col. Yolland.) Can you say whether there are any columns from the south end of the bridge up to the last pier that is standing which have any hoops round them?—There are none.

7112. None?—None that I have seen.

7113. You say for certain that there are none?—None that I have seen.

7114. (Mr. Barlow.) Did you notice in the case of any of the columns that in the casting of them the upper flange had shifted with reference to the lower flange, leaving a mark of about a quarter of an inch on each side of the column?—No.

7115. Have you not seen that?—No.

7116. Are you aware that they are to be seen on the columns of that shape?—Possibly, but I did not notice it.

7117. (The Commissioner.) Do you know anything about casting?—No; I know nothing about it.

7118. If there was any mark such as had been mentioned to you, you did not observe it?—The only mark I noticed was one rib which comes down on each side of the casting. I do not know what it is caused by.

7119. (Mr. Barlow.) With reference to a question that was put to you by Colonel Yolland, when did you last go over or examine the columns?—I examined them up to the time I left—the last job I was on.
TAY BRIDGE DISASTER:

7120. That was December 1877?—Yes.
7121. Not since?—No.
7122. Whether anything has been put on since you cannot tell?—No.

The witness withdrew.

7123. (Mr. Balfour, to Mr. Newcombe.) You mentioned Mr. Gordon, who had been working; do you know where he is?—I do not know.

G. Macbeth

Examined by Mr. Balfour.

7124. What are you now?—An inspector.
7125. Where?—At the Montrose and Arbroath Railway.
7126. Were you inspector of the iron work on the Tay Bridge from the 7th July 1877 to May 1878?—Yes.
7127. That was practically when it was open for traffic?—Yes.
7128. Did you leave just before the painting began?—Yes.
7129. Before you were employed on that work what had you been doing?—I had been working as a journeyman boiler-maker.
7130. Have you had 17 years' experience as a journeyman boiler-maker?—I have had 12 years' experience.
7131. How long have you been at boiler-making?—About 18 years.
7132. Then I suppose you understand all about rivetting?—Yes.
7133. What were your duties as inspector?—My duties were to overhaul the work, and see that it was satisfactorily done.
7134. You, I believe, were in the employ of the Railway Company?—I was in the employ of Sir Thomas Bouch.
7135. The engineer of the Company?—Yes.
7136. Your duty was to inspect the work that was put upon the bridge by the contractor?—Yes.
7137. Will you just tell us when you came to the bridge how far had they got on with the girders?—There were 12 of the large girders erected and one to erect; there were 11 girders brought out and two to float out.
7138. Did you examine particularly the part of the bridge that contained the high girders?—Yes, more especially the high girders.
7139. Why more especially the high girders?—I could get much easier at them.
7140. The girders were riveted together, were they not, at that place?—Yes.
7141. What did you do in the way of examining the rivets?—Tested them.
7142. How did you test them?—By testing them.
7143. How did you do that?—Practically speaking, there are several ways of testing them.
7144. What did you do?—I generally tap them with my hand and with a hammer.
7145. Does that enable a person to know whether a rivet is loose or tight?—Yes.
7146. Did you find any loose?—Yes.
7147. What did you do with them?—I got them taken out.
7148. And tight ones put in?—Yes.
7149. Do you find in any work occasionally loose rivets, which a person requires to go over and reject after the work is done?—Yes, as far as rivetting is concerned I have never seen any rivetting done yet without taking out some.
7150. Was there anything done in the rivetting in this case contrary to what you find in your other experience of rivetting?—No.
7151. Did you think after you had gone over the rivets and rejected the loose ones that the rivetting was tight and well done?—Yes.
7152. Were there any rivet holes without rivets in them in the high girders?—I believe there were.
7153. What were the kind of places where the holes were which had been left?—Just exactly at the bracing there (pointing to the model), and in some places we had to take it out just at this place (pointing to the model), and inside the boom under here (describing) where this angle comes across here, we had in some cases to cut the rivets out to let the angle iron get up to the bottom of the boom so as to let them get up tight to the lower top of the boom.
7154. In a case like that might there be a rivet hole?—Yes.
7155. It was necessary to enable this (pointing to the model) to be right up and properly fastened?—Yes; we could do without a rivet where we could not cut the angle iron.
7156. You must have cut either one or the other?—Yes.
7157. It was more important to have the angle iron a stronger thing than the rivet?—Yes.
7158. Do you think that any rivet like that being removed could possibly affect the stability of the bridge?—No.
7159. Now as regards the lower booms, were there any rivet holes?—Not that I saw.
7160. Were there some holes for letting the water out?—Yes.
7161. Were there a good many of the rivet heads which you had directed to be cut lying about the bridge?—Yes.
7162. Did you see any spring rivets broken out lying about the bridge?—I do not understand.
7163. You know the difference between a cut rivet head and one that is broken off, do you not?—Yes.
7164. Were the rivet heads on the bridge rivet heads which had been cut out by some one's directions, or were they rivet heads which had broken off themselves?—Cut.
7165. You know the cross-stays and these things (pointing to the model)?—Yes.
7166. What is their name?—That is the diagonals—the bars at the end posts.
7167. What were they for?—For stiffening the bridge.
7168. Will you describe the size with reference to the metal—how long were they and how broad were they?—About two by two by half an inch.
7169. (Mr. Balfour.) The angle irons?—Yes.
7170. (Mr. Balfour.) They were there to stiffen the end posts of the girders?—Yes.
7171. To prevent an outward or inward movement of the posts?—Yes.
7172. Did you see any of them wrong when you last inspected the bridge?—No.
7173. Did you ever examine the columns of the bridge, or any of them?—Yes.
7174. Will you kindly tell me when, and in what way, did you examine the columns?—By starting at the bottom and climbing right up, and going round each from the bottom right up to the top.
7175. What did you do when you got to each stage in your ascent?—I just walked round the bracing.
7176. Will you point out on the model where you walked round?—I walked right round there (pointing to the model).
7177. Along there, round the columns and round the piers?—Yes.
7178. At every stage did you examine all the junctions?—Yes.
7179. And all the joinings?—Yes.
7180. What did you look for?—For bad work.
7181. To see if there was any bad work?—Yes.
7182. Had you any tool near at hand to test or tap?—I always carried my hammer with me in my
7188. Anything that looked doubtful you tested with the hammer?—Yes.
7189. Did you examine the flanges or the lugs amongst other things?—Yes.
7190. Will you just tell me what you found the state of the column to be in?—There were some short bolts into the column, and I got them taken out.
7191. What was done with them?—They were replaced.
7192. With bolts of proper length?—Yes.
7193. Were they so short that they had not a good hold?—Yes.
7194. Did you then get those bolts removed, and bolts of a proper length upon which the nuts would hold tight, and put in in?—Yes.
7195. Then were all the bolts caulked upon the nut?—Yes.
7196. Then before you had done with the columns, were they in your judgment sound and strong?—They were all sound.
7197. Did you ever find anything wrong with any of the lugs?—No.
7198. Did you ever find any pieces broken off any of the lugs?—I found three.
7199. Tell us what you did about them?—I got them chipped off, and malleable iron lugs put on.
7200. Could you form an opinion from their appearance as to how they had been broken?—When they were coming across, something must have come up against them and knocked them off.
7201. On what piers did you find those broken lugs?—There was one I remember on No. 9 pier.
7202. Where do you count from?—From the north.
7203. I think that is still standing, is it not?—No.
7204. You mean No. 9 of the high girders?—Yes, it is No. 14 and No. 15 from the south.
7205. Are those still standing?—Yes.
7206. Will you tell us what did you substitute for those broken lugs?—Malleable iron lugs.
7207. How did you direct them to be fastened on?—By screws and tap bolts.
7208. How many screws to each lug?—Two.
7209. Was that one at the top and one at the bottom?—Yes.
7210. Are they right through the side of the column?—Right through the column.
7211. Through the side of the column?—Yes.
7212. Through what part of the column?—The body of the column—this part (pointing to the model).
7213. Was there one at the top and one at the bottom?—Yes.
7214. (The Commissioner.) It was only piercing the coat of the column—not right through.
7215. (Mr. Balfour.) Through the side until you got into the hole?—Yes, from the outside of it.
7216. Was the thread of the screw tipped with cast iron?—Yes.
7217. Were you particular to see those three lugs put on?—Yes.
7218. In your judgment was the work strong with reference to those lugs when you left them?—Yes.
7219. They were quite fit to hold the bracing pieces?—Yes, the diagonal bracing.
7220. Were they, in your judgment, quite fit to hold the diagonal bracing?—Yes.
7221. What was the size of the screws?—An inch.
7222. Do you mean an inch across?—Yes, an inch in diameter.
7223. How long were they?—It will depend upon the section of the metal.
7224. They were an inch in diameter?—Yes.
7225. Were they good strong metal screws?—No; malleable iron screws.
7226. Were they strong?—Yes.

7227. But you did not see any signs?—No.
7228. Ballast trains?—Yes; ballast trains.
7229. Now, when the trains were passing did you feel anything particular on the bridge, or what did you feel?—No; nothing particular.
7230. Did you feel anything different from what you feel on other iron bridges?—No.
7231. Have you been on many?—Not on many, on some.
7232. You found nothing different to what you found on them?—No.
7233. Were you on the bridge frequently when the wind was high?—Not very high.
7234. Can you give us anything that will enable us to judge how high it was?—It was so high that all hands had to knock off and leave their work.
7235. When was that?—I cannot give you the date.
7236. Did it occur more than once?—Yes.
7237. Why had they to knock off?—They could not work for the wind.
7238. In case it should blow them off?—Yes; that is about it.
7239. Did that wind affect the bridge in any way on those occasions?—Not that I am aware of.
7240. Did it shake it perceptibly?—No; I could not say that.
7241. When you left that bridge had you any doubt with reference to its safety and stability?—No.

Cross-examined by Mr. Treanor.
7242. You were entirely in the employ of Sir Thomas Bouch?—Yes.
7243. In whose employment are you now?—In Sir Thomas Bouch's.
7244. Working at the place you told us of on the North British line?—Yes.
7245. In a general way what were your instructions with reference to the duties to be performed by you when you were employed?—I had to overhaul all the girding work.
7246. That means the bridge from end to end?—Yes.
7247. And that work included the examination, I suppose, of all the rivetting?—Yes.
7248. With regard to the rivetting in the high girding, you went over the whole of it?—Yes.
7249. Can you give me an idea of the number of rivets there were in the high girders from end to end?—Altogether 18,000 or 20,000, so I suppose.
7250. (The Commissioner.) In each girder?—That is from end to end of each of the high girders.
7251. (Mr. Treanor.) You say there were from 15,000 to 20,000 rivets?—Yes, as near as I can give it.
7252. And the diagonal bars at the end posts were also rivetted?—Yes.
7253. Did you give any particular attention to the rivetting in one place more than another?—No.
7254. When you left the bridge were you satisfied that all the rivets in the high girders were perfect and as they ought to be?—Yes.
7255. You did not anticipate that any of them would spring or break?—No.
7256. I suppose the rivetting in the diagonal bars...
at the end posts was of the same kind and of the same quality as the other rivetting in the girding.—
Not in all cases.
7237. In what cases was it different?—When I had to take and renew them we put in a different class of rivets altogether.
7238. What was the class of rivet you put in when you removed them?—A hammered rivet.
7239. As distinguished from what other kind of rivets?—A snap rivet.
7240. What is the difference?—It is a round ball to form a round head, a hammered rivet is quite a different thing; that is furnished by the hammer.
7241. Is it a cup-headed rivet?—Yes.
7242. What kind of rivets were they, snap rivets or hammered rivets, that were in the diagonal bars?—Both.
7243. And in the high girding in other places, were they cap or snap or hammered?—All snap.
7244. What were the original kind of rivets that were put into the high girders all through?—Snap.
7245. When any of those were found defective they were taken away and hammered rivets put in their places?—No, that was only if they could not put in snap rivets.
7246. Would not the number of hammered rivets be very small?—Yes.
7247. Were they as secure as the snap rivets?—Yes.
7248. As regards the security of the rivets in the diagonal bars, were they as good as the rivets in the rest of the girders?—Yes.
7249. Did any of the rivets in the diagonal bars give way?—Not to my knowledge.
7250. If they did give way could you account for it?—No.
7251. Your inspection of those diagonal bar rivets was neither better nor worse than your inspection of the whole of the other rivets in the high girders?—No.
7252. Do I understand that you went with a hammer over every rivet in the high girders?—There was no necessity to do it.
7253. But did you not do it?—No; not every rivet.
7254. What proportion of the rivets in the high girders did you test with a hammer?—More especially the junctions, where the rivets had a tendency to be loose.
7255. Will you answer my question; what proportion of the rivets in the high girders did you test with a hammer?—I should say 1,500 or 1,600.
7256. In each girder?—Over that in some cases; about 1,500 or 1,600 in each girder.
7257. That is to say, 1,500 or 1,600 out of from 15,000 to 20,000?—Yes.
7258. Will you point out the place where you saw the inspection of your rivets was most careful, what you call the joinings?—Here (pointing to the model) at the intersections.
7259. At the end posts, where two girders were joined, you were careful there?—Yes; at those intersections.
7260. Will you mark the intersections with your finger?—It does not show it here.
7261. On the sections between the end posts?—And the connexions here in between these junctions (pointing to the model).
7262. Where the sections of the girder met?—Yes.
7263. So that every place, in a word, where there was a joining you were particularly observant of?—Yes.
7264. I suppose it comes to this, that your examination of the rivetting, except at these places, was slight?—Well, it would simply depend upon what like the work was.
7265. If the general appearance of the work was good, you did not tap particularly?—Where I was doubtful of one here and there.
7266. But I suppose the 1,500 rivets or so that you did examine particularly in a girdor would be the whole of the rivets at the joinings in the corus of that girdor?—Yes.
7267. Were the diagonal bars of any use in the bridge, or were they merely ornamental?—They would be intended for some use, I believe.
7268. What was the use of them?—To stiffen the end posts.
7269. And to stiffen the end posts I suppose was a material thing in stiffening the whole length of the high girders?—No, just to prevent the end posts from getting together.
7270. And if those end posts were not prevented from getting together, would that not have materially weakened the structure from end to end of the high girders?—No.
7271. Then they were of no use?—No.
7272. If the end posts getting together was not a matter that affected the stability of the bridge, these diagonal bars were of no use at all?—They were of use.
7273. What was the use of them?—To stiffen the end posts.
7274. What was the good of stiffening the end posts?—Just to keep them in position.
7275. And what was the good of keeping them in position?—To keep the girders in position.
7276. And what was the use of keeping the girder in position?—To keep the bridge in position.
7277. And what was the good of keeping the bridge in position?—To make it safe?—Yes.
7278. How many hammer holes or rivets do you think you ordered to be put right in each high girder?—Well, a few; I could not exactly say how many.
7279. But approximately; you said that you went on them, and that when you found rivets that were not satisfactory you marked them and had them taken out and replaced; how many rivets would you treat in that way in the course of each high girder?—Perhaps 20 in one junction, and perhaps 15 in another junction.
7280. Do you mean in each span or in each section?—In each span.
7281. Was there an average of 20 in each span, or more or less?—More or less.
7282. But what was it?—There were 20, more or less, in each span.
7283. You marked them and gave orders to somebody to go and replace them?—Yes.
7284. Who was it that you gave your orders to?—To the engineers; Hopkins, Gilkes, and Co.'s engineers.
7285. What was his name?—Mr. Campbells, and Mr. Lowndes and Mr. Newcombe.
7286. Did you give your orders all round in that way?—I generally gave my orders to Mr. Grothe.
7287. Who was the superintending engineer?—Yes.
7288. How were the rivets marked that you wished replaced?—We centre punched them.
7289. Did you go back again to see whether your instructions had been fulfilled in each case?—Yes.
7290. Had you taken a note of the particular place in which you replaced each rivet head?—No.
7291. Then is it possible that there might have been a rivet head left there with a punch mark on it that was not replaced that you did not see when you went back?—I do not suppose they could deceive me as far as the punch mark was concerned. I could see at once if it was replaced.
7292. I quite understand that, what I am pointing at is this; did you go over the same place so as to ascertain exactly whether the 20 rivets more or less had been taken out and replaced?—Oh, yes.
7293. And are you quite sure that on each occasion you tested the new rivets to see whether they were satisfactory?—Yes.
7294. Are you speaking to a certainty?—Yes; I tested the new rivets.
7295. Had you ever occasion to challenge a rivet
twice—I mean to challenge a replaced rivet?—No; not a second time.

7316. But is it the case, or is it not the case, that sometimes you were satisfied with the replacing of the rivet without any very minute examination or test of it?—Yes.

7317. Just understand the question before you answer it; is it the case that you were sometimes satisfied with the new rivet without subjecting it to a new test or examination?—I generally tested them.

7318. You did not test heads on the way of the bridge you said?—Yes.

7319. How many were there?—There might be 200 or 300.

7320. Did you look at those to see whether they were all cut?—No.

7321. Then it was scarcely correct to say that to your observation they were all cut rivets?—I could not say whether they were all cut rivets.

7322. They might have been sprung for anything you saw?—They might have been cut off the other side of the head.

7323. But those rivet heads that were lying on the way of the bridge might either have been cut off or have been cut off and sprung off?—I could not account for the springing off of them; I don’t think they could spring off.

7324. But you did not look at them to see whether they had been cut off or whether they had broken off? No, I did not look. I have picked them up and found them out.

7325. And in every case did you find that what you picked up had been cut?—Yes.

7326. And you never saw one that had come off except by being cut off?—No.

7327. How many do you think you would look for between a dozen and two dozen?—Two dozen.

7328. At that time, I suppose, you were not paying attention to the columns of the bridge from end to end?—Yes.

7329. From south to north?—From south to north.

7330. And every one of them with the same care, landing at each of the stages and going round it to see what the work was?—Yes.

7331. Did you find any of the lugs that showed signs of having been burnt on?—No.

7332. Not one?—No.

7333. Did you look to satisfy yourself whether any of them had been burnt on, or whether they were all parts of the original casting?—I don’t know anything about the burning on.

7334. You do not know a burnt-on lug when you see it?—No.

7335. Then you could scarcely have detected it. Did you see any lug that was cracked or away from the flange?—No.

7336. Not even to the extent of 3/4 or 1/4th or 1/2 of an inch?—No.

7337. No crack at all?—No.

7338. Did you notice any of them that were cracked at the column or the column cracked at the lug?—No.

7339. Are you quite sure of that?—Quite sure.

7340. I understand that you inspected all these columns before they had been painted?—No; after they were painted.

7341. Then you did not examine any of the columns until after they had been all painted?—No.

7342. (The Commissioner.) When they were on situ?—Erected in position.

7343. (Mr. Trauger.) And painted?—Yes.

7344. Then a crack such as I have been describing might have been there, but covered over with the paint?—Yes.

7345. Either in column or in lug?—Yes.

7346. Could you gather from your inspection how
The witness withdrew.

GEORGE FENDER SWORN.

Examined by Mr. BALFOUR.

7395. I believe you are an iron turner at the Wallace Foundry, Dundee?—Yes.

7396. Belonging to Messrs. Robertson and Orchard?—Yes.

7397. Of which firm ex-Provost Robertson is the senior partner, I believe?—Yes.

7398. Had you charge of the turning department at the Tay Bridge works from the time these works began until the time that they were finished?—Yes.

7399. Did you turn all the columns which were put into the bridge?—Yes, in the portion that fell.

7400. In the high girders?—Yes.

7401. Did you turn any of the others?—Oh, yes.

7402. What columns in the bridge did you not turn?—There were some that came from Midlothian for rakers for the north side.

7403. But except the raker columns at the north side, did you turn all the columns that were put into that bridge?—Yes, all that were cast at the Worimi Foundry.

7404. Were all the columns that were put under the high girders cast at the Worimi Foundry?—Yes, I believe they were.

7405. And what other columns besides those under the high girders?—There were a good many others.

7406. What other columns were cast at the Worimi Foundry besides those to support the high girders?—Well, I believe from No. 50 pier on the north side.

7407. Did you turn a large majority of the columns put into that bridge?—Yes.

7408. What state are the columns in when they come to the turner?—Immediately from the dresser, after they are dressed after leaving the mould.

7409. After they leave the mould then they go into the hands of the turner, and then they come into the hands of the turner?—Yes.

7410. When the columns came into the hands of the turner, were they painted in any way?—No.

7411. They were as regards the skin or outside as they came from the mould except that they were dressed?—Yes.

7412. I suppose in turning these you had to handle each column and put it in the lathe?—Yes.

7413. And then to work it in the lathe?—Yes; and worked it in the lathe.

7414. So that each column went round in the lathe under your hands?—Yes.

7415. Would you just tell us what part of the column you worked upon with the tool in turning?—There was the face of the flange and the top of the flange at the outside, and then there was a projection about an inch long, or one inch and a quarter at the one end to fit into the other end of the column male and female all the way along.

7416. (Mr. Barlow.) Do you mean a socket?—Yes; we bored out one end of the column, and the male piece came in all the way up.

7417. (Mr. Balfour.) It was like a small spigot and facet almost all the way up, apparently?—Yes.

7418. What was the object of that?—To give it stability.

7419. And to keep them in shore line?—Yes.

7420. In saying that, do you speak not only of the columns that were put under the high girders, but of all that were cast at Worimi?—All that were cast at Worimi.

7421. In turning the columns and handling them, had you an opportunity of seeing what kind of castings they were?—Yes.

7422. And seeing whether there were any defects in the castings?—Yes.

7423. Must you have seen any such?—Well, if there were any I should have seen them.

7424. From the way you had to handle them, did you the opportunity of seeing if there were any cracks, or blown holes?—Yes.

7425. Did you ever find anything of that kind?—Yes.

7426. When you did find any such defect, what did you do?—I reported it to my superiors.

7427. Who were your superiors?—Mr. Camphuis, Mr. Beatie, and Mr. Grothe.

7428. Was Mr. Beatie first?—Yes.

7429. He is in Birmingham now, I believe?—I do not know where he is.

7430. Mr. Camphuis is here. What was done in consequence of your objections?—They were often thrown aside if they were thought defective.

7431. And broken up?—And broken up.

7432. You say "very often." Was it quite a common thing during the time you were working for columns to come from the moulders which on your examination you found bad, and which were broken up?—Yes.

7433. Can you give us any idea how many columns might be rejected and broken up in that way?—I could not say exactly the number.

7434. But would it be a large number?—Well, not exceedingly large.

7435. How often would it happen?—Perhaps once or twice a week.

7436. And how long were you working at that turning?—Two years and eight months altogether.

7437. Then it must have been the hundred?—(The Commissioner.) Do you mean that
that happened once or twice a week?—A column or two a week, but there might be some weeks that there were not any.

7438. But, taking it on the average, that was the number?—Taking it on the average, that was the number.

7439. (Mr. Balfour.) Then if you were working for 2 1/2 years it would come to the hundred?—Well, there would be no line.

7440. Who broke them up?—The labourers generally broke them up.

7441. And then was the metal put into the cupola and cast over again?—Yes; recast.

7442. Did you ever find in any of those columns very small blown holes which in your judgment did not affect the stability or strength?—Yes.

7443. And did you pass those?—Yes, if I considered that they were defective so as to detract materially from the strength of the column.

7444. Would you describe what kind of a blown hole, by size or otherwise, as you think best you would reject materielly from the strength of the column.

7445. Is the blown hole just a bubble, where there has been air of greater or less amount retained in the metal?—I cannot say how one would account for it.

7446. Is it just like what would hold an air-bubble? —Yes.

7447. Does it vary from a very small hole to a larger one?—From a sixteenth to a quarter of an inch.

7448. And would a little bubble of a sixteenth of an inch have affected the strength of the column?—I would not think so.

7449. But if it came to be large then you would reject it?—Yes.

7450. Was any column sent to the bridge from the turning shop which in your judgment was defective or insufficient for its purpose?—Not that I am aware of.

7451. And you were there in charge?—I was there in charge.

7452. Could it have been so sent?—It might have been. There might have been some turned during the night. I was not there always, you know.

7453. Then who else was going about?—There was a man by the name of Stewart; he was there in my place during the night.

7454. Where is he now?—He is in Dundee, I believe.

7455. What is his first name?—William.

7456. Can you tell us his address or where he is working?—He is working at Paterson's Saw Mill, I think, at the present time.

7457. Did you see on any of the columns signs of scales which had been chiselled off?—Yes.

7458. Was the scab where there had been a slight rise, beyond the normal surface of the column in consequence of the sand having risen up?—Yes.

7459. So that until the scab was chiselled off, it was beyond the standard thickness at that place?—Well, I thought so, it appeared to be so from that side.

7460. And did you see that the scab had been chiselled off?—Yes.

7461. Had the removal of that roughness in your judgment any effect on the strength of the column?—I do not think it had.

7462. Did you ever find that where there had been a scab there had been any kind of hole or depression chiselled in the column?—I have seen blown holes.

7463. I asked about blown holes before; my question was, Now did you find that any hole or depression had been chiselled into the columns at any place where the scab had been?—No.

7464. But merely that the scab had been chipped off?—Merely that the scab had been chipped off.

7465. So as to reduce the surface of the column to its normal standard?—Yes.

7466. In saying that the columns had not been painted, did you mean that no part of them had been painted before they came into your hands?—No part of them.

7467. Of any of them?—Of any of them.

7468. Did you ever see any cement or putty upon any part of the columns?—I have seen some, but in that case it was picked out.

7469. Just tell us about what you saw when it came into your hands?—I have seen some of the holes filled with the cement.

7470. Blown holes?—Blown holes.

7471. Did you know who had done that?—I knew that it must have been a dresser, but who it was I could not say.

7472. When anything of that kind came under your notice what did you do?—I probed it to see the extent of the hole, and then picked it out.

7473. And if the hole was an important one, what did you do?—I generally showed the column to my superior.

7474. And got the column broken up? (Mr. Trayer.) He has not said so.

7475. (Mr. Balfour.) Is that what you did?—Yes.

7476. Had you any difficulty in seeing where the dresser had put in the cement in that way?—Not any difficulty: if I looked particularly I was bound to see it.

7477. And did you do so?—Yes.

7478. What was the colour of the cement?—Black, generally; about the same colour as the columns, perhaps.

7479. But in handling it as you did you had no difficulty in seeing it?—No difficulty.

7480. About the lugs, did you ever see anything wrong with the lugs of any of the columns as they came into your hands?—Yes; I have seen them burnt on many times before they came and after, but I was always under the impression that where they had been burnt on they had been cast solid.

7481. Where they had been burnt on the column was still unpainted, I suppose, at that place?—Yes, it was still unpainted.

7482. So had you an excellent opportunity of seeing the junction between the piece that was burnt on and the substance upon which it had been burnt on?—Yes.

7483. Was there any crack or separation between the original and the added piece?—Not that I observed.

7484. And if there had been any such, would you have passed the column?—No.

7485. Did any columns pass out of the turning shop with burnt on lugs, where the lugs were not solid to the original metal?—Not to my knowledge.

7486. What part of the bridge did the column go into that had lugs burnt on?—The whole of it.

7487. Were there any that went into the high girders which had lugs burnt on?—Yes.

7488. What was the diameter of the columns?—15 inches.

7489. Were there 18-inch columns too?—Yes, but none of those were burnt on that I know of.

7490. Had you anything to do with the building of the bridge?—Nothing.

7491. Did you see any lugs burnt on to columns 18 inches in diameter?—No.

7492. Then was it exclusively upon columns 15 inches in diameter that lugs were burnt on?—Yes.

7493. Do you know which parts of the bridge those two kinds of columns went into respectively?—Yes.

7494. Which?—The high girders.

7495. Which went into the high girders?—The 18-inch columns.

7496. And where did the 15-inch columns go?—In the inside.

7497. Point out where the 18-inch columns went?—There (pointing to the model).
7522. Did you notice in any column on the side opposite to a scab little holes or holes? — No.
7523. In no case? — I do not remember one.
7524. Did you notice any hole or defect opposite a scab at any time? — Yes, I saw one.
7525. In one case? — In one case.
7526. Do you mean in one solitary case in the two years and eight months that you were at this work? — So far as I observed, I only saw one.
7527. Would you kindly tell us the particulars of that one, because it must have impressed you? — Yes; there was a hole right through.
7528. Right through the side of the column opposite to where the scab had been? — No; I think it was on the same side as the scab.
7529. Then that had been knocked through in taking off the scab? — No.
7530. How had it been produced? — It appeared to be cracked.
7531. But I thought a scab was where there was more than the usual thickness; how did it come in that case that a scab had made a hole? — That I could not exactly say.
7532. But can you say in any way at all? — No; the hole was there.
7533. Was the hole that you saw in a part of the column that was beyond the normal thickness, or in a place which was within the normal thickness? — The thin part.
7534. Was not that a place opposite where a scab had been? — I could not say; I do not remember exactly.
7535. But it was a solitary case; surely you remember it? — I do not remember which side it was.
7536. All you can say is that there was one column presented to you with a hole on one side of it through and through? — Yes.
7537. But whether that was produced by scabbing, or how it was produced, you have no opinion? — No opinion.
7538. Now, coming back to the scabbing proper, you saw some columns where a scab had been chiselled off? — Yes.
7539. In any column where that had taken place did you examine the opposite side of the column to find out whether there was any undue thickness of metal there? — It appeared to be the same to the eye; I could not say that it was thinner.
7540. Externally it appeared the same? — Externally it appeared the same.
7541. In any case did you notice in a column opposite to the place where the scab had been taken off any hole or indentation in the metal at all? — No.
7542. Or any sign of a blow hole at such a place? — No.
7543. Then so far as you could judge or see, the scabbing on the one side had produced no effect whatever on the opposite side of the column? — No; not so far as I could see.
7544. I rather take it that you are not skilled in moulding? — No.
7545. And you really do not know what the effect of scabbing upon the column is? — No; I do not know exactly what effect it would have.
7546. Nor anything about the effect that it would have? — No.
7547. You have said that you have seen blow holes in some of these columns? — Yes.
7548. Were these near or opposite to what had been a scab? — No.
7549. What attracted your attention to the blow hole? — My seeing it.
7550. Seeing a hole in the surface of the column? — Yes.
7551. Unless you saw a hole in the surface of the column did you examine the column carefully to see whether there had been holes that had been filled up? — Not particularly.
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G. Under.

1 March 1880.

7538. So that I suppose a good many columns might have passed with holes filled up with black cement which you did not observe?—I do not think they could.

7539. How do you think they could not if you did not examine the columns particularly to see?—Simply because we were moving along from one end of the column to the other, going from end to end of the column.

7540. If it was a hole filled up with black cement, there was nothing to attract your attention to it?—Nothing.

7561. And your only examination, which would have made these holes apparent to you, was the cursory examination of passing from end to end of the columns?—Yes, and handling them.

7562. But in going along the columns or handling the columns from end to end you were not looking for holes?—No.

7563. Nor for filled-up holes?—No, nor for filled-up holes.

7564. The holes that you did discover, and in consequence of which you rejected the columns now and then, were holes which had been left when they came from the dresser?—Sometimes.

7565. Which did you discover most frequently, the open hole or the filled-up hole?—The open hole.

7566. Did you discover any filled-up holes did you discover in the two years and eight months?—I could not say.

7567. Give us an idea?—There might be a hundred or more.

7568. You only discovered a hundred defective columns during the whole time you were there?—Yes; but those were columns that were rejected.

7569. Were they all columns that had the holes filled up?—Some of them.

7570. You are not following my question. How many columns did you reject in which the holes had been filled up by cement?—Well, I could not say to one or two.

7571. But you rejected about a hundred altogether; what proportion of these were rejected on account of holes that had been filled up with cement and discovered by you?—Perhaps 30 or 40.

7572. In the case of these 30 or 40 what was it that attracted your attention to the filled-up holes?—Seeing different colours.

7573. I thought you said a little while ago that the colour of the cement was the same as the colour of the iron?—In some cases only.

7574. Then it was in the cases where the colour of the cement differed from the colour of the iron that you found it out?—Yes.

7575. And not in cases where the colour of the cement and the colour of the iron were the same?—In both of them.

7576. How many of the latter?—Well, I could not say.

7577. But you could give us an idea; you discovered 30 or 40 filled-up holes altogether; in how many of these were the colour of the iron and the colour of the cement the same?—Perhaps there were 10 or 15.

7578. Was not the same kind of cement used on all occasions?—Not that I am aware of.

7579. What kind of cement was it?—I do not know that they had any cement for the purpose. I have seen blue clay put into the holes.

7580. Was that what you were able to discover; was that what showed the difference of colour?—No; that showed pretty nearly the same colour.

7581. What was it that showed the difference of colour?—White cement or cement of a greyish colour.

7582. But a colour that was markedly different from the surface of the column?—Yes.

7583. Did you pick out any of that blue clay?—Yes.

7584. Did you find on any occasion that after you had picked-out a hole, the cement which was in the hole was different from the colour that was on the top of it?—No.

7585. Are you quite sure of that?—Quite sure.

7586. When you rejected these columns, do you know what was done with them?—Yes.

7587. What?—They were broken up.

7588. Did you see them broken up?—Yes, very often I saw them broken up.

7589. At once?—At once.

7590. Does that answer refer to a great many of the rejected columns?—The great majority.

7591. Then I think you said these broken-up columns were used for re-casting in the cupola?—Yes.

7592. Are you aware of that, or is it merely what you have heard?—What I have seen.

7593. You have seen these broken-up columns being put into the cupola?—Yes.

7594. To mix with the iron?—Yes.

7595. You said that the scab, so far as you were of opinion, had no effect upon the strength of the columns?—I would not think so.

7596. Have you any particular scale as to what affects, or what does not affect, the strength of a column?—Not if it is not visible.

7597. But supposing that you saw a scab on a column, are you in a position to form an opinion as to what effect that would have on the strength of the columns?—No.

7598. So that it might, or might not, have affected the strength of the column, so far as you know?—So far as I know.

7599. You have seen a blow hole, I suppose, when the pipe has been broken?—Yes.

7600. You have seen the full extent of it?—Yes.

7601. What appearance does it present?—It appears to be clear in colour.

7602. What appearance does the hole present; it is a distinct hole, a distinct vacuum, is it not?—Yes.

7603. With a little nodule of iron in it?—Yes, sometimes, and sometimes without it.

7604. What depth of hole did you think it safe to pass?—I have seen them a quarter of an inch deep.

7605. And what diameter?—About the same, from that to three-eighths of an inch.

7606. A hole like that you did not think it necessary to report to your superior?—No.

7607. Was anything done with the hole, or was it left when you had done with turning the column?—As it came to you?—It was painted after that.

7608. But before it left your shop was anything done to fill up the hole?—Nothing.

7609. So that so far as you know the columns went to the jetty as they came from your shop with this difference only, that they were painted?—Painted, and the holes filled up.

7610. Who filled up the holes?—The dressers generally—it was them that painted the columns.

7611. The columns went to the dressers after they left you?—Certainly, to be painted.

7612. And they may, or they may not (for you don't know it, I suppose), have filled up those holes?—I have seen them filling them up.

7613. What was the use of filling them up?—To make them easier to paint.

7614. What was the difficulty of painting over the holes?—Well, it looked bad.

7615. It was a mere matter of appearance then?—Yes.

7616. You have told us the size of a hole that you would have passed, what was the smallest hole that you reported?—Well, I have seen several nearly through the flange.

7617. Take the columns first, what was the smallest hole that you saw in a column and reported?—Well, I should think it would be about half an inch.

7618. Half an inch in depth?—Yes.

7619. And what in diameter?—About the same, narrowing as it got to the bottom.
TAY BRIDGE DISASTER:

G. Fander. 1 March 1886.

7620. But that is the smallest hole that you remember ever reporting?—Yes.

7621. And anything that was within that mark you passed?—Not if it was very bad.

7622. If the smallest hole that you reported was half an inch in diameter, and half an inch in depth, anything that was less than half an inch you did not report?—Sometimes I did.

7623. Did you notice my question, "What was the smallest hole that you ever reported?" and you said, "Half an inch in diameter, and half an inch in depth?"—Thereabouts.

7624. Did you ever report anything smaller than that?—I don't believe I did.

7625. Then anything up to that point, as a rule, you passed?—Yes.

7626. How many holes have you seen in one column?—Never above one large one.

7627. How many small ones?—I have seen a few small groups.

7628. Grouped together?—Grouped together.

7629. Did you ever reject a column on account of a number of small holes grouped together?—Yes.

7630. How many?—Well, I could not say; there might have been a dozen grouped together.

7631. But how many columns did you reject or reject in consequence of these groups of holes?—I could not say.

7632. When you found these groups of holes, as a rule, what was their average size?—They would be three-sixteenths of an inch upwards to perhaps about three-eighths of an inch.

7633. But you did not report these?—Yes, if they were in large groups.

7634. How many columns did you report of these that had holes from a sixteenth of an inch to a quarter of an inch in size grouped together?—I should say a dozen, perhaps, altogether.

7635. But I suppose there were a great many columns that you passed that had groups of holes smaller than a quarter of an inch?—Not very many.

7636. How many holes were there in a group, as a rule?—Well, I have seen five or six.

7636a. And I suppose you have passed columns with groups of five or six holes if they were small?—Yes.

7637. The effect of that upon the strength of a column you do not know?—I do not believe that it would have any material effect.

7638. But are you not a man who is enabled to form a skilled opinion upon that subject?—I could not test them.

7639. And it was not within your business?—No, it was not.

7640. You talked of the lugs; did those always come to your shop as a part of the original casting?—Yes.

7641. You know that lugs are burnt on sometimes?—Yes.

7642. Do you know a burnt-on lug from an original lug when you see it?—I can tell that before it is painted.

7643. Did no column ever come to your turning shop where the lug had been burnt on either wholly or in part?—Oh, yes.

7644. Many of them?—Many of them.

7645. And were they passed?—They were passed.

7646. And they went to the jetty?—They went to the jetty.

7647. Do you know whether it is possible to burn on a lug so as to be as completely a part of the column as it had been part of the original casting?—Well, I am led to understand that.

7648. But you yourself do not know it from your own skill in your own craft?—I do not know it.

7649. Did you never see in these burnt-on lugs that there was a crack between the lug and the flange?—Never.

7650. Did you ever look for that particularly?—Not particularly; but I think I would have seen it if it had been there.

7651. You would not like to say there was no such thing?—No.

7652. The moulder that burnt it on would be the best man to say whether there was a crack or not; would he be not?—Yes, he could see it.

7653. He would be most likely to be accurate about it?—Yes, when the column was heated, it would be seen better than when it was cold.

7654. Did you ever notice a crack in the column near the place where a lug had been burnt on?—No.

7655. Would that be more easily seen by the man who was putting on the lug than by you, if it existed?—Well, I do not know, I would see if it existed.

7656. But you would have seen the crack between the lug and the flange if it existed?—Yes.

7657. But the moulder would most likely to see it than you?—Yes, if he was burning on.

7658. And he would also be more likely to notice the crack in the column if it happened in that burning-in of the lug?—Yes.

7659. From first to last in that turning-shop you never saw a lug that had been burnt on, that showed signs of a crack between it and the flange?—I never saw one.

7660. Your business was, I suppose, to dress the surface of the columns more than anything else?—More than anything else.

7661. (Mr. Traill.) Did you do anything to the surface of the columns from end to end?—Not further than to trim it up.

7662. How did you trim it up?—By placing blocks or the body.

7663. Did you trim it up in any way with a chisel or tool?—No.

7664. Then the column from end to end was left as it came to you?—Yes, it was left as it came to me.

7665. What you did with the lathe was to turn the ends?—Yes.

7666. And that was the only thing for which the column came to you?—Yes, the only thing, and to get bored as well.

7667. (The Commissioner.) For the flanges to be drilled?—Yes.

7668. (Mr. Traill.) And I suppose if you got the ends turned, and the flanges drilled, you had really nothing else to do with the column whether it was entire or not entire?—Nothing else to do with it.

7669. And anything that you may have seen therefore about these holes, was from casual observation rather than in the fulfilment of your duty?—It was no duty of mine.

7670. You said you spoke about burning on to Strachan and Ferguson, and asked them if they thought it was as strong burnt on as if it had been the original casting?—Yes.

7671. What did they say?—They said it was.

7672. Both of them?—Both of them.

7673. Did you speak to them separately?—Yes.

7674. They were there at different times?—Yes.

7675. Why did you speak to Ferguson about that?—To see if his opinion coincided with that of the foreman who was there before.

7676. Had you any reason to doubt the correctness of the previous foreman's opinion?—I had no reason to doubt it, only I wanted more information.

7677. You told us that you had the charge of turning all the columns that were cast at Wormit?—Yes.

7678. And you mentioned, I think, that those were through the whole of the high girders?—Through the whole of the high girders.

7679. And you said from pier No. 50?—Yes.

7680. What pier is that?—That is No. 60 from the north side.

7681. Where were the other columns cast?—I could not say exactly.

7682. Did they come to the ground cast?—They came to the ground turned, and cast, and dressed.
Re-examined by Mr. Baljyou.

7683. Let us understand about these scabs; what quantity of metal would you suppose had been chiselled off from the surface of a scab?—Well, I should think perhaps one-eighth or three-sixteenths of an inch in thickness.

7684. Over what surface?—Well, I have seen perhaps a foot long nearly.

7685. And what breadth?—From 3 to 4 inches across.

7686. There would be very little weight in that?—There would be very little weight.

7687. What is the weight of one of the 15-inch columns?—I could not exactly say what it would be altogether.

7688. Should you say that it would be from 16 to 20 cwt.?—About 12 to 14 cwt. I have seen the weight, but I do not exactly remember what it was.

7689. Do you know the weight of the 18-inch columns?—Yes, they were about 17 to 18 cwt. I believe.

7690. Do you think that any chiselling off to level down a scab could affect the strength of the column?—Not materially.

7691. Mr. Trayner asked you a question about whether you would see the cracks that were in the column before it was hot or when the column was cold. When would you see them best?—You would certainly see the crack best, if there was a crack, when the column was hot.

7692. Would not the crack reveal itself when the column cooled and the metal contracted?—In some cases.

7693. I have thought that when the column was hot, the crack would have been tightened up; and that when the column cooled down, and the metal contracted, and the two sides of the crack departed from each other, then the crack would reveal itself; is that so?—Yes.

7694. Then which is it? (Mr. Trayner.) It was not my suggestion, for it startled me as much as it surprised you.

7695. (Mr. Baljyou.) Which is it?—I think you would see it best when it is cold.

7696. (Mr. Trayner.) You saw one hole that went through and through the column?—Yes.

7697. What size was it in diameter?—About half an inch.

7698. (The Commissioner.) The columns first were cast by the moulders?—Yes.

7699. Then they passed directly into the hands of the dressers, did they?—They then passed directly into the hands of the dressers.

7700. They did not come then into your hands?—No, not from the moulder's.

7701. And they cut off the scabs and trimmed them up, did they not?—Yes.

7702. And then and only then did they come into your hands?—Then and only then did they come into my hands.

7703. And then you passed them you passed them back to the dresser, did you, and they painted them?—Yes.

7704. Will you tell me how it is that you know those scabs which had been cut off by the dresser were only one-eighth to one-sixteenth of an inch thick?—Simply because I have seen them cutting them off.

7705. How was it that you saw them cutting them off; it was in a different part of the shop, was it not?—No, just immediately behind me I have seen them cutting them off.

7706. Then those that you have seen them cutting off have been from one-eighth to one-sixteenth of an inch?—From one-eighth to three-sixteenths of an inch.

7707. But scabs might have been bigger than that, might they not?—There may have been some a little bigger than that.

7708. Was it your duty to overlook all these columns for the purpose of saying whether they ought to be passed or ought not to be passed?—It was my duty to report it if I saw anything.

7709. But was it your duty to pass these columns or not?—was it your duty to overlook them with a view of seeing whether they should or whether they should not be passed?—No.

7710. It was no part of your duty?—No.

7711. And even if you had seen any defect you would not have known what the character of that defect was or its influence on the strength of the column, would you?—Well, I would have had an idea.

7712. But if you saw a scab one side you would not know, would you, whether or not the sand which that scab filled had entered into the composition of the iron on the other side, and so weakened it?—I do not know what effect it would have.

7713. And your only knowledge whether a burnt-out lug would be as good as an original lug, is because Mr. Strachan and Mr. Ferguson told you that it would be quite as good, is it?—Yes.

7714. Was it the only reason you had for saying it?—That is the only reason I had for saying it.

7715. Then we are quite to understand that after you had planed columns, if you observed nothing to which you thought it necessary to call the attention of your superior, they passed at once into the hands of a dresser to be painted?—Yes.

7716. (Col. Yolland.) Had you instructions that there was to be a socket on the end face of each column, a sunk part on one, and a raised part on the other, that was to be placed on the top of it?—Yes, I had instructions as to that.

7717. And were those raised parts and those sunk parts prepared and made in all cases for the columns that were set up?—Yes, they were turned all the same size.

7718. The 15-inch ones?—The 15-inch ones.

7719. Were all those for the high girders turned while you were superintending the work?—They were all turned certainly under our observation.

7720. And you believe that there was this sunk socket in the one column, and that the other that went into it had a raised surface?—Yes.

7721. Were those turned to certain dimensions?—Yes.

7722. Do you recollect at all what the diameter of the centre of the socket was right across?—13 inches, I think that it was.

7723. What was the depth of the sunk part, one-sixteenth or three-sixteenths, or what?—I should say it would be about three-sixteenths or a quarter of an inch.

7724. And then the column that went on to that would have a raised part of nearly the same dimensions?—Yes.

7725. Do I understand you rightly that the drilling of the flanges through these columns was done under your superintendence?—Yes.

7726. What size were the holes made for the 15-inch columns?—The holes were an inch and one-eighth, and we bored them a little bigger to give them clearing room.

7727. You made them larger than an inch and one-eighth in diameter to give them a little more freedom?—Yes.

7728. For the 18-inch columns were the holes made the same size?—The holes were cast in the 18-inch columns.

7729. Was there any raised part and a socket in these 18-inch columns?—Yes.

7730. On all?—On all.

7731. When you were making the holes by means of a drill through the flanges of a column, were the two columns put together so that you made the hole in the top column and the hole in the bottom column at one and the same time, or was it done separately?—Separately.

7732. Then you saw some of the columns which were rejected and broken up?—Yes.
7733. Can you at all say whether there was any unequal thickness in the metal of these columns where they were fractured, or were they of equal thickness on each side? -I have seen them of different thicknesses.

7734. What do you think was the least thickness that you had in these columns? -The least thickness that I saw was five-eighths of an inch, I believe.

7735. And the greatest thickness? -One and a half inches.

7736. (Mr. Barlow.) With regard to the lugs: each of these diagonal braces are held in a pair of lugs, is it not; there is a lug on each side of the brace? -Yes.

7737. When you speak of a lug being deficient, do you mean one of these two lugs, or do you mean that both are deficient? -Sometimes one and sometimes both.

7738. Was it ever the case that a part of each lug was deficient or was the entire lug deficient? -I have seen only one deficient.

7739. But in the case of the one that was deficient, was it the whole of the lug that was gone, or only a part of it? -A part of it.

7740. When the other lug was burnt on, did they burn on the remaining part? -The remaining part.

7741. Supposing that a lug was 3 inches deep and that an inch and a half of it was gone, what they burnt on was the remaining inch and a half? -Yes.

7742. And they trusted to the joint formed between the new metal and the old? -Yes.

7743. Did they work day and night at your place? -Part of the time.

7744. Were you there on day duty? -Yes.

7745. You cannot speak to what took place in the night when you were not there? -I generally looked at them the next morning.

7746. Why were the holes in the 18-inch columns cast in whilst those in the 15-inch columns were bored? -Our machine would not take the 18-inch columns in; that was the reason.

7747. That was a matter for the convenience of the contractor? -Yes.

7748. Do you know whether the specification required the holes to be bored in the 18-inch columns? -I do not know.

The witness withdrew.

ROBERT MILLER sworn.

Examine by Mr. Balfour.

7786. What are you? -A moulder.


7788. You were, I believe, at the Tay Bridge Foundry at Worn for nine months? -Yes.

7789. When Mr. Ferguson was foreman moulder? -Yes.

7790. Can you give us the months when you worked, or can you only say that it was during Mr. Ferguson’s time? -I think I went there in December 1875 and left in either August or September 1876.

7791. Are you right about the months? -I think so; it was either August or September, I do not remember which.

7792. But it was when Mr. Ferguson was there? -Yes.

7793. And at no time when Mr. Strachan was there? -No.

7794. Did you work in the moulding shop casting the columns? -Yes.

7795. What part of the work did you do; did you help to cast the columns? -The part that is high.

7796. The part, you mean, to support the high girders? -Yes.

7797. What was the diameter of the columns that you helped to cast? -18 inches.

7798. Was the casting conducted carefully? -Yes.

7799. Were you particular about it? -Yes.

7800. Did you produce good work? -Yes.

7801. Have bad castings sometimes come out? -Yes.

7802. What was done with them? -They got the hammer.

7803. What did you do by that? -They were broken up.

7804. And put in the furnace and melted over again? -Yes.

7805. Were any of the bad castings that came out sent down to be built into the bridge? -Not that I know of.

7806. Did you sometimes have a scab on the columns? -Yes.

7807. Will you describe the kind of thing it was? -Just the iron—in taking away the sand it left it a little higher.

7808. Is that a common incident in moulding? -Yes.

7809. What did you do with the scab, or what was done with it? -It was chipped off—the dressers chipped it off.

7810. What was the thickness of any of the scabs that you saw? -About one-eighth or one-fourth of an inch the thickest I ever saw.

7811. Was that a seldom thing, or a frequent thing
or raw?—It was pretty frequent for a while until we could get over it.

7791. Can you get the better of it?—Yes, by mixing stronger sand.

7792. What do you mean by that?—I used better sand to mould, making it stronger.

7793. Then you got the better of it in that way?—Yes.

7794. Had you any cold shunts while you were there?—I never saw any.

7795. Did you ever see any lugs or parts of lugs burnt on to the columns when you were working there?—Yes, on the small columns.

7796. Those that are still standing?—Yes.

7797. Did you ever see, while you were working there, any lugs burnt on to the columns for the high girders?—Not to the 18-inch columns.

7798. Or to the 15-inch columns?—Yes.

7799. Some of them that were put into the high girders?—Yes.

7800. Have you seen many lugs burnt on during your time?—No; I did not see a great deal, four or five exceeded all that I ever saw.

7801. Did you see the columns after the lugs were burnt on?—I saw one—I examined one.

7802. What was it like?—I thought it pretty strong as long as the original.

7803. Did you examine the others?—No; I never examined them.

7804. Is burning on a thing well known in moulding?—Yes.

7805. And often practised?—Yes.

7806. Did you see any crack at any part of any of the columns that were sent out to go to the bridge?—Never.

7807. Do you think that those scabs would have any effect in weakening the columns?—No; I do not.

Cross-examined by Mr. THAYER.

7808. I suppose what the effect of the scab on the column would be is not a matter within your skill or knowledge as a moulder—you say that it would not weaken the column. Is there a matter upon which you are able to give a competent opinion?—That is my opinion, that the scabs I saw on those columns did not injure them.

7809. Did you ever see a scab that would have the effect of weakening the column?—No.

7810. What was the deepest scab that you had?—A quarter of an inch.

7811. I mean at any place, not at Wormit?—They were not exactly any, but that is the general state, a quarter of an inch.

7812. So that if there is a scab on one side of the column, there will be less metal than there should be on the opposite side?—No.

7813. Where does the sand go to?—On the top.

7814. On the top of the column is there not less metal without any scab?—Yes, if it all went into the body; it is like dust, it goes right through.

7815. It floats up from the scab—at the place over the scab, would it weaken it there?—It depends on the size of it.

7816. The bigger the scab was at the bottom, the weaker the column would be at the top?—With the same sand.

7817. The weaker the column?—Yes, if it weakened it any.

7818. Sand is not so strong as iron?—No.

7819. The more sand there was, and the less metal, the weaker the column would be?—Yes, if it was all in one part.

7820. When a column is cast, it is intended to take out the lug as part of the original column, is it not?—Decidedly.

7821. Is there any benefit in that, casting the lugs along with the columns?—I do not understand you.

7822. Is there anything gained by the lug being part of the original column, rather than having to put it on a column that has been cast without it?—Yes, it saves the time of putting it on.

7823. Is there any other advantage gained by casting them together?—Are they not closer together than you can ever get them by burning on?—Yes.

7824. That is an advantage, is it not?—Yes.

7825. Have you burnt on lugs yourself at times?—I never did.

7826. Have you had any experience as to whether you can burn on one as firmly as if it had come out as part of the original casting?—I do not understand you.

7827. You say that you have never burnt on a lug?—No.

7828. From your experience, can you tell us whether a lug was ever burnt on as closely to the column as if it had come out of the mould attached to the column?—No.

7829. How long have you been a moulder?—Ten years.

7830. Were you moulding columns with lugs during that time?—Yes, at the bridge.

7831. Did every column that you cast at the bridge come out with lugs on it?—Yes.

7832. Who were working with you in your squad?—There were five of us; there was William Carr, Alexander McKaye, George Nelson, myself, was the fourth. I do not remember the fifth.

7833. Although you never did it yourself you saw lugs burnt on at Wormit, did you not?—Yes.

7834. Frequently?—Three or four.

7835. Do you know what part of the bridge they went to?—No.

7836. Were they 15-inch columns?—Yes.

7837. You said that the castings were broken up?—Yes.

7838. What was the badness in them that led to that?—There was, as I remember, a bursting in at the sides; it made a hole in the sides, and it was broken up.

7839. Of what size was the hole?—Two or three inches, I expect.

7840. In diameter?—Yes; the sand came out.

7841. Do you mean that the mould broke?—It burst in.

7842. Through the mould?—The weight put upon it; the metal going upon it, it gave way.

7843. That was with regard to one of the columns; what was the defect like in the others that were broken up?—The others had burst away at the sides.

7844. Was it the same kind of thing?—No; one of those lugs about the sides of the box came right out; it ran out, and we could not stop it.

7845. And it was broken up?—Yes.

7846. Apart from those two, what kind of castings did you see broken up?—I do not remember any more of those broken ones that I was at.

7847. Those were the only two, were they, that you saw broken up?—That I was working at.

7848. Were those the only two that you saw broken up all the time that you were at Wormit?—[No answer.]

7849. I ask you, were those the only two castings that were broken up during the whole of the time that you were at Wormit?—Yes, of our own castings.

7850. Did you see any castings of other men's broken up?—Yes, small ones.

7851. Fifteen-inch castings?—Yes.

7852. Why were they broken up?—I remember one that burst away the same as the others, and it was broken up.

7853. Did you see any others broken up for any defect except their bursting away in that way?—I do not remember; they were broken up outside; there was many a one broke up that we did not see.

7854. So far as you saw of the castings that were broken up, were those three castings that had burst out of the moulds?—Yes.

7855. And those are the only three that you know about being broken up for defects?—Yes.

7856. (The Commissioner.) Was the iron, of which...
your castings were made of good quality?—I do not think it.

7837. Why not?—By the dress and bodge that rose on the top of it, and the smell it caused.

7839. There was a good deal of dress and scum from it, was there?—Yes.

7869. Used it to run freely?—Yes.

7860. Would it keep hot?—Yes; it kept pretty hot.

7861. Did you ever see any instance of cold shut?—No.

7862. You never did see that?—No.

7863. Did you ever see any of those piers broken up at all?—I have seen those three personally.

7864. None others?—No; I have heard of it only, but never seen them.

7865. If they were imperfect inside, and unequal at the sides, would you not know it?—No; I never saw them.

7866. You said that you never saw any crack in any of the columns that were sent out to go to the bridge, but I suppose after they passed from your hands to the dressers you saw nothing of them?—No.

7867. If there was anything wrong we were generally told about it, that the casting was wrong. The foreman told us about it—Mr. Ferguson.

7868. But if he did not tell you anything about it, you would not know anything about it?—No; we considered that they were all right.

7869. (Mr. Barlow.) Did you ever know of any case of a column being broken up and rejected because of a defective lug?—No.

The witness withdrew.

After a short adjournment,

EA. FERGUSON sworn.

7889. You are a moulder?—Yes.


7891. How long have you been a moulder?—About 22 years.

7892. Did you work in the Tay Bridge Foundry at Wormit?—I did.

7893. Between what dates?—I think as near as I can say was the 25th of April 1875 when I started, and when I dropped it it was the 2nd of June 1878.

7894. Were there some of the columns that were used in the northern part of the bridge cast at Middlesborough?—As far as I can recollect there were.

7895. With the exception of those was the casting of all the other columns done at Wormit?—Except some 12-inch columns that they used from 15 to 47 of the small piers. I think they were about 12 inches in diameter which were cast at Middlesborough, all the rest were cast at Wormit. The 12-inches on the Tay Bridge were cast at Middlesborough, all the rest were cast at Wormit.

7896. (The Commissioner.) Only the 12-inches were cast there?—Yes, as far as my knowledge goes.

7897. (Mr. Balfour.) Were those taken into the piers in the northern part of the bridge, the 12-inch columns?—No, I think they reckoned from the north side of the large columns up to 47 or 46—they are put in as raker columns.

7898. The rakers are at the side?—Yes, just so.

7899. (The Commissioner.) On the north side?—I am not sure whether they extend from No. 27 pier to No. 15. I am not sure that they are on that—they are on those piers of the 15-inch columns were on.

7900. (Mr. Balfour.) Were they all to the north of the high girders?—I cannot tell, Mr. Campbhill or Mr. Delpratt will be the best able to tell you that.

7901. Were there any of those 12-inch columns used in the piers under the high girders?—No.

7902. So that all or some part of the 12-inch columns, which were cast at Middlesborough, are in some part of the bridge that is still standing?—They are all standing and can be seen.

7903. Were all the columns that were used in the construction of the high girders which were cast at Wormit under your supervision?—Yes.

7904. I want to know, not only whether they were cast at Wormit but whether they were cast at Wormit after you came there?—All the high girders columns were cast under my superintendence. Mr. Strachan had nothing to do with them.

7905. How was the casting done, was it well done?—As far as my experience led me.

7906. And carefully done?—Undoubtedly it was.

7907. In casting the columns, did any come out of the moulds defective?—Many of them.

7908. Does that always occur in casting?—Always; in the best regulated foundries you will find defective castings.
you said that sometimes the columns came out scabbed?

—Yes.

7908. Did the scabs vary from being slight and trivial to being material?—Yes, at first when I started I found a great deficiency there round the scab and I worked them on—in fact I put my whole skill into it to see if I could remedy the scabs. I got men to do it.

7909. Did you find what it was due to?—It was due a good deal to the sand.

7910. But you managed to remedy it latterly?—Yes.

7911. Before you remedied it were the scabs somewhat slight and sometimes material?—Yes.

7912. Did they vary very much?—Yes.

7913. Where you thought that the scab was serious, or would injure the strength of the column, what did you do with it?—I sent a labourer and a furnace man and broke it up.

7914. Then when the scab was slight what was done with the column?—If it was trivial and it was no detriment to the column we just passed it as a good casting.

7915. Did you pass any column which had a scab which in your judgment would weaken the column?—Never.

7916. What kind of scabs, what thickness and size of scabs did you pass?—Where I have seen them they may have been about an eighth of an inch thick, about the size of my hand.

7917. In flatness you mean?—Yes.

7918. What was done with a column with that sort of scabs?—I have seen them which were burnt on to the edge of the scab and let it go. I have seen them often chip the scab off, but I would say that there was no use in it because it would be seen as well as any other thing.

7919. What was the weight of column in which those scabs occurred?—They varied a good deal, the columns. There are working columns, and they varied here (pointing to the model) from 21 cwt. to 23 cwt.; these columns here (pointing to the same) varied from 21 cwt. to 23 cwt., and these columns here varied. I have seen them as low as 15 cwt. to 19½ cwt. They varied according to the length.

7920. Were they all of the same thickness, or did they vary?—They were of the same thickness owing to the length.

7921. What was the thickness?—The specified thickness was an inch.

7922. In the case of all of them?—That was the specified thickness, but they were always thicker.

7923. The specified thickness was an inch?—Yes.

7924. But what were they, in point of fact, as cast?—As cast. I am bound to say they ran from an inch and an eighth to an inch and three-eighths.

7925. Did you cast any under an inch?—None.

7926. Do you think that you ever turned out any column with a scab on it which could affect the column more than the additional element of strength that you gave beyond what was specified?—No.

7927. Nor so much?—No.

7928. Did you sometimes find blown holes in the column?—Yes, when I started first I found a good deal of them; they used chaplets when I started first, but I was not in favour of chaplets.

7929. Will you explain what a chaplet is?—A chaplet is a thing for holding down the core; the chaplets we used were about a quarter of an inch thick by about 4 inches to 5, and circular to fit the core with a stalk about three-quarters of an inch thick.

7930. What evil resulted from them?—Whenever hot iron strikes against cold metal it is always sure to fly, or at least very often.

7931. Were the chaplets cold metal?—They were bound to be so.

7932. Were they cold metal?—Yes.

7933. What did you substitute for the chaplets?—I spoke to Mr. Beattie; he was the manager then, and I said, "These chaplets could be taken out," and he said, "Do you think they could stand without it?" and I said that I should not fear, but to make everything sure we will cast new bars a good deal stronger.

7934. New core bars?—Yes.

7935. Did you accordingly cast new core bars of greater strength and thickness?—Yes.

7936. Did you find that those new thickened core bars enabled you to cast pipes free from blowed holes without any chaplets?—Yes.

7937. From the time you devised those you troubles with blowed holes?—I was.

7938. After you devised the thickened core bars, were you troubled with blowed holes?—No. I have seen one or two occasionally, but not to the same extent; in fact, you will find it always.

7939. Are blowed holes then common in almost all castings more or less?—Yes.

7940. If you found in any of your castings blowed holes which you thought would injure the strength of the column, what did you do?—If I thought that there was such a thing, of course I went to the furnace.

7941. You broke it up?—Yes.

7942. Were there sometimes in the columns blowed holes so small that you thought they would not injure the strength of the columns?—Yes.

7943. In the case of those what was done?—Just pass them.

7944. Can you give the Court an idea of about what was the size and kind of blowed holes you thought you would condemn in columns, and what others you would pass?—If it was not deep, say a quarter-inch deep, owing to the extra thickness I gave of metal, I considered that I was giving sufficient strength, even supposing it may have been an inch long, or an inch and a half long and a quarter of an inch deep.

7945. If it exceeded that in length and depth what happened?—The hammer.

7946. Then I suppose that there would be some smaller than that; it is the biggest kind that you would pass, is it not?—Yes.

7947. Did you find the castings come out with defective snugs?—I have seen some come out so.

7948. What was done with them?—They were very often broken up, to the best of my recollection.

7949. Were all of them broken up that came out with the defective snugs or not?—As far as I can remember I think they were, but I am not sure; it is such a long way back.

7950. Were the snugs sometimes broken which had come out right enough from the hands of the workmen?—Very often.

7951. Had you any instances of the snugs being burnt on?—Yes.

7952. What was it?—I have burnt on the snugs.

7953. Were the snugs that you burnt on to remedy the snugs which had come out defective from the mould, or to remedy defects caused by breaking?—To remedy defects caused by the breaking.

7954. Only?—I have seen one or two come out, and if they were not passed, and the defect was not passed the hole for the seating bar, and it was above the hole for the seating bar, I have seen them burnt, but if it was below the hole for the seating bar it was broken up.

7955. In cases where new bars were burnt on that was to unite with the original metal?—Yes.

7956. So as to be quite strong?—Yes.

7957. Did you look carefully at all of those that were burnt on to see whether they had formed a proper union?—Yes.

7958. Had they?—I have seen them when they did not form a proper union.

7959. What happened to them?—I never tried it a second time.

7960. Was it the hammer?—Yes; the hammer again.

7961. Did you ever send any to the bridge to be built into it any column the size of which when burnt on did not form a proper union?—No.

7962. Did you ever send any to the bridge which
7992. Did you ever see any blown holes filled up with cement?—Yes, at the foot of the core, all the square bases; they were for the small piers, and I have seen blow holes in them full of cement, and they can be seen any day yet.

7993. They were all metal castings?—Yes, they went round the piers; the top of the piers.

7994. Did any of the blown holes in them affect their strength?—No.

7995. Have you seen any blow holes in any of the columns filled up with cement?—No, not with cement.

7996. Anything else?—Yes, there was a stuff

called Beaumont egg, which is a thing every founder uses.

7997. What stuff is that?—It is a composition; it is bee-wax, rust, and other things mixed up together.

7998. What kind of holes were filled up with that?—These small bit- of holes.

7999. The little ones you have mentioned which were regarded as inmaterial?—Yes.

8000. Why were they filled up?—Just merely to look like another thing.

8001. Did you ever see cracks in any of the columns? Was there any column sent out to the bridge with cracks in it?—Not to my knowledge.

8002. While you were foreman would you have known of it if there had been?—I do not think the men would have gone past without telling me about a crack.

8004. Were you always in the moulding shop?—I had often to go out to the jetty with regard to the stuff in the forenoon.

8005. Was anything that you had to do incidental to the business of moulding?—What I had to do was all connected with the foundry.

8006. Nothing but what related to the foundry?—No.

8007. Anything else that you had to do related to supplies to the foundry?—Yes.

8008. In it possible that cracked columns could have been turned out of the foundry without your knowing it?—I don't think it.

8009. Had the men instructions to mention any defects?—Yes.

8010. Was there ever any crack in a pipe filled up with putty or with cement to your knowledge?—Not with the cement.

8011. Or putty?—No.

8012. You know of no cracks?—No.

8013. Can you tell us this—you have pay-sheets applicable to the foundry, have you not?—Yes.

8014. I want the dates from the time when Mr. Strachan came till the time that he went—did you make notes on the pay-sheets?—Yes.

8015. Will you give me the dates from the time that Mr. Strachan came till the time he left?—Mr. Strachan started in Wornit foundry on the 27th of July 1874, and left on the 15th day of April 1875.

8016. When did James McGowan start?—He started on the 25th of August 1874, and left on the 28th of May 1876. Richard Baird started on the 27th of December 1876, and left on the 2nd of June 1877.

8017. It would be incorrect to say that he was there for 19 months?—That is the full date.

8018. Then Hampden?—He started the first time on the 18th July 1874, and left on the 31st July 1874; that makes him 12 days working at the Tay Bridge. Then he started again about the end of March 1876 and left on the 6th of April 1876; he wrought 10 days.

8019. When did he commence?—On the 26th March.

8020. To the 6th April 1876?—Yes, he left the 6th of April 1876.

8021. He had been 22 days altogether on the bridge?—Yes, three weeks and four days altogether on the bridge.

8022. From first to last?—Yes.
8023. He was not there six weeks.—No, that is the exact time he went on the bridge.

Cross-examined by Mr. TRAVERSE.

8024. What is your age?—Thirty-five.

8025. And you have been 23 years a moulder?—Yes.

8026. So that you began it when you were 13 years of age?—Thereabouts.

8027. What was your position in Worsam foundry—were you a foreman moulder merely, or foreman of the whole place?—I was foreman of every person under the roof except the turners.

8028. Where were you before you were employed at the Tay Bridge?—I was employed with Mr. W. Thompson at the Tay foundry.

8029. Where are you now?—Now I am with Mr. Thompson at Douglas foundry.

8030. What was the specified thickness of the columns that were to be used in the Tay Bridge?—An inch.

8031. Was that the specified thickness?—Yes it was.

8032. No matter whether they were 15 inches diameter or 18 inches diameter?—No matter.

8033. And all the columns that were found at Worsam and cast there, were inch columns in thickness?—That was the specified thickness, but they were all cast above that.

8034. What did you cast them at?—I have cast them from an inch and an eighth up to an inch and three-eighths, I have seen them. There were very few cases below an inch and an eighth in thickness.

8035. Just tell me, if you please, of what thickness did you generally cast them?—Between an inch and an eighth and an inch and a quarter—about an inch and three-sixteenths.

8036. For what purpose did you put any metal into the mould of any specified thickness?—I just took it upon my own responsibility to do so. I thought it better to give an extra thickness than have them the other way.

8037. Was that your only reason?—Yes.

8038. If you had only poured in hot metal to the extent of an inch in thickness what would the column have been when it came out in thickness?—The mould might have given a little.

8039. Do not you know what the contraction of iron is between its molten state and it cold state?—The general rule is 1/8th part to a foot.

8040. You had, therefore, had you not, to put more into the mould than is an inch in thickness if you wanted to get a pipe an inch thick?—No, I did not. I did not do it with that intention.

8041. It was necessary to do that, was it not?—No.

8042. If you had bored a hole in the mould and the core being exactly an inch and you filled it up with metal what would be the thickness of that pipe when it was cooled?—An inch.

8043. Fully an inch?—Yes.

8044. You made no allowance for the contraction?—A contraction of one inch would be merely a bagatelle.

8045. But you made no allowance for that?—No, never.

8046. If you cast many of those columns three-eighths of an inch beyond the specified thickness you were giving very nearly half as much again of iron as was specified for?—Perhaps I was.

8047. Do you mean to say that you took upon yourself as foreman to use your employer's metal in that way?—Yes.

8048. They never knew it, did they?—Yes; I told them about it.

8049. And they made no objection?—They said I was quite right to do such a thing and they did not object to it.

8050. Is it usual in casting columns of a specified thickness of an inch to cast them an inch and three-eighths?—Very often I have seen it done; I have seen it often cast beyond the specified thickness.

8051. Is it customary to cast a column three-eighths of an inch thicker than the specified thickness, if the specification is an inch?—No, it is not customary in other places.

8052. Those are all 18 inches?—No, the lifting columns are 15 inches.

8053. All of them?—Yes.

8054. Are any of the others, the 18-inch columns, cast an inch and three-eighths?—No, about an inch and an eighth.

8055. May I explain the reason why the inch lifting columns ran a little thicker: we had two patterns for the 18-inch columns, and the pattern we used for them was a little larger than the other part of them in the diameter, and the cores were run up both of the same size, and that was the reason they gave us an extra thickness. For the lifting columns the cores were always the same size; I found a variation of the patterns by about three-sixteenths.

8056. You said that a good many castings came out of the mould defective, and that you had seen as many as four broken up in a morning?—Yes, one morning.

8057. That I suppose will not happen often?—Not very often; it did happen.

8058. Do you remember what was the defect for which those four were broken up that morning?—I do not mind what the defect was, but they were defective any way.

8059. Did you find that they were defective by your own examination?—Yes.

8060. But you cannot remember what the defect was?—No, I do not mind.

8061. It was not usual, was it, to break up in a morning as many as four?—We would not have broken up one or two for two weeks before that.

8062. It was unusual to break up four in a morning?—Yes.

8063. You cannot say what was the cause that led to that unusual result?—I think some of them had bad lugs.

8064. Was that near the beginning of your working?—Yes.

8065. What was the defect about the lugs that you generally noticed on the castings?—A little blown.

8066. Were they always entire when they came out of the mould?—Very often I have seen one or two defects.

8067. On those occasions when they were defective what was the nature of the defect, was part of the lug away?—Yes.

8068. When you got columns with part of the lug away, did you as a rule burn on a bit?—If it was above the hole for the bracing bar I would have burnt it on, that is the hole to hold this bar here (pointing to the model); if it was above that I would have burnt it on, but if it was below I would have thrown it aside and broken it up at once.

8069. Is the burning on of lugs a common thing in the moulding shop?—Yes.

8070. Quite common?—Yes.

8071. Which is the strongest; the lug which comes out as part of the original moulding or the one that is burnt on?—A lug that is properly burnt on I consider as strong as the original lug.

8072. Would it not be as well to cast columns without lugs and then burn them on after?—Certainly not.

8073. You do prefer to have columns cast with lugs?—A lug is just as good burnt on as if it were cast on.

8074. The only difference in the two cases in your mind is that to cast them with the column is cheaper than to burn them on afterwards?—Certainly.

8075. Except in regard to expense there is no difference?—Yes, if it was brought to a certain point.
1880. Terrill *ith the whole lug burnt on pwoa.

1894. Undoubtedly. As a matter of fact it would not suppose that the iron that you were pouring on?—It would be in here be pure enough. (describing the molten metal thnt you were pouring on?—Tcs, after you 8113. As a matter of fact it would not make a safe job. it '-No.

2005. But it can be done, can it not?—It would not make a safe job.

2006. Suppose that that did not take place, and suppose that the iron that was adhering to the column was not melted and was not brought up to the same state of heat as the metal you poured in; in that case would they fuse completely?—No.

2007. Therefore if you were pouring hot metal, that is, molten metal, against metal which was cold you would never get a perfect joint?—When we are burning we use a rod to feel the metal, we tell by the feel of the rod.

2008. If you pour this molten metal against metal that is cold, you will not get the two to make a perfect joint, will you?—No, because you must pour on the metal until you melt the other, to make it adhere.

2009. Unless you get the metal that you are pouring it on up to the same state of heat you will not get a perfect adherence, will you?—No.

2010. About the scabblings, they are produced by the washing away of the sand out of the bottom of the mould—the molten metal going in displaces the sand and that makes the scab?—Yes.

2011. The sand that is washed away floats to the top?—Sometimes.

2012. Generally?—Yes, perhaps not in the pipe.

2013. Where will it float to?—It may adhere to the core spreading round.

2014. In any case, whatever the sand adheres to, if it adheres to the core it will make an inequality in the thickness of the pipe to the extent of the sand that has been washed away?—The sand, when the mould is seablub; is not lifted in a body, but gradually.

2015. Do not you find, as a man of large experience, that when sand is washed away at the bottom it rises on the surface of the metal it goes round the core?—Sometimes.

2016. As a rule?—Yes, as a rule it will.

2017. And mixes with the metal on the top of the core?—Yes, spreads through it.

2018. There was when you had a scab there is less pure metal outside the scab than you would have if the scab had not taken place?—Not right outside— the sand must be away at the other end of the casting altogether.

2019. As a rule the sand rises with the metal from the scab to the top, does it not, and you have to clear it?—No.

2020. If that is not right perhaps you will correct it?—It will not rise exactly to the top, it will rise with the top of the iron and it may run away at the end of the column.

2021. Did you ever see a scab where the iron had risen just to the top of the column outside where the sand was?—Very rare.

2022. On such rare occasions when it had happened, there was less pure metal outside the scab, was there not, than there would have been if the scab had not taken place?—I do not think it made any difference to the column.

2023. Was it so in point of fact?—Will you put the question again?

2024. If the sand rose with the metal to the top of the outside place, where the scab was, would there not be less pure metal there than there would have been if the scab had not taken place?—Yes, the metal would be pure enough.

2025. But less metal, and just so much less as it is occupied by the scab?—The small quantity it would be would not be worth speaking of.

2026. As a matter of fact it would not be so; it would be so, would it not; what was the thickest scab that you ever saw on any column at Wormit?—From one-eighth to three-sixteenths.

2027. The excrescence on the surface of the mould?—Yes, just so.

2028. Did you ever examine to see whether the column outside that scab was thinner or thicker than it should be according to the scab and the shape of the mould?—I can hardly tell that.

2029. Did you ever examine to see?—I have examined, but it is hard to tell.

2030. Did you break up any pipes that were seablub?—Yes.

2031. Could you tell me whether, in the case of the pipe you broke up, the metal outside the scab was thinner than the specified thickness?—No.

2032. It was not?—No.
There might be a little sand below, but the specified thickness would be there.

8121. In fact you would have poured in more than was necessary for the specified thickness?—No.

8122. Is a scarf of any importance at all in dealing with the sufficiency of the moulding: or, in other words, does the scarf, in your opinion, affect at all the stability or completeness of the column?—If the scarf is that serious it is bound to do it.

8123. What is, in your opinion, a serious scarf on a column an inch thick?—That depends upon how you see the dirt that has come off the scarf; a scarf might be six-twentieths of an inch thick, and it may be three-sixteenths thick, that would not be a serious scarf.

8124. My question is what would be a serious scarf, and what would not, what would be a serious scarf?—If you see a column scabbaged from end to end that will be a serious scarf.

8125. Did you ever see that?—No.

8126. What would be a serious scarf less than that?—A scarf might be 7 or 8 inches by 4, about 7 or 8 inches long by 4 or 5 broad.

8127. What depth?—A quarter, fully.

8128. In your opinion, as an experienced moulder, is there scarf about two of those dimensions scarred in a column an inch thick?—No. I should not consider it a great deal; but if it was much bigger than that I should think it would be serious.

8129. Would you consider that serious?—Yes.

8130. But anything under that would you not consider serious?—Unless it came a good deal below that, I should not consider it serious.

8131. If you think that less than that is serious so; and if you think that nothing less than that is serious, say that?—I would say that it would be serious if it was gone below that—not very much below it, then.

8132. You have put it in figures, I think?—It may be from 3 to 4 inches broad by about 7 inches long. I would not consider that a serious scarf.

8133. Would a scarf such as that which you say is a serious one have any effect on the opposite side of the column from it?—It would.

8134. What?—It would have a tendency to make a sort of weakness at one part, the sand and the metal together; but if the sand was spread over the casting it would have no effect upon the strength, if it was all together it would leave a large hole.

8135. Or a group of holes equally dangerous?—I should consider a group of holes as sound altogether.

8136. How many columns do you think you broke up at the Waunfawr foundry, from first to last, on account of scarfing?—I could not say; I broke up a good few; I am not certain.

8137. Were they in tens or hundreds?—I suppose I have broken up for scarfing between, say, from 30 to 40, at a rough estimation.

8138. You understand my question, that was over the whole two years and better that you were there?—Yes, certainly.

8139. Were these scarfing defects at any particular period, or did they extend over the whole period of your service?—It was more when I started there.

8140. Within the first few months?—Yes, within the first few months.

8141. And after that there was practically no scarfing?—Very little.

8142. Blow holes are dangerous things in a column; what sized blow hole would you pass as not affecting its strength?—About 1 inch and a quarter long and a quarter deep, or thereabouts. On three or four times you would pass a blow hole an inch and a quarter long and a quarter inch deep?—Yes.

8144. In an inch column?—Yes.

8145. Tell me the dimensions of a blow hole that you would not consider it safe to pass?—If it was gone above that I would break it up.

8146. How many do you think you broke up from defects arising from blow holes?—I could not say.

8147. You saw 30 or 40 broken for scarfing; give us as near as you can the number broken up for blow holes?—I could not exactly say. I do not keep a note of all these things.

8148. You did not keep a note of the others either?—I could not say, 20 or 30.

8149. But it was an exceedingly small proportion of the castings that were made that you broke up?—Yes.

8150. You broke up 20 or 30 of those for blow holes and 30 or 40 for scarfing, so that you broke up altogether 60 or 70 castings?—No, they were broken up for other defects besides blow holes and scarfing.

8151. What other defects?—I have seen a good few broken up for the defects of the sand giving way at the part, we do not count that a scarf, we count that a drop.

8152. Was that where the mould burst away?—No.

8153. What defect in the top part was it?—The sand had given way between the weak parts (describing it); it is not shown on the column, but there are brackets all round the column to strengthen it. Between the bracket and the pocket the moulder forgot to put in iron to strengthen the sand and it gave way, and therefore it was a defect.

8154. You broke up some for that?—Yes, I broke up a good many for that too.

8155. I want to get at the number of columns that you broke up during the time you were there; how many did you break up for this cause?—I could not say. As far as I remember there would be a good number of those too.

8156. More for that than for any other cause?—No.

8157. How many do you think?—There might have been a dozen for that cause.

8158. Have we got, do you think, the whole of them if we say that you broke up about a hundred columns from beginning to end?—No.

8159. How many thou?—I have broken up over a hundred columns.

8160. How many more?—I have broken up I suppose for defect of one kind and another about 200; perhaps the turners rejected them, and one thing and another.

8161. What did the turners reject them for?—I have seen them reject them if the flaws were too thin.

8162. Did the turners ever call your attention to holes filled up with cement, or with Beauamont egg?—Yes, I have seen him doing that several times.

8163. How many times?—I do not mind how often, but several times.

8164. Did they do it often?—Not very often, I could not mind the exact number of times that he did it.

8165. Where did you make your last examination of the columns before they were sent down to the pier?—Well, I have gone over looking for them after they came from the turners very often.

8166. Did you make it a practice?—I have seen Mr. Campbell send to me for, and send all the columns to line. When I picked out the columns of course I made an examination then.

8167. As a rule, did you examine them after they left the turner's shop?—As a rule I did.

8168. Was that before they were painted, or after they were painted?—At both times. You could not examine them after they were painted very well.

8169. You did not examine them after they were painted, I suppose?—No, before they were painted.

8170. When you examined them after they came from the turner's shop, it was before they were painted?—Yes, certainly.

8171. And if you examined them in that way I suppose you had them passed as ready for going to the pier when orders came from the pier to have them sent down?—Just so.

8172. Did you know that the men had either cement or Beauamont egg for the purpose of filling up holes?—I never knew them have cement for the filling up of holes in columns.

8173. Did you know they had the other?—Yes.
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F. Ferguson.
1 March 1880.

8174. But I suppose you would not have authorised them to use it for filling up a hole that was in your opinion a dangerous hole to remain in the column—Certainly not.

8175. Do you not think they may have done it sometimes without your knowing?—Perhaps they might.

8176. Where was that Beaumont egg kept?—I have seen the dressers keeping it.

8177. So that they had the opportunity of using it if they wished?—Yes.

8178. I mean they had not to come to you for it every time they wanted it?—No.

8179. What did you think of the iron that was used for the columns?—Well I would not like to say that it was the best, but as a general rule for building work it was not what you would call terribly bad iron.

8180. Is that all you will say for it?—The iron manufacturer will speak for himself.

8181. But is that all you will say for it, that it is not terribly bad?—Yes.

8182. What do you mean by building work?—It was very hard iron, and I would not like to put it into machinery.

8183. Do you include piers in building work?—Yes, it is an iron generally is used for all building purposes.

8184. Is a great deal of it used in this town of Dundee for building purposes?—Yes, for building purposes.

8185. You were asked whether a man might not have filled up a dangerous hole with Beaumont egg, or with cement, do you think that if they had filled up a hole of such a size as to be dangerous it would have escaped your notice and also the notice of the turner?—I do not think it, and I do not think any of the men would do such a thing.

8186. Had they any inducement to do such a thing?—Certainly not; they were honest men and they would not have done such a thing.

8187. If they had been paid by the piece it might have been different, but they were all on day wages, were they not?—Just so.

8188. (The Commissioner.) I think you said that all the columns passed under your observation before they were sent on to the dressers?—Yes.

8189. You examined them to see if they had any defects in them?—Yes.

8190. And if they had any defects which you considered serious, you took it upon yourself to break them up?—I took it upon myself and at other times I got my superior's permission before I did such a thing.

8191. But there were many cases in which you took it upon yourself to break them up?—Yes.

8192. They then passed from your hands to the dressers to chip off the irregularities?—Yes.

8193. And you have told us that the dressers could have no object whatever in filling up any cavities?—Yes.

8194. In fact there would be no cavities of any consequence, would there, because they had passed from your hands without any such cavities?—No, I do not think there would be.

8195. Then by the time they got to the turner there could be no such cavities at all, could there?—No.

8196. Then if he has told us he has found cement in some serious cavities and had dug it out, and had then condemned the column, you think there must be some exaggeration in what he says, do you?—No, I could not say in regard to that.

8197. If you examined the columns before they left your hands to see that there were no serious holes, and if you say also that the dressers certainly would have had no interest whatever in filling up any of those holes, how is it possible that they could have got into the turner's hands with some of those holes filled up with cement?—Well, I do not know.

8198. You cannot make that out?—No, I could not make that out.

8199. What was the objection to this iron that you said made terribly bad iron; was it sluggish?—Well, it was a little sluggish. I found that if the men did not puddle very often the way I wanted it, they raised a good deal of scum. If they stirred the iron properly from the bottom of the ladle, I found it pretty good iron, but if they were careless and threw up the iron and cooled it upon the top, it made it sluggish; but if they raised the iron from the bottom of the ladle, I found it always a good deal better in that manner.

8200. But if it was rather sluggish, was it?—Yes, it was sluggish.

8201. Did you ever know of any of your columns having a cold shut?—No.

8202. Did you ever condemn any one for it?—No, I never noticed any cold shuts upon them, I have seen them a little clean, but I have told you what you would call a cold shut mark upon the column.

8203. It might have been there without you seeing it on the outside, may it not?—Perhaps it might.

8204. Supposing that the core got out of place, I suppose you would have the column thicker on the one side than it would be on the other?—Yes.

8205. Did you ever look at it to see whether it was so?—I have tried the columns very often before they were cast, and the way I tried the columns was this: I tried the thickness of the clay; that is the general rule how moulders try all metal; I have put it on top of the core and made them hold the box on the top of it, and then the box pressed the clay through down to the thickness, and then after they lifted up the top of the box again in a moment you would see the thickness of the column, and then if it was defective they had to alter the core. I always did that, and then I did that it was always unknown to the moulders at what day I should do it and at what minute, so that I would take them unawares.

8206. You have told us that you never cast on a lug if it was broken below the hole in the lug?—I mean to say that when it came out of the foundry I never cast on a lug below the hole, but if a lug was broken off below the hole in casting out of the yard with a clean break I would have burnt it.

8207. Do you say, as a fact, that if you pour hot metal on to cold iron it will fuse the iron so as to make a completely close joint?—Yes.

8208. Or did you heat the end of the lug before you poured the hot metal upon it?—The way you burn it is thus: you have to put a large fire and heat up the column to a certain temperature before you can put the iron on, and if the column is not up to a certain temperature by pouring the iron on you are sure to break the column. If you were to start and burn on a cold column you could not do it.

8209. You would break the column if you did?—Yes.

8210. Therefore you had to heat it up to a certain point?—Yes.

8211. And if it was not heated up to that certain point it would break the column?—Yes.

8212. And if it was heated up to that point the pouring of the hot metal on to what I may call the base of the lug would fuse the base of the lug?—Yes, it would soften it.

8213. Would it fuse it?—I do not understand your question.

8214. Do you not know what fused metal is; would it melt it?—Yes, it would melt it.

8215. That is fusing it; it would melt it, would it?—Yes.

8216. And only in the event of its melting it would you get perfect union?—You could not get it in any other way without you melted the original iron.

8217. After the columns had passed your hands and gone into the dressers' hands, did they come back...
again into your hands or did they go then to the planner?—They went to the turner.

8218. And then they went to the dresser to be painted?—Yes.

8219. And then you did not see them after that until they went down to the jetty, did you?—Many a time I went up and looked at them.

8220. But they did not pass regularly under your own observation?—No.

8221. You had nothing to do with them after they left your hands?—They were all under my supervision until they were painted.

8222. The painters were under your management, were they?—The painters were merely the dressers.

8223. The dressers and the painters were the same persons, and they were under you, were they?—Quite so.

8224. You said that if there was plenty of rain that you used the rain water for the moulds; that sometimes there was plenty of rain and then you used soft water?—Yes.

8225. Then you preferred to use soft water to salt water, did you?—It is a little easier for the men to work with fresh water.

8226. Why?—Because it is softer on the hands and the salt water raises such a steam and makes such a heat that it destroys the men's clothes; so much so that every moulder would prefer fresh water before salt.

8227. You would prefer fresh water if you could get it?—Yes. And there is another thing, the tools do not rust with fresh water, and with salt water you could hardly lay them down on the sand and lift them up without their being rusted.

8228. (Col. Yolland.) Had you many cases in which the columns were cracked when you were burning on the lugs?—I have seen them cracked when we burned on the lugs.

8229. What was the extent of these cracks?—I have seen them vary, maybe on the packet here (pointing to the mould) from 3 to 4 inches.

8230. Did you ever see them as much as 14 or 15 inches?—Never.

8231. Did these cracks extend to the inside of the metal?—I never saw them on the body of the column all the time I was at the Tay Bridge.

8232. You never saw them extend through the thickness of the column?—No, the only crack that I ever saw was on the lug; I never saw a crack on the body of a column after burning.

8233. You never saw a crack on the column?—No, it was always on the lug.

8234. Then you had no occasion to condemn the columns on account of the cracks on them?—I would not pass them if they were cracked.

8235. But you had no occasion to condemn them on account of your observation?—You never condemned any on account of cracks in the column?—Yes, I always condemned them when they were cracked.

8236. Do you or do you not keep an account of the columns that you are obliged to break up for any defects whatever?—No.

8237. Do you not make any return of them to your superiors?—No, I do not.

8238. (Mr. Barlow.) You stated with regard to these columns which had the lugs burnt on that they were used from No. 15 to No. 27; that is to say, somewhere in that part of the viaduct; was there any other part of the viaduct in which they were put?—On the north side of the large girders.

8239. That is from pier No. 41 northward?—Yes.

8240. Was there none put in where the columns were cracked?—I saw them varied many on the packet here do not rust with fresh water, and with salt water you never condemned any on account of the cracks on them?—I would always put them in the proper position.

8241. What was the extent of those cracks?—I told you before, it went to about 3 to 4 inches.

8242. And then they went to the dresser to be turned out. Was there any employment of the columns in the foundry?

8243. Those were the large columns, the 18-inch columns?—Yes, and the 15-inch columns the same; the 15-inch columns were cast with a recess. In a large column, an 18-inch column, the recess was turned out.

8244. What I mean is this; was there anything projecting from below the flange of one of them which fitted down?—You want to know if it is a male and female bearing, as we term it?

8245. Yes, that is what I mean; do you know that?—Yes, there was male and female bearings to every column.

8246. To every one of them?—Yes, both 15-inch and 18-inch columns; there were male and female bearings.

8247. And there were none of them cast without it?—None.

8248. They were all cast with it, were they?—Yes.

8249. (Mr. Balfour.) Was that on the high bridge that was last put up?—Yes.

8250. Was there any projection which went down into the one below any plot, or anything of that kind?—The large columns, the 18-inch columns, had a sort of recess turned out of a centre, so that the column fitted properly.

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8271. And there were none of them cast without it?—None.

8272. They were all cast with it, were they?—Yes.
TAY BRIDGE DISASTER:

8269. And they had flaws at each end, had they not?—Yes.

8270. So that you do not know whether or not the inside of the columns was or was not defective?—I could not tell.

8271. And you do not know whether or not one side of it was thinner than another?—No, without they were broken up.

The witness withdrew.

HERCULES STRACHAN sworn.

Examined by Mr. Balfour.

8272. You are a moulder working at Messrs. Goulty's works, are you not?—Yes.

8273. At East Foundry, Dundee?—Yes.

8274. How long have you been a moulder?—About 36 years.

8275. Were you a foreman moulder at the Wormit Foundry connected with the Tay Bridge?—Yes.

8276. For what time?—About 10 or 12 months, I think, about 10 months it may be.

8277. Was that from July 1874 until April 1875?—Yes.

8278. Before Fergus Ferguson, the last witness?—Yes.

8279. Were you there from the time that they began to cast at the foundry?—Yes, before it.

8280. Were you there when the first castings were made?—Yes.

8281. Were there some spans of the bridge upon the north side before the foundry at Wormit was opened?—Yes, there were a few good spans up before that.

8282. And you do not know where the columns for those came from, I believe?—No.

8283. Were the columns for the rest of the bridge cast at the Wormit Foundry during your time?—Yes.

8284. I believe your pig iron was Cleveland iron?—Yes.

8285. And you had also some scrap?—About 120 tons of scrap.

8286. Have you been in the way of working Cleveland iron in this town before?—No.

8287. Have you done it since?—No, it is not used in the foundries in the town by itself, it is mostly mixed.

8288. Did you mix it with the scrap at Wormit?—Yes.

8289. During the time that you were there did you superintend the casting carefully?—Yes, to the best of my knowledge.

8290. Did you take pains to see that bad work was not turned out?—Yes, there was very little bad work turned out when I was there.

8291. Did castings ever come out of the moulds which you broke up?—I only broke up two columns all the time I was there, and one was a bad casting made by myself. It was a cold shut; the fireman had knocked too little iron and I thought I would rather risk it to pour it, and it just filled the mould; and it was a little blistered, so I broke it up.

8292. What was the other?—In the other case the mould made it by mistake. I do not recollect now whether it was too short or too long, it was the top column of the small pier, and it was either the capital short or the capital long. I cannot recollect which.

8293. When were there were you troubled with scabs coming out at all on the castings?—Yes, I was very much troubled with scabs, but they were small things the size of penny-pieces and half-crowns and five-shilling pieces.

8294. Were those serious scabs?—No.

8295. Did they affect the strength of the column at all?—Not in my estimation.

8296. Were you troubled with any blow holes at all?—I was troubled with them fluttering off the chaplets and they got honeycombed.

8297. During your time were there any blow holes which in your opinion weakened the columns?—No.

8298. Were they quite small things?—Quite small things.

8299. Such as occurred in ordinary castings?—Yes, from a pin-head to half a pen.

8300. Did you ever burn on any snugs on to the columns?—I burnt on two the time I was there; the one was a defective snug, and the other was one that the dresser broke.

8301. Were those the only snugs burnt on in your time?—The only ones. There was another broke, but I left it in the columns.

8302. What happened to it?—It was broken by the dresser too. I left the snug in the column. When I left I was to burn it, but I left before it was burnt.

8303. It remained to be dealt with by Ferguson?—Yes.

8304. Did the two snugs that you burnt on in your opinion make a good joining?—Yes.

8305. Was there any crack between the part that was there originally and the part added?—None whatever; Mr. Grothe found fault; he asked me what I was doing, and I told him that I was burning on a snug, and he said, 'I do not like that, Strachan;' and I think it was McGowan said, 'I will let you see that it is solid,' and McGowan got a bar and burnt it in the shop and gave it to Mr. Grothe, and it broke in a different place from where it was burnt, and Mr. Grothe seemed to be pleased with the burning afterwards.

8306. Was such a thing as the burning on of these snugs a kind of thing that you were familiar with as a moulder?—Yes, I am quite acquainted with burning; it is done nearly daily where I am just now, or weekly.

8307. In all kinds of work?—In all kinds of work.

8308. Have you any doubt that the two snugs that you burnt on were quite strong?—Quite solid, as solid as any other piece of the column.

8309. Did you ever see any cracked column when you were working?—Never.

8310. If there had been any cracked columns what would you have done with them?—I should have broken them up most decidedly.

8311. Or if there had been any with such big blow holes as to endanger the column, what would you have done with them?—I should have broken them up.

8312. Or if there had been such big scabs as to weaken the column, what would you have done?—I would have broken them up or shown them to my superior.

8313. Who was your superior?—Mr. Grothe and Mr. Beattie.

8314. Did you see the castings before they passed into the hands of the dresser or turner?—Yes.

8315. Did you see the castings at any time after they had passed into the hands of the dresser or the turner?—They were lying on the jetty till they went away, there was very few of them went away; during the time I was there they were all lying on the jetty.
8316. They were being stored?—Yes.

8317. How many were made do you think under your supervision?—Well I was thinking I had made about from 160 to 200 columns.

8318. The great bulk of them had been made after you left?—Yes.

8319. That was a small thing to what was on the bridge altogether?—Yes, a flea-bite.

8320. What diameter were the columns that you used?—All 15 inches.

8321. Are and all that you cast in the pier still standing?—Yes.

8322. If you cast nothing for the high grade part?—No; they all are on the south pier.

8323. Which are to be seen there yet?—Yes.

8324. Then in your opinion were all the columns that passed out of your hands fit for the work they were intended to do?—They were all good castings so far as I could judge.

Cross-examined by Mr. Trayner.

8325. Were any of the columns sent away to the pier or to the bridge before you left?—Yes, there were a few went down; I think there were two piers if I recollect right.

8326. And on those two piers how many columns would be placed before you left out of the 160 or 200 that you superintended?—I think there are 16 in a pier in the columns that went down—I think they were four in height, and four in a pier.

8327. Four altogether, and four in a height?—Yes.

8328. So that their would be 16 in each pier?—Yes, and I think there were two piers went out.

8329. Then about 32 of your columns went out before you left?—Yes.

8330. Lying in the jetty or up in the yard painted red to get to the bridge?—Yes.

8331. When the column was cast and taken out of the mold, did you look over it?—Always.

8332. And then from you it went to the dresser's, and from the dresser it went to the turner's?—Yes.

8333. Who had charge of the turning shop when you were there?—It was the same man in charge of it the whole time.

8334. George Fender?—Yes, that's the man.

8335. Did you know of any columns that went to the turning shop with holes in them filled up with cement?—Yes.

8336. What holes were those?—Small honeycombs.

8337. Were they blow holes?—They were blown holes; but they were of no extent.

8338. But were they blow holes, or were they the result of the scabbing?—No, they were the result of chippings—the hot iron mingling with the coal.

8339. The hot coke getting against the coke of the chippings?—Also I think you said from the admission of air at the gates?—Yes.

8340. What was the size of the biggest hole that you ever saw of that kind that you passed to go to the turner's shop?—Half a pen, or perhaps the point of your finger.

8341. And what depth?—From one-eighth to one-sixteenth of an inch or thereby.

8342. Never deeper than one-eighth?—No.

8343. You would not get much cement into a hole that was the eighth of an inch deep. What was the use of putting cement into a hole the eighth of an inch deep; would not the rub of a paint brush have filled up that hole itself?—Hardly, I think.

8344. It was scarcely worth while cementing a hole that was only the eighth of an inch deep; are you sure it was not deeper?—There were none of them very deep at the time I was there.

8345. Do you think there were any of them deeper than the eighth of an inch?—They might have been a little deeper; I did not measure them, and it is a long time since.

8346. I quite understand that; but as nearly as you can recollect what was the deepest hole that you passed before the columns went to the turner's shop?—I am quite certain that there were none of them three-eighths of an inch.

8347. What length were those holes?—They were generally round.

8348. What would their diameter be?—From half-an-inch to three-eighths of an inch, the largest of them.

8349. The biggest was half an inch seemingly?—Yes, round the neck of the chaplet.

8350. Were there many of these?—No, we got iron from the furnace very hot, and I always took great care to cast them on the hot side rather than the cold side.

8351. Did you see any inequality produced by scabbing?—No, nothing to speak of.

8352. You never saw a scab larger than a penny piece?—No, I have seen a few of them around the gate, these penny pieces.

8353. All these penny pieces together?—Not altogether but near each other.

8354. Did you think that all these penny pieces had been occasioned by the same thing?—Yes, by the run of the iron and the closeness of the sand; the sand was new and never been wrought with. What the sand had been wrought with it is not so ready to scab.

8355. Had that any effect on the column on the opposite side from the scab?—No, not in my estimation.

8356. Is not a scab a material thing to consider in the strength of a column?—Yes, if it is on the side.

8357. And if you have a lot of scabs like penny pieces near each other would that seriously affect the strength of that column, especially on the side opposite where the scabs were?—The run of the iron separates the sand into small particles. I never observed sand in a column that was worth speaking about; it was spread over a large surface.

8358. How many penny-piece scabs there were the sand was so much disturbed through the whole casting as not to make it of any importance?—No you could not see it, and you could not tell where it went to.

8359. Then I suppose you never rejected a column on account of a scab?—No, I never had occasion.

8360. You burn on one lug and part of another?—Yes.

8361. How do you burn on part of a lug?—We have the whole lug, we have the broken lug. I chip a piece off the lug so that there would be three-eighths of an inch of a space between the broken lug and the part of the lug that was on the column; I heated up the column to a red-hot heat, a blue heat.

8362. Which is it, a red heat or a blue heat?—A red heat.

Then I put the two lugs together, the three-eighths of an inch part and the other part and pour about 5 cwt. or so of hot iron (as you can get into the part between the two, and scrape it with a rod all the time, and you feel distinctly where the two sides melt, and the three irons get as it were amalgamated.

8363. Then you are pouring that in between the bit of the lug that was adhering to the column and the bit that you were adding?—Yes.

8364. Did any of the hot metal in that way touch the column itself?—No.

8365. Then the column would always be colder than this heated metal that you were pouring on?—The column was heated up to prevent expansion afterwards with this hot iron going in.

8366. It never heated up to anything like the heat of the molten metal?—Oh, no.

8367. And do you not think that that was very apt to produce a crack in the column?—Yes; if we had not taken care that the column was heated.

8368. But even with the column heated in the way that you have described, was not the application of the still greater heat of the molten metal apt to produce a crack in the column?—Yes, I have seen castings cracked in that way.

8369. In either of the two cases where you burnt on the lug did neither of them show a crack?—No.
8370. But you know that it often happens?—Not often; but I have seen it happen; I have seen it where I was working about a fortnight ago.

8371. Supposing that you were burning on a new lug on one of these columns, would not there be a danger too about the lug not fusing completely with the flange?—No; you can feel with the rod where the iron goes away.

8372. The thing can be done, can it?—Oh, yes; made as solid as possible.

8373. But you would require to be careful in probing it with your pricker or whatever it is?—A feeding rod.

8374. To ascertain that the metal you are pouring it upon has become as soft as the metal that you have poured in?—Yes.

8375. And unless you can get them both to fuse in that way as melted metals you cannot make sure of having them join?—They will not get solid.

8376. (The Commissioner; Did you say that during the ten months you were there there were only two columns that you broke up of all those that you cast?—Just two columns that I broke up. I did not have a bad casting the time I was there, speaking correctly. In the case of the one I made had I poured the iron into it because I had too little rather than pour it on the floor. I thought I would risk it.

8377. There were only two columns that you broke up at all?—Yes.

8378. And you never saw any columns broken up whilst you were there, except those two?—There were no others to break up but what I made.

8379. Then you don't know whether or not the inside of the column was evenly cast or not, whether it was thicker on one side than it was upon the other?—No; Mr. Gilkes was very particular about it. Mr. Gilkes, sometimes once a fortnight and sometimes once a month, would rap a column with a hammer, first on one side and then on the other, and he used to go over most of them in that way sounding them.

8380. You saw Mr. Gilkes doing this, did you?—I was with him.

8381. I suppose it would be a very wrong thing to put up on the bridge a column which you would know in that way was thicker on one side than it was on the other?—Most decidedly in a structure of that kind.

The witness withdrew.

William Stewart sworn.

W. Stewart.

Examined by Mr. Balfour.

8396. You are an iron turner, I believe, in Messrs. Peterson and Company's saw mill?—Yes.

8397. You have been asked to come from your work to-day, having been spoken to a short time ago?—Yes.

8398. Were you for twelve months an iron turner at the Tay Bridge Foundry at Wormit?—Yes, about twelve months.

8399. Can you give me the dates?—No, I cannot.

8400. Was it when Ferguson was foreman?—Yes.

8401. After Strachan had gone away?—Yes.

8402. What did you do to the columns as turner?—I felled up the flanges.

8403. Would you tell us about the flanges; was there a male and female fitting on the columns?—Yes, in the centre.

8404. On every column?—Yes, on every column.

8405. Inside of the flanges?—Inside and outside.

8406. So that the flanges not merely lay against each other, but fitted?—Yes, they fitted in the centre.

8407. Was that the case in all the columns that you turned?—In all the columns that I turned.

8408. While you had the columns on the lathe and were handing them, had you an opportunity of seeing whether anything was wrong with them?—Yes, we had every opportunity of seeing that.

8409. If there had been any serious defects in them do you think you could have seen them?—Yes, we must have seen them.

8410. Either bad scabs or bad blown holes or cracks, or anything of that kind?—Had there been any we might have seen what there was of them.

8411. Did any columns come under your notice on which scabs had been burned?—There was one that I recollect.

8412. Could you see where a scarg had been burnt on?—Oh, yes.

8413. Was there any crack between the bit that was burnt on and the original piece?—Not that I saw.

8414. And if there had been any crack would you have seen it?—Yes, I should have seen it very easily.

8415. It was just very near to the place where you bad to turn?—Yes.

8416. So that you were working close to it?—Close to it.

8417. Were they 15 or 18 inch columns?—Both.

8418. Was the one that had got the scag burnt on a 1½ inch or an 18-inch column?—I do not exactly recollect.

8419. You told us, I think, that you saw no crack; can you say that there was no crack there?—Well, I believe there was no crack; if the crack had been fastened over we should have noticed it; it would have let you know itself if there had been a crack there.

8420. With a sort of bise or grip different from solid metal?—Yes; with solid metal there would be no jump at all.
8421. And you did not find anything of that sort?—We did not find anything of that sort.

8422. Speaking of the columns that passed through your hands, what kind of castings were they?—I took them to be very good castings.

8423. If you had seen anything wrong with the castings, what would you have done?—I would have had to tell the foreman.

8424. Who was he?—George Fender.

8425. Was he your foreman all the time?—All the time.

8426. Were you sometimes in charge at night when George Fender was on the day shift?—Yes; I had the night shift and he had the day shift.

8427. But he was your superior?—He was my superior.

8428. Then whenever there was night work doing, were you in charge?—Yes.

8429. So that Fender in the day and you in the night saw all the columns that were turned, during the time that you were there?—Yes.

8430. When the columns came to you were there any serious scabs or blown holes upon them?—Yes; I have noticed a blown hole, but very little.

8431. Anything to hurt the column or to weaken the column?—No, not in the least.

8432. Were there any scabs when they came through your hands that would weaken the columns?—No; I have noticed scabs, but not very large ones.

8433. What would be the deepest blown hole that you have seen?—Perhaps a quarter of an inch.

8434. And what size in diameter?—Just about the same diameter, very little.

8435. Would that do any harm to the column, do you think?—No; not in the least.

8436. Did you ever pass any column through your hands that had any cracks at all in it?—No.

8437. Were the castings unpainted when they came to you?—Yes.

8438. Had they been through the hands of the dressers, but not through the hands of the painters?—Yes, they were just dressed when we got them.

8439. So there was nothing on them to hide any defects?—No; no paint or nothing.

8440. How long would each of the columns that passed out of your hands?—That was no part of your business or Fender’s business.

8441. That was the night shift, but I am speaking of a particular column; supposing that you took up a column to put it on the lathe and torched it and put it on the lathe and put it aside, how long was each column in your hands?—Some of them took longer than others. Sometimes you were an hour or an hour and half longer over one than you would be over others.

8442. Would an hour and a half be the average?—Between two and three hours was the average.

8443. And during that time were you handling and working away as a workman does at the column?—We had one at each end of the columns.

8444. Was a man at each end?—Yes.

8445. And it was moving about, of course?—Yes.

8446. So that you could see anything, at all events, near the end, and in handling it, if there had been anything seriously wrong with the rest of it, must you have seen that too?—We must have seen it.

8447. And although you were working at night, I suppose you must have had plenty of light?—Yes, plenty of light.

8448. During all the time that you were there, did any columns pass out of your hands that was not, in your judgment, sound and fit for the bridge?—There was one; it was very hard metal, I could scarcely get the tools to touch it, but I told Fender about it in the morning.

8449. And what was done with it?—I do not know.

8450. You do not know whether it was broken up or not?—No.

8451. Excepting that, then, had you to complain of any other passed out of your hands?—No.

8452. Were there any that did pass out of your hands, excepting that, in your opinion sound and fit for work?—Yes.

8453. And whether the hardness of that one made it unsuitable for the bridge you would not undertake to say?—No.

8454. And whether it was put into the bridge you do not know?—I do not know.

Cross-examined by Mr. TRAYNER.

8455. What is your particular business? Are you called a fitter, or what?—An iron turner.

8456. And I suppose you do not know what strength the columns needed to keep the bridge up?—No.

8457. And you could not give us any confident opinion as to whether a column was fit for its work or not?—No.

8458. You could tell us whether there was a hole in it?—Yes.

8459. But you could not say whether, without the hole, it was good for its work or not?—No.

8460. What was the purpose for which these columns were put into your hands at all?—It was to give them the proper bearings up against one another.

8461. And to do that you had to drill the proper holes into the flanges at each end?—Yes.

8462. Your lathes never touched the body of the column so as to speak?—No.

8463. You drilled holes in the end, and you gave them a flat surface at each end, and then you had done with them?—Yes.

8464. They did not come into your shop to be examined there by anybody from end to end to see whether they were perfect or imperfect?—No.

8465. That was no part of your business or Fender’s business?—No.

8466. I suppose that the columns were brought to your turner’s shop or to your lathe and just put down beside you?—Yes.

8467. And you and somebody else would lift it up from the floor it was on, and put it on the lathe?—Yes.

8468. In doing that did you go along the column, looking to see whether it was defective or not?—No, I did not.

8469. You simply lifted it up and put it upon the lathe?—Yes.

8470. And then you set your lathe going, and it wheeled the column round so as to turn the face?—Yes.

8471. At what speed did the column go round when you were making the face straight?—Well, I would say about half a dozen revolutions in a minute.

8472. Not more than that?—Sometimes more and sometimes less.

8473. But that was the kind of average?—Yes.

8474. When it was revolving where did you generally stand?—At the end of the column.

8475. And what were you watching?—Watching the cut.

8476. Just to see that you took the proper cut off the end?—Exactly.

8477. And the man who was at the other end of the column was watching the same thing?—Yes.

8478. And whether of you paying any attention to any condition of the column between the two ends?—You had to stop the column and mark it to the length of a steel, and then take your cut accordingly.

8479. But you at one end and the other man at the other end of it were attending to what you cut off at the end and not to the state of the column between the two ends?—Yes.

8480. You said you did not see any blown holes or scabs of any importance; you saw some blown holes a quarter of an inch deep and a quarter of an inch in diameter?—Yes.
Did you notice any holes that had been filled up with cement?—No.

Did the cement never pick out of a hole while you were there?—No.

Did you see the Yender do it?—No; I never saw a hole filled up with cement.

Were you working mostly with Yender or mostly on the night shift?—I was mostly on the night shift.

So that generally speaking you and he were not in the shop together?—No.

Where was it that you placed the face of the columns outside this flange?—We cleared the outside and then faced it.

So that the two flanges would have perfectly flat bearings upon each other?—Yes.

Therefore your lathe never affected the columns inside the flanges?—No.

Was it in that way that there should have been a crack between the log and the bottom of the flange without your noticing it, as if the lug was not adhering exactly to the flange?—There might have been a crack and not to see it there.

And might there have been a crack close by the flange and running vertically by the side of the lug that you would not have observed?—I believe I would have noticed that.

If it was a hair crack would you have noticed it?—No, unless the tool had come across it.

Did you notice any holes that had been filled up across it until the crack passed through the flange?—No.

(The Commissioner.) It was your duty to see whether or not the lug was close to the flange or close to the column or not?—No, I had nothing to do with that at all.

All your duty was simply to plane off the surface of the flanges, was it not?—Yes.

And also to drill the holes?—Yes.

In planing the face of the flanges did you plane the whole of the face, or was it the outer part of the face?—We turned the whole of the face and the outside skin.

But between the face of the flange did you plane it all down to a flat surface, or did you leave anything in the centre?—We left the female centres in some, and cut them right down in the others.

You cut them quite down sometimes?—Yes.

So that they were quite flat on to the others?—Yes, that was the female centre, but then there was a male fitted to it; the pipes fitted to each end.

Was there always the case; were they all male and female, to fit into one another?—Yes.

The female you cleared quite down?—Yes.

Did you clear it down all round, so that it was a perfectly flat surface?—Yes, so that they would go quite close, to a perfect closeness.

You understand what I mean, do you not?—No, I do not.

THE WITNESS WITHDREW.

EDWARD McGOVAN SWORE.

Examin'd by Mr. Balfour.

8504. You live in Dundee?—Yes.

8505. What are you by trade?—I am a labourer.

8506. You are working just now with M'r. Waddell at the lifting of the girder?—Yes.

8507. Did you work at the building of the bridge for 34 years?—Yes.

8508. Were you employed on the lifting gear by which the girders were lifted into their places?—Yes.

8509. Were you first a labourer, afterwards a leading man, and at last a foreman?—Yes.

8510. Which of these posts did you hold when you were working at the big girders?—As a leading man first, and then on a double shift. There were two foremen on.

8511. You were a leading man; a foreman when they came to the big girders?—Yes.

8512. Did all the columns of every pier supporting the high girders come under your notice?—Yes.

8513. What had you to do with each?—We were supposed to see that each of the joints of each of the columns were properly screwed up together tight.

8514. By saying that you were supposed to do so, do you mean that that was your duty?—Yes, that was our duty.

8515. What else had you to do; had you anything to do with the lugs?—No, except putting in those bracing bars.

8516. Had you to put the bracing bars on and fix them to the lugs?—Yes.

8517. And you did so?—Yes.

8518. In doing these duties could you see if there had been anything wrong with the columns?—Yes.

8519. Or if there had been anything wrong with the lugs?—Yes.

8520. Did you test the lugs in any way in putting on the bracing bars?—All the testing we had was when we were putting in these gibbs and cotters, we had to put in the bracing bars, and braced them up tight.

8521. And you stretched them tight?—Yes.

8522. Did you put a heavy strain upon the lugs?—Yes.

8523. If there had been any crack in any part of the lug, or in the connection between the lug and the flange, would you have seen it?—It would have to be large, or else we could not see it, because they were all painted when they came to us.

If there had been any weakness in the lug, would it have yielded to the strain you put upon it in fastening the bracings?—Yes, I think it would.

Was it a heavy strain that you put upon it?—Yes, a very heavy strain.

If you had come upon any defect in a column or in a lug, what would it have been your duty to do?—To report it.

To whom?—To Mr. William Delpratt.

Had you any occasion to report any defects to him?—Yes, one.

What was that?—A temporary column.

What was wrong with it?—It was cracked on a lug.

Would you explain what you mean?—It was a lifting column that goes at the top of this (describing it on the model), and one of the lugs had gone quite down.

That was a column which was used for getting up the girders, but was no part of the permanent structure of the bridge?—No part of the permanent structure of the bridge.

And it was removed, I suppose?—Yes.

Suppose the temporary ones would be removed?—Yes.

(The Commissioner.) The lifting columns are still there?—It was a temporary lifting column.

(Mr. Balfour.) The temporary lifting columns were removed?—Yes.

The permanent lifting columns were not removed?—No.

What did you find bad in this one, and what did you do?—It was cracked close by the lug; it was a bad casting, so I let the manager see it, and he condemned it and put it ashore.

Do you mean Mr. Delpratt?—Yes.

If you had found anything of the same kind in any other column would you have done the same thing?—Yes.

Was it broken up?—I could not say.

As the columns were put up did you bolt the columns together?—Yes.

Not only the lugs and bracing bars; when you had done the work were all the columns properly bolted together and all the bracing bars properly attached and duly tightened up?—After the bridge was
8544. Then you went over them again? — Yes.
8545. If any bolts had got loose were they tightened up? — Yes, they were all properly tightened up.
8546. And caulked? — And caulked.
8547. When you left the piers for the last time, were you satisfied that they were all right and sound? — Yes.
8548. The girders were all upon them at that time, were they? — Yes.
8549. And had trains been going on before you were on them for the second time? — Yes.
8550. For how long? — From the time that we were pulled off first; that was before they were properly finished.
8551. But before the second that you were there, had there been any trains travelling upon it? — There had been no passengers travelling upon it.
8552. But had there been ballast trains? — Yes.
8553. Were you at the painting? — Yes.
8554. At what time? — From the first commencement till we came to No. 15 on the south side.
8555. Had you to do with painting the high girders? — No.
8556. But with regard to those that you did paint, did you find them all in good order? — Yes, I did.

Cross-examined by Mr. Thayner.

8557. Are you a labourer? — Yes.
8558. You seem to do more than labourer's work. You paint and you bolt columns. Do you mean that you had charge of the bolting of those columns on to others in the construction of the bridge? — Yes.
8559. Was that a portion of the carriage way? — No.
8560. What did you do? — I took up those columns and bolted them together.
8561. Had you charge of columns like that (pointing to the model), and did you bolt them together? — Yes; at the time the double shift was on another man and me had the full charge.
8562. You had full charge in the one shift, and he had full charge in the other? — Yes.
8564. Had you ever charge of a job like that before? — No.
8565. You are 26 years of age now? — Yes.
8566. Who put the bolts into the different holes so as to connect the piers together? — The men that built them put them in.
8567. Who were they? — Men under your charge? — Yes.
8568. They were labourers too? — Yes.
8569. And they drove the bolts into the bolt holes? — They put them in.
8570. And screwed them up tight? — Yes.
8571. Who came after you to look at the work? — After the girders were all up they had to go over again.
8572. You saw the men put the bolts in and tighten them up. Who came after you? — Alexander Robertson, he took on the work.
8573. When you were there in charge was anybody with you? — Yes, Mr. William Delpratt.
8574. There was no one between Mr. Delpratt and you? — No.
8575. You saw the columns bolted together, and you also saw those tie rods bolted to the lugs (pointing to the model)? — Yes.
8576. What strain was put upon the lugs by the bolting of those tie-rods? — I cannot exactly say.
8577. Do you know of any? — Yes.
8578. How do you know that there was a strain upon them? — By the testing of the hammer on the bars.
8579. On the tie rod? — Yes.
8580. What was the length of each of those tie rods?
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8614. That is since you were foreman of this work?—Yes.
8615. What are you doing now?—I am with Mr. Waddell now.
8616. Are you a labourer still?—Yes.
8617. You have said something about putting on these two, I think between the lugs?—Yes; bracing bars.
8618. You have told us about your putting a strain on them?—Yes.
8619. Do you think that the strain was anything at all like the strain they would be subjected to when a train passed over?—I cannot say. I am sure we put them up till they were also inspected by the inspector and passed by him, Mr. Macbeth, the inspector.
8620. Then he overlooked your work in that way, did he?—Yes.
8621. (Mr. Barlow.) Did you put the horizontal struts in as well as the tie-bars, those that go round (pointing to the model)?—Yes.
8622. Did you screw them all up?—Yes.
8623. Whereabouts was the strain that you say you put upon the tie-bars? How did you put any strain upon them; was it by dragging upon the key?—I put no more strain upon them than tightening the bolts up.

The witness withdrew.

Mr. Gerrit Willem Camphuis sworn.

Examined by Mr. Barlow.

8624. I speak of the cross-bracing, how did you do that, by driving in the key with the hammer?—Yes.
8625. Did you put anything on the other side of the struts?—No, we kept the hammer on one side, and drove in the keys opposite to one another.
8626. How did you know when you had enough strain upon them, and that they were tight enough?—We put them so tight as we could, and allowed them to stand until the inspector inspected them.
8627. Had you any instructions with respect to how far you were to tighten up?—No; we were left to use our own judgment till the inspector came.
8628. Had you anything to do with putting the concrete into the columns?—No.
8629. Who had?—At one of the ends Johnson had the contract for them—Charles Johnson.
8630. When was it done; before the columns were put up?—They were filled after the girders were put up.
8631. Filled from the top to the bottom after the girders were up?—Yes.
8632. How did they get it in?—On the brick piers before the span was lowered into its place.
8633. Did they pour it in at the top?—Yes.
8634. It was poured in from the top?—It was made up and poured in sand and cement mixed together and poured in at the top wet.

Mr. Gerrit Willem Camphuis continued.

8635. Are you a civil engineer in Dundee?—Yes, I am residing at Dundee.
8636. Were you employed as the assistant engineer to the manager for the contractor for the Tay Bridge during its construction?—I was.
8637. Was the manager under whom you were Mr. Grothu?—Yes.
8638. When did you come?—I came at the beginning of August in 1873.
8639. Were you there until the bridge passed the Government Inspector in 1878?—Yes. I was there after that, till October 1879.
8640. What were your duties?—My duties were those I superintended the sinking of the piers; I erected the columns and the piers; casting the columns, I lifted the girders, and I assisted in floating off the piers and girders. I had moreover the general supervision under Grothu with the view of making up at the ends of the months a general statement of how the work was standing. Therefore I was supposed to be acquainted with everything that had been going on for the last 11 or 12 months I think. I had the management of the foundry and the workshop on shore as well.
8641. With regard to that last term—when you assumed charge of the foundry, who had preceded you?—Mr. Frank Beattie.
8642. He is now in Birmingham, I believe?—I think so.
8643. Were there some manufactured columns lying in the yard at that time?—Yes, a great many.
8644. How many would be lying there?—I think some 400 or 500; may be more.
8645. Did you find also columns there which had been rejected by Mr. Beattie?—Yes; they had been put aside.
8646. In a separate heap?—Yes, away from the rest altogether.
8647. They had been rejected for defects?—Yes.
8648. How many might there be in that separate heap?—There was one heap, or rather one parcel of columns, lying at one side, I think three or four, which had been thrown aside for defects. There would be 30 or 35 columns that had been cast to be used as lifting-columns, and were thicker at one side than the other. They were intended to be used as lifting columns, but the means for lifting had been changed, and those columns were of no use.
8649. How many were there of that class?—I think 33.
8650. Had those 33 columns been cast thicker on the one side than the other on purpose?—Yes.
8651. For what purpose?—To scour on wrought-iron brackets, which were of cast iron, as in the present lifting columns.
8652. But that plan being changed they were broken up?—Yes.
8653. Did you see them broken up?—Yes.
8654. Are you acquainted with the process called the burning on of girders?—Yes.
8655. Was that done during your time and to what extent?—I saw some 10 or 12 columns with lugs burnt on them. They were columns that had come from Middleborough. I found only one failure. The burning on was in the case of the 15-inch columns.
8656. What I want to know is, first, to what extent did you see the practice of burning on adopted in the foundry?—I saw it practised, I dare say in 10 or 12 columns in all.
8657. During the 10 or 11 months whilst you were in charge?—Yes.
8658. What sort of columns were they upon which the lugs were burnt on?—There was one 15-inch column, and the rest were 12-inch columns.
8659. Any 18-inch columns?—No.
8660. What led to the lugs being burnt on?—Because they were broken off.
8661. Was it because they had been broken off, or because they had come out bad castings?—They had broken off during their transit from Middleborough.
8662. Those 12-inch ones were what I think some of the witnesses have called the maker column?—Very likely.
8663. Was the burning on successful?—Very successful. I tested every one of them myself; I was very particular.
8664. Speaking not only of the 12-inch columns, but also of the 15-inch columns as well?—That was not so.
8665. As regards the 12-inch columns, was that process successful in all cases?—Yes.
8666. Will you kindly mention to what test you subjected the lugs?—By hammering them, and in one instance, which is distinctly before my eyes, when I expressed some doubt to the foreman about the solidity
of the snug, he took up a sledge hammer and gave it a good swing round, which would have knocked off a perfectly sound lug, and that lug stood it perfectly well.

8667. If there had been any interstice or crack between the outer part of the lug and the original part remaining, must the weakness have yielded to such a test?—Yes, of course, and beside I would have seen it.

8669. Were they painted at that time?—They came painted from Middleborough.

8669. Had they been painted after the lug was burnt on?—No.

8670. At the time that you examined them had the part on to which the lug had been burned painted?—No.

8671. So that there was nothing to hide any crack or defect?—Nothing.

8672. And you looked at them carefully with your eyes and tested them with your hammer?—Yes; I must explain that the columns came painted from Middleborough, and therefore the lug was broken off; the part that was left on was painted, of course.

8673. But surely the heating which would be in immediate contact with the cut would burn off the paint?—Yes.

8674. So that the bit which had been weak or defective had been demud of paint?—Yes.

8675. That is the 12-inch column. How did the burning on of the lugs answer in the case of the 15-inch columns?—In the case of the 15-inch columns, so far as my recollection goes, my experience of burning on lugs on the 15-inch columns is limited to the one column. The foreman came to me and reported to me that this was a lug that required a piece on, and I gave him the order to do it; I mind distinctly that he came and said, "Well, sir, I have been trying it, but it is no success, and I gave the order to break it up."

8676. What is the name of that foreman?—That was Ferguson.

8677. What kind of man did you find him to be?—A very attentive and accurate man.

8678. Intelligent?—Very intelligent and careful. In most cases he came to me reporting columns that were defective, and I only found, as far as I can mind, two or three columns which I rejected without his telling me of it previously, and those were columns that I am not sure that he cast at all, because I found them in the yard.

8679. Apart from those that you have spoken of, the 12-inch columns and the 15-inch columns, did he frequently report to you that there were defects in columns?—Pretty often I think, that is mostly before and for what?—Yes; of course I did not do that.

8680. How often would it happen taking one week to my knowledge I never saw any doubt about it?—It must have been used.

8681. And you looked at them carefully with your hammer and tested them with your hammer?—Yes; I mind distinctly that thing had been used.

8682. That is the 12-inch column. How did the burning on of the lug answer in the case of the 15-inch columns?—In the case of the 15-inch columns, so far as my recollection goes, my experience of burning on lugs on the 15-inch columns is limited to the one column. The foreman came to me and reported to me that this was a lug that required a piece on, and I gave him the order to do it; I mind distinctly that he came and said, 'Well, sir, I have been trying it, but it is no success, and I gave the order to break it up.'

8683. What is the name of that foreman?—That was Ferguson.

8684. That suggested to your mind a possibility that the metal on the opposite side might be defective?—Yes, that there might be sand mixed with it.

8685. And you looked at them carefully with your hammer and tested them with your hammer?—Yes; I mind distinctly that thing had been used.

8686. Would the ring of the metal under the hammer reveal whether it was sound metal, or whether it was so filled with sand as to be defective?—Yes; if the deficiency in thickness was anything perceptible, it would.

8687. In thickness or in quality?—In thickness or in quality of course.

8688. And if the metal had been mixed up with sand, so as not to be proper metal, it would have revealed itself to the ring of the hammer?—Yes.

8689. And therefore it was a test both for thickness and for quality?—Yes; of course I did not do that for every column, but a column that I had doubt about I managed to examine more closely.

8690. You mentioned some scabs; did you see scabs on any of the columns that were passed?—Yes, when I had occasion in the foundry when the moulds were taken off in the morning.

8691. That is to say where they unclothed the cast pipe?—Exactly; I have seen scabs there, but never of any serious nature. I suppose that any serious scabs that occurred, occurred in those columns that the foreman reported to me that he had broken it up; but to my knowledge I never saw any scab amounting to anything that I could express in dimensions.

8692. Although the roughness was visible to the eye?—Exactly.

8693. Do you think that any inequality you saw in the shape of a scab on the one side could diminish the amount of the metal on the other side so as to weaken it?—Not perceptibly.

8694. Or to send up such a quantity of sand to the other side as to deteriorate the quality of the metal there?—It is quite possible, but if on inspection you see that scab has taken place you can take a chisel and cut a piece out and see how deep the sand goes in.

8695. If the sand has risen up over the top of the casting and settled down in a lump you would see it?—Yes.
8706. Or if it had settled down so as to make the metal a mixture of metal and sand, would you see that ?-Yes, of course.

8708. Is the result of your evidence this, that as regards the column cast under your supervision none were sent on to the bridge weakened by sand?-Decidedly not.

8709. As regards blow holes, did they appear occasionally?-I have never seen blow holes to a great extent. I might have seen a column molten.

8710. To some extent?—To some extent.

8711. Small blow holes?—Small blow holes like a rough surface—nothing worth speaking of except one column which I must mention, which I think had a considerable blow hole, and that was filled up with some waxy stuff which I forgot to mention, and which was melted by the sun. It was lying at the door of the foundry, and the column happened to be one that had been cast that day if I am not mistaken. I think I almost remember the letter it went by, but it was broken up, of course. It was not a blow hole which I think would have interfered with the strength of the column, but that may have been the suggestion that I got that putty or any wax was used.

8712. Lest there should be any doubt about it, it was broken up?—Yes.

8713. Do you know what this waxy stuff was?—No.

8714. Do you know a composition called Beumont egg?—I have never heard of it.

8715. But perhaps it was Beumont egg?—I have heard of it here.

8716. However, it did not go in the bridge?—No, not so far as I am aware.

8717. And that is the only one you saw any stuff of that kind in?—Yes.

8718. As regards the question of cracks, was your examination such as would have enabled you to see if there had been any cracks in the column?—No doubt.

8719. Were there any such?—I never found any cracks.

8720. And was your examination such as would have revealed them?—Most decidedly.

8721. The columns, after passing out of the hands of the moulders, passed into the hands of the turners?—Yes; that is to say, they went to the dressers first.

8722. And then to the turners, and then to the foundry and finished?-Yes.

8723. Do you think that any material defects could have existed in the columns without being observed by some of these people?—I do not think it likely at all.

8724. Had any of them any interest in passing bad work?—They had not the least interest in it, they were all paid by the day's work; neither had the foreman any interest in it, because I never made a remark when I came to me and said that a casting had been broken up, without my sanction; on the contrary, I approved of it; I myself had no indorsement whatever.

8725. It was not the case of people being paid by time, to whom it would have been a loss?—Exactly.

8726. But nobody, then, had any temptation to pass bad work?—Certainly not.

8727. Did you find the men in each of those departments that you have mentioned, careful and skillful in their business?—I did, or I would have dismissed them, of course.

8728. Had you any instructions in regard to the kind of work that you were to see put into the bridge?—I had instructions to put in the best work, of course.

8729. And nothing else?—And nothing else.

8730. Had you seen the metal when it was in a state of fusion?—Yes; as a rule I made a point of being in the foundry when the metal was running, unless I was prevented by something exceptional.

8731. What was the object of your being there at that time?—To make sure that the metal used was as free as possible from slag.
8753. Turned smooth? — Yes.
8754. And the female was turned smooth also, so that they would fit quite tight? — Quite so.

8755. Then there was something which came out above the point at which the diminution in the case of the male fitting occurred? — Yes.

[Mr. Barlow.] Perhaps the witness would be kind enough to make a sketch which would explain this more clearly.

The witness made a sketch, which was handed into the Court.

8756. (Mr. Balfour.) Of course you saw the metal of the columns which were broken up? — Yes, I made a particular point of examining these columns whenever I had a chance of breaking one up, because I had seen sufficient columns after the fall of February 1877, to satisfy myself that a core had not shifted.

8757. And that consequently there was not an inequality on the thickness of the different parts? — Exactly.

8758. What had led you to attend particularly to that? — That is because I saw one or two columns I think which were rather defective in thickness at the time of the breakdown in 1877.

8759. Did you find that in the case of the columns broken up after the fall there was inequality of thickness on the different sides or not? — No, I never noticed anything more than between the sixteenth and the eighth of an inch.

8760. Did you after the fall provide for any additional thickness beyond that specified? — No, because I concluded that those columns must have been cast before they had made any provisions against the rising of the core, and my experience led me to think that the cores employed were perfectly rigid.

8761. Was it divided at each end? — It was divided at each end; and it must have been a mere accident that the thin column could have been turned out.

8762. Was it possible that the kind of cores employed while you were casting could cause so as to be thinner upon the upper side than the lower side? — I would think not, but I have made no experiments with that kind of core.

8763. Do you know that Ferguson thickened his core bars? — Yes.

8764. Do you think that the precautions he had used with those thickened core bars preceded the possibility of the core rising so as to be thinner on one side than on the other? — Yes.

8765. Your observation of the columns that you broke confirm that view? — Yes.

8766. You know what a cold shut is? — Yes.

8767. Did you ever see any columns disclosing a cold shut? — No, I never saw one.

8768. Did you see in any of the columns that were broken up the signs of a cold shut? — No.

8769. Yet, you would have seen it, I suppose? — Yes, I should have seen it, the cold shut must show on the outside.

8770. Would you see the appearances of a cold shut on the outside of a column even if it was not broken up? — Yes, in my opinion you must, for the simple reason that if it is a cold shut that is occasioned by the metal cooling in the moulds and getting too cold to unite the cooling, would be most marked where it was in contact with the cold mould, and therefore the outside mould would be the first to show the cold shut.

8771. There would be a sort of rising and depression such as would be caused by two quantities of metal meeting but not mixing? — Exactly, but even had they united close together where the junction is not done in a fluid state, you would have a line on the outside.

8772. Those would be the extremities of the cold metal? — Yes, and being nearer the mould of course.

8773. To what are cold shuts due? — To insufficient heat in the metal.

8774. You have to see that the metal poured into the moulds was sufficiently hot? — Yes.

8775. What kind of sand was used in the moulding? — Common foundry sand.

8776. Was it quite good sand? — Yes.

8777. Have we heard of anything about the water that was employed; was salt or fresh water usually employed? — I cannot say what was usually employed, both sources were available. There was a barrel of salt water, or at any rate water pumped from the Tay, and the barrel was supplied from the boiler house, and connected with a pipe, and there was fresh water to be had not very far from the foundry, and in rainy days I dare say fresh water was collected. I never made it a point to inquire carefully into that, because I never considered it material, it was a question of conscience.

8778. Does salt water make bad castings? — No, not in my opinion and not in my experience.

8779. Have many of the castings, which you broke up been cast in moulds wetted with salt water? — Every one of them I believe, or at any rate the salt water was in the sand if the moulds were not wetted with salt water.

8780. Did that produce any effect upon the metal? — If anything I think it would take a little sulphur out of the metal. If there were any sulphur in the metal salt tends to take it out.

8781. Was that an advantage or disadvantage? — An advantage if anything.

8782. I suppose you, being a civil engineer, know something about chemistry? — Not very much.

8783. Does it occur to you, thinking the matter over, that there is anything in the sea salt such as that which would affect the castings? — No, I know there is a patent taken out for taking out sulphur from coke by the use of common salt chlorine if the salt is used to combine with the iodine. I do not think salt water would have any material effect, but if it had it would certainly not harden it.

8784. Where was the coke got from that was used? — The coke was got from Midlothian.

8785. Was it good coke? — It was good coke.

8786. Have you heard that there was any complaint of it? — I never heard any complaint of it.

8787. Was it part of your duty to examine the rivets of the girders? — Yes, at times after Mr. Beattie left, it was my duty to examine the rivets of all the large spans that were on the jetty.

8788. Had Mr. Beattie the same duties with you with respect to the foundry and other matters? — Yes, with respect to the foundry and the workshops.

8789. Would be be the gentleman who would tell us about the system pursued before you took the charge? — Yes.

8790. What opportunity had you of knowing as to the quality of the riveting? — The quality of the riveting was good, and if it was not good it was made better.

8791. Did you examine it yourself? — Yes.

8792. To what extent? — I examined it after the girders had been put up on the jetty by a foreman. I either went over it myself, or I raised the inspector, Mr. Macbeth, to go over it; I only had occasion to do that in the case of four or five of these spans, I think.

8793. What was the name of the gentleman whose charge they were built? — Mr. Beattie, to begin with, and they were built under my charge.

8794. Who was the functionary under you? — Mr. Newcombe.

8795. Who was examined this morning? — Yes.

8796. Did you find Mr. Newcombe a careful and intelligent officer? — Very.

8797. And then what did you find the quality of the riveting to be? — I found the quality of the riveting to be exceptionally good.

8798. In rivetting, do you always now and again find a loose rivet at the first going over? — Yes, the rivetting is entrusted to a man and he has to look after different squads; he has to go over them and he will find loose rivets, it is quite natural.

Q. 204.
8799. Was the usual system pursued carefully for the purpose of ascertaining the pressure of bad rivets? —Yes.

8800. And they were rectified? —Yes.

8801. How were they marked? —The rivets that I found in Mr. Newcombe's girders I marked with chalk; as a rule I did not find more than two or three.

8802. Did you take a hammer in your hand and try them? —Yes.

8803. I suppose when you are about such works you usually have a hammer? —Yes, I have a little hammer which is called a testing hammer; you have to do it all by feeling, and you have to have a little experience of that.

8804. You know the mug and the feel? —Yes.

8805. Was that the same kind of thing that Macbeth did in other cases? —Yes.

8806. Did he go over and watch you? —Sometimes he went over after me and sometimes before me; this was only before a girder was floated out.

8807. But he was watching the contractors on behalf of the Company? —Yes.

8808. Then after they were floated out and put in place, and you any occasion to test them afterwards? —No, it would remain under my charge then.

8809. Under whose charge did they remain then? —Under Mr. William Delpratt.

8810. Where is he now? —He is in Spain. In the very beginning I had the superintendence of these girders, and Mr. William Delpratt was under me, but I had occasion to leave for a short time, and when I came back I found that Mr. Grothe had taken the superintendence in his own hands.

8811. Is Mr. Grothe in Spain just now? —Yes.

8812. Can you, of your own personal knowledge, speak as to the state of the rivets of the girders, or do you not know? —Yes, I was supposed to keep my eye on the various sorts of bad work, and occasionally, although I should not be expected to do so regularly, whenever I had a spare moment on the girders, I took a hammer and tested it if I thought it was necessary.

8813. Can you speak with regard to the columns after they were built into the pier? —Yes.

8814. What opportunity had you for examining that? —I erected the greater number of the small piers, and I erected two or three of these big ones, I think, at any rate I began to, but I would not speak to a certainty on that point as to how many of those columns I put into position.

8815. But as regards those that you did put in position, what opportunity had you to see as to their sufficiency? —I saw every one of them from top to bottom daily, because that, the whole of the bridge was painted twice under my supervision, and I had occasion to inspect every column.

8816. As the result of your whole inspection, can you say whether the various columns of the different piers were all standing perpendicular? —No, some of them are racking.

8817. But when you left the job? —They are not all perpendicular, they rake in a certain direction a few of the piers—they are perpendicular, looking up the river, but they are racking in another direction.

8818. But were they in the kind of lines that they were intended to be? —Yes.

8819. Were they all straight according to the lines that they were designed to be in? —Yes.

8820. The male and female screws duly fitted in every case? —Yes.

8821. And duly bolted together? —Yes.

8822. And the bolts caulked and all tight? —Yes, I cannot speak to the bolts being caulked and all tight, because that was done under another engineer, Mr. Reeves. Partially it was done under Mr. Delpratt, but Mr. Reeves went over the whole.

8823. Where is Mr. Reeves? —I believe he is in Portugal, but I am not sure.

8824. Had you opportunities as regards some of the columns of seeing lugs? —Yes.

8825. All of them? —Yes, every one of them, because I saw them first in the foundry and next in the erection.

8826. Did you see them after the cross beams had been put upon them? —Some of them, not every one of them.

8827. And they were painted by that time? —Yes.

8828. If there had been any important cracks in them, do you think you would have seen them, or would the paint have hidden them? —No, we could have seen them.

8829. If the braces had been drawing the lugs at all, would you have seen it? —Yes, you could see it at once, any crack shows at once by means of rust; the water settles in it.

8830. If there had been any crack it would have rusted? —Yes.

8831. Do you think that if there had been any cracks between the lugs and the flanges, or between the lugs and the columns, the crack would have been revealed when the braces were strained as? —Yes, certainly, but if not then, very likely it would have been seen at any other time.

8832. But if they have been causing weakness in the structure, would that weakness have been revealed when the braces were strained upon? —Yes, that would depend, of course, a great deal upon the amount of strain put upon them.

8833. Was the strain put upon the braces? —Yes, I have seen a strain put upon many braces.

8834. Are you not satisfied that the condition of those piers was that they were made of proper columns, properly fitted before the bridge was left? —Yes.

8835. Now will you tell us about the composition of the iron? were the piers Cleveland pigs? —Yes.

8836. Was there any scrap mixed with them? —Yes.

8837. Where would that scrap come from? —We get that from old castings which had been intended for use in the bridge at one time but the plans had been altered.

8838. Was that Scotch scrap? —I have not seen it cast, but I have plenty of opportunity to know that it was cast in Falkirk.

8839. Then was it Scotch? —I suppose it was.

8840. It was not English iron? —No.

8841. Was it Scotch scrap? —Well, I have reason to believe, but I have not seen it.

8842. What is your reason for believing it? —Because I do not think that in a Scotch foundry where you are supposed to get Scotch iron you would get any other sort of iron, and it looked like Scotch scrap.

8843. Was it bought for Scotch iron? —I cannot speak for certain because these things were on the ground before I came there.

8844. But that was your understanding and judgment, as far as your judgment would guide you? —Yes.

8845. Were you often on the bridge when trains were passing along it? —Yes I was the only engineer left on the bridge for a year after it was on the hands of the contractor.

8846. Were you often on it both while ballast trains were running on it for three months before it was opened, afterwards when passenger and goods traffic was plying upon it? —Yes.

8847. Will you kindly describe what you felt or were conscious of in the case of passing trains? —A general tremor in the girders, and when a train entered one girder (keeping in mind that they were connected) it would deflect that girder, and it would have the same effect as placing your hands on the one side of a balance; it would lift the other side, so it would lift the corresponding girder, or at any rate there would be a tendency to lifting, and that was a motion which could be detected and which of course was expected to be detected.

8848. Was there anything more than you would have anticipated? —No.
8849. Was there anything more than what is used in such structures?—No, I would think less. I was astonished to find so little movement in it.

8850. Was there anything which it struck you an engineer could be an indication of weakness?—None.

8851. Was there any oscillation from side to side?—I was on the bridge with very heavy trains and with very light passenger trains, and I never experienced any oscillations.

8852. Have you been there in a high wind?—Yes, rather.

8853. Do you mean that rather to be emphatic?—Yes, emphatic. In a very strong gale, I thought of this occasion, for instance, the morning after the girders were blown down, there was a very strong gale blowing then.

8854. Have you been on it when the gale was blowing so that you could hardly work?—Yes, I had to hold on to what they call the lattices.

8855. Did you find the wind produce any effect upon the structure?—No more than to make these little suspensions bars, the tie bars (pointing to the model) tremble a little with the winds.

8856. Were you sensible of anything like the structure being caused to oscillate backwards and forwards, or being blown over to one side?—No, not on the larger girders at any rate.

8857. Were you conscious on the small girders of anything of the sort?—I took some observations on the brick piers in strong gales, and there was a little longitudinal motion when the wind was from the north. The brick piers on the south side had the largest surface exposed to the wind, and there was an oscillation of one eighth of an inch. I am speaking of the 14 southernmost piers.

8858. They present a much longer surface to the wind than those metal piers?—Yes, of course.

8859. Did you observe anything like an oscillation in any of the metal piers?—Never.

8860. Had you opportunities of doing so?—Yes, twice I went distinctly for the purpose of seeing whether there was any motion on the rollers when the trains were passing.

8861. Have you sat upon the top of the columns and watched for motion?—Yes.

8862. More than once?—Yes.

8863. When heavy trains were passing?—Yes.

8864. When they were passing as quickly as they ever did?—Yes, I should think sometimes that it was very nearly 20 or 25 miles an hour, the barrel trains, I mean the heavy trains.

8865. Did you ever see them passing at what you thought was more than 20 or 25 miles an hour?—Yes, not barrel trains, passenger trains.

8866. What do you mean by saying you have seen them pass at more than 25 miles an hour?—First of all the observations, if they crossed the bridge in five minutes starting slowly, is, that they must run at a higher speed than 25 miles an hour inside the girders.

8867. At a much higher speed?—Thirty miles, I think.

8868. Do you think that you ever saw a higher speed than that on the bridge?—No, I do not think so. I have been standing by the side when they passed with ladies and the dogs.

8869. Was anybody frightened?—No, except the dogs.

8870. Did you ever see any rivet holes that had been left empty on any parts of the bridge?—Yes.

8871. Where were those?—Some rivet holes here (pointing to the model) and some here (pointing to another part of the model); of course I had them filled up. I looked at them and my eye caught one or two, and that made me look for more, and I went over the whole of the girders and did not find more than may be a dozen.

8872. Did you find any of the diagonal bars loose?—Yes, I think I saw one or two, but that was before the bridge was out of the hands of the contractors.

8873. Did any explanation occur to you of how those had come to be loose?—Very likely they had never been fastened.

8874. Were they fastened before the bridge was taken off the hands of the contractors?—I could not speak to that, because I was not entrusted with the finishing of all that.

8875. Would you kindly tell us as an engineer, whether these diagonal bars had much or any strain to bear?—I think not.

8876. What are they there for?—I suppose they are there more for ornament than for anything else, because I often found them slack, and they should have tightened themselves if there had been any use. Occasionally one was slack.

8877. They were passing between the upright piers?—Yes.

8878. Does it appear that they could have any strain upon them except that of keeping these upright things apart?—Not even that; I do not think there is a tendency to those upright things coming apart at all. The structure of this end-post and of the top boom is exactly the same, and they both have to sustain a compressive force, and the top boom has not these diagonal bars, and does quite well without them.

8879. Speaking generally of the bridge, do you think your opportunities enable you to say generally whether it was a sound and stable structure when it was taken off the hands of the contractors?—Yes.

8880. Was it so in your judgment?—It was.

The witness withdrew.

Adjourned to to-morrow at 10 o'clock.

EIGHTH DAY.

Tuesday, 2nd March 1880.

Mr. Gerrit Wilmann Camphius recalled.

Further examined by Mr. Balfour.

8881. You have made a sketch I believe?—Yes, but it is only a rough sketch from memory (handing in the same).

8882. Do you wish to make an explanation?—I want to explain that unless I am greatly mistaken, a particular socket does not exist in the bottom length of the 18-inch column. I did not understand the question properly yesterday, and unless I am greatly mistaken, that is my impression, that it does not exist there in the bottom length, only where the column rests upon the base where the bottom of the 18-inch column is connected with the base. There is no male and female connexion as I have sketched it out. I do not want to confine myself to the exact dimensions, the little socket may have been turned off a little more or less.

8883. (The Commissioner.) But in all the others, you are sure it was there?—Yes.

8884. (Mr. Barlow.) Subject to some variations of dimensions?—Yes.

8885. (The Commissioner.) In the 18-inch ones all the way up except the bottom?—Yes.
Cross-examined by Mr. Traynel.

8905. The last year?—Yes.
8906. Was not the work during the last year of it behind what you had expected it to be looking at the specified time in which it was to be concluded?—No, not so far as the weather was concerned.
8907. Well, as far as anything was concerned?—As far as the turning was concerned.
8908. Turning what?—Turning the columns and busts.
8909. And was not there a considerable push in the last eight or nine months of the contract to get it finished?—Yes, but nothing beyond the personal power or ability of any of those employed in it. I mean to say that there was a push to get the thing finished no doubt.
8910. Mr. Gröthe was there during those last eight months, was he not?—He was there all the time that I was there.
8911. You are aware that he has written a description of the erection of this bridge?—Yes.
8912. In "Good Words"—Yes.
8913. I will read you the passage. "The fallen girders had to be removed and new ones built, and the piers to be erected again; and this threatened seriously to interfere with the expectations of having the bridge finished for the passing of a train by September. Only eight months were now available for the erection and floating out of six, and the lifting of ten, 245 spans. Five and seven respectively of the 145 spans had yet to go through the same processes. Seven large and three small piers had yet to be built. The weight of iron which had to be put in its place was 2,700 tons, and it seemed incredible that all this could be done in eight months. A good deal would depend on the weather, but this was far from favourable. During February there were only five days on which work was possible out in the river, and the spring and summer of 1877 will certainly be remembered by bridge builders, sailors, and farmers as the most unfavourable. The last year?—Yes.
8914. Apart from the state of the weather mentioned, there are the statements in consistency with your recollection of the facts?—I did not pay particular attention to the weather in that spring.
8915. So that you had an unusually busy eight months to look forward to for the last eight months?—Yes.
8916. The part of the work that had to be got forward within that time was the columns, amongst other things, were they not?—No, I did not interfere with them.
8917. Had all the columns been cast at that time?—No, they had not, but they were not behind.
8918. You were well up to time afterwards with those columns, were you?—Except with the turning; we had to turn day and night.
8919. In view of the necessities arising from the circumstances was it then that you put on a night shift at the turning shop?—I think it was before that.
8920. Anticipating some necessity?—No, we saw that the turners could not keep pace with the necessities.
8921. With regard to the examination of the columns, where generally speaking did you examine the columns after they were cast?—Sometimes I examined them immediately after they came out of the mould, and at other times I most generally examined them after they came from the turner's.
8922. After they came from the turner's were they put down in heaps in the yard?—No, they lay side by side.
8923. In your examination of those columns did you examine them as they lay, or did you turn them each separately from each other and turn the column all round so that you could get a view of it all?—I did not do it one after the other, but I did it as a rule and I often did it. I may have turned over the same
columns two or three times for all I knew, it was very easy, I just gave them a push with my foot and turned them over.

8924. You were not content with merely examining the surface that was visible, as they lay together, but you did turn them over so that you got a full view of the columns?—Yes, I may mention that that had often to be done for the purpose of selecting the columns that had to be sent out to the river; they were tall and slender, and it often happened that the letter was just at the bottom.

8925. Did you turn them over for the purpose of finding out where they were going to and then with the purpose of examining them as to their efficiency?—I combined the two together.

8926. I think you said that you could not say that you examined every column, that by turning them over?—I could not say, but my impression is that I did examine every column, but it is quite possible that I examined one column more than once.

8927. Having got a column before you and turned it over and seen it all round, what else did you do if anything to test its efficiency?—Humane speaking if I had a hammer at hand very often, and the dressers were there, I may have used it, but I mind distinctly that I used my knife very often.

8928. What for?—Because I saw this colouring on the columns, and I wanted to make sure that there was nothing wrong there.

8929. The result of that: using of your knife was you could not get it in the place I saw, which roused my suspicions, which proved to be the part that had been chiselled out, and therefore it assumed a different shape from the rest of the columns.

8930. Did you ever discover any hole that had been filled up with cement?—I mentioned one yesterday, that was the only one.

8931. What was it that attracted your attention to that particularly? Was it the different colour?—No, it was in the melting, you could see that it was quite a distinct small hole.

8932. If it was not cement it must have been some other substance which was giving way under the heat of the sun, and the melting might have drawn your attention to it—Yes.

8933. Have you never discovered any pipe with a hole stopped up, with cement?—No, that is to say, sometimes I found sand on the columns or what I took for sand; it may have been cement, at any rate, it was not more than a glance.

8934. I should have the difference between cement and sand, would you not?—No, when it is painted, I did not notice.

8935. Did you not scrape it with a knife?—No, it was too small for that.

8936. You never took out of a hole a perceptible quantity of cement which had been obviously put in to stop up the hole?—No.

8937. When I mention this I may say that sometimes there was a rough place on the casting where you could see that grains of sand were embedded in the skin of the casting, I would not say that I never tried them in any other way than that.

8938. But you may have seen inequalities from sand or something else which were of so trifling a character that they were of no moment?—Yes.

8939. You never found a column from beginning to end out of which you took with your knife cement that had obviously been put in to fill up a hole, large or small?—Never except that one.

8940. And that was not cement?—They call it cement, I believe.

8941. The cement would melt with the sun and run out?—Cement is a very general name given to ever so many substances.

8942. Was your examination of the columns sufficient to enable you to detect whether there were any such holes in the columns that were filled with cement if they had existed?—To my own satisfaction.

8943. To your own satisfaction?—Was your examination of the columns sufficient to satisfy you that such holes did not exist?—Yes.

8944. Further you know, I suppose from what you have said already, that the existence of such holes was a risk to be guarded against in moulding?—Yes. I do not mean any indentures which may not be given the name of holes—mottled. I did not watch it after the column was painted, to see that the dressers did not fill it up with Beaumont egg; at any rate it was not worth mentioning, or not the 60th part of an inch.

8945. The holes I refer to are very much more than that?—Yes.

8946. You said that the dressers might have painted them; was your examination generally before or after they had painted them?—I should say so, generally after the turning, I mean.

8947. Before being painted?—Yes, generally, except those columns that I found in the yard, and which were painted.

8948. If there had been an inequality in those columns as regards the thickness, was your examination sufficient to enable you to detect it?—Whenever my suspicion was roused, I tried to satisfy myself.

8949. Was your examination with hammer or otherwise sufficient to satisfy you that the columns were equal in thickness all round?—Yes, I must explain that I did not examine every column with the hammer; I did not go all over with the hammer, but where I thought it necessary to try with the hammer from the outward appearance I did so.

8950. I understand that you examined as many columns, and as much of each column with the hammer as satisfied you that those columns were in a condition to go to the bridge?—Yes.

8951. One of the essential conditions of their being satisfactory was that they were uniform in thickness, or practically so?—Yes, at any rate, having a thickness of an inch, or thereabouts.

8952. All round nothing thinner than an inch?—It might be a trifle thinner. I would not condemn a column; the inspector would. I have never seen a column thinner than an inch when it was broke up.

8953. You said the inspector would have condemned a column that was not an inch in thickness all round?—Most decidedly, at any rate, if I was one of the inspectors, and I for this reason might say that he simply carries out the instructions.

8954. You would have allowed a column of less than an inch in thickness to go?—I would not say; it would depend a great deal upon circumstances; I never should pass one of less than an inch.

8955. Did you inspect and pass all the columns that were used in the high girders?—No.

8956. Did you inspect or pass any of those columns?—All that were cast during my time.

8957. Do you mean during the two years that you were there?—It was not fully a year, I think.

8958. During the last year only?—Yes, it was principally the lifting columns, the 18-inch columns.

8959. (The Commissioner.) That you superintended?—Yes, for those large columns, and the 15-inch columns for the small piers.

8960. (Mr. Trayner.) Did any of the 15-inch columns that you passed go in to support the high girders?—Yes.

8961. Can you tell me any piers into which your columns did go to support the high girders?—They may be in the piers between the first fallen pier and the fifth from the north side; they may be, but certainly not in any of the others. I will not say for certain, but that is my impression.

8962. (The Commissioner.) From the south you mean?—Yes, to the fifth from the north; that is my impression at any rate.

8963. (Mr. Trayner.) Would that include pier No. 34 from the south?—I have been accustomed to name them by other figures; I think so.

8964. (The Commissioner.) You count from the south?—Yes, I began with No. 29, that would include No. 34.

8965. (Mr. Trayner.) Were all the columns that...
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were used in No. 34 passed by you?—Not necessarily, very likely not.

8966. By whom would they be passed?—Very likely some of them would be passed by Mr. Beattie.

8967. The columns, I understand you to say, should have been an inch thick?—Yes.

8968. Whether you show you a piece of metal marked "No. 1;" never mind the label, just look at the metal (handing a piece of metal to the witness), and tell me, if you please, what is the thickest part of it, take the calipers and measure it, or give me first the thinnest part in the body of that piece of iron?—It is five-eighths of an inch.

8969. Measure it, if you please, to the edges at the thinnest part, and tell me what is the measure from edge to edge on the face?—That is a little short of five-eighths.

8970. How much short?—Not a sixteenth, I think.

8971. Do you know of any column that went to the bridge of which such iron as that formed a part?—No.

8972. Would you have sent any column to the bridge to form a part of it of that thickness?—No.

8973. I show you now another piece of metal marked "No. 2" (handing the same to the witness). Tell me, if you please, the measurement of the thinnest part of that with the calipers and then on the face of it?—(The witness measured it.) That is five-eighths of an inch, or a little more; fully five-eighths.

8974. Tell me what the thickest part of it measures, if you please?—That is seven-eighths.

8975. Now look at this piece, marked "No. 3" (handing the same to the witness). What is the thickest part of No. 3, or take it in the other order, the thinnest part of it; what is that?—That is seven-eighths, less one sixteenth.

8976. The thinnest part?—Yes.

8977. What is the thickest?—That is an inch.

8978. Assuming those three pieces of metal to have been taken from one column, does that show an improper inequality in the thickness?—If they are all from one column, yes, decidedly.

8979. Assuming that these came from one of the 15-inch columns in tier No. 34, can you account for its getting there without your inspection?—It is very likely I never saw the column, because it was not cast in my time; if it was cast in my time I do not think I should have passed it, not from the inequality, but judging from that blow hole that is in it.

8980. Would the inequality, if you had been aware of it, not have induced you to prevent that column going out?—Yes, decidedly.

8981. You would not have passed one such column into the structure of the bridge?—No.

8982. Whoever did it, should you regard it as an improper thing to pass such a column as that into the bridge?—No, because it might be quite accidental.

8983. If it got there from want of supervision it was wrong, was it not?—Yes, decidedly; but that is hardly possible; the supervision may have been very good high that blow hole is there; some people are deceived by these blow holes.

8984. I am speaking now of the thickness?—That thickness could not have been detected by proper instruments it may be.

8985. Was there no way in which the thickness, as I prefer to call it, of that column could have been detected before it went out of the foundry yard?—Some people might have done it.

8986. Is there a mode by which it could be done?—Yes; I should think so; I am not prepared to say how; but I think I could devise a mode for doing it.

8987. Was there any mode in practice so far as you know at the Wormit Foundry by which columns of that thickness could be detected before they were sent out for the bridge?—Nothing but the hammer; it requires an experienced ear.

8988. Would the ring of the hammer to an experienced ear have told him that that column was only five-eighths of an inch thick at one part?—I have heard of it, although I do not say that I would myself be able to detect it—I would have to try it; I never tried it, but I do not think it.

8989. Therefore, if you had applied your hammer by any chance to that particular column in Wormit Foundry it might have been passed notwithstanding its thickness?—I cannot say that, because I am not sure that would have been an inch thick.

8990. You have never yet detected the thickness of a column by the ear and the hammer?—Yes; I have.

8991. What thickness have you detected?—About a quarter of an inch to three-eighths and half an inch too; I must qualify that, because that was where there was a hole in the column, and I know that one was half an inch and the other thicker—they had a different sound.

8992. Given a column externally complete, with no suspicious sign about it, could you by the ring of the hammer have told that instead of being an inch thick it was only five-eighths?—I am not prepared to say that.

8993. Was any one else at Wormit Foundry with the duty of inspecting the columns that went to the bridge during the last eight or twelve months of the work but yourself?—I was the responsible man so far, of course.

8994. There were foremen turners and dressers, but you were the responsible man?—Yes.

8995. (The Commissioner.) Did I understand you to say that you could not have detected it if it had been five-eighths of an inch?—I am not prepared to say, because I never tried it.

8996. Therefore you cannot say that you could have detected it?—No.

8997. (Mr. Trayner.) Was it good work to put a column in the supports of the high girders any part of which was only five-eighths of an inch thick?—If it was known, certainly not.

8998. It would not have been safe, would it?—I am not prepared to say that it was not according to contract.

8999. Apart from its not being according to contract was it safe workmanship in such a structure?—I would not consider it dangerous. The section of the column is not materially decreased. It depends very much upon the position the column occupies in the structure whether it would endanger it to a great extent.

9000. In any position whatever would not the column have its own part of the structure to bear that it was intended to bear?—Yes; but in that respect it would not make any difference, that is not material.

9001. Would it make no difference that there was only five-eighths of an inch to bear the weight that an inch was intended to bear?—You must take the whole section round. It remains practically the same.

9002. (The Commissioner.) Let me understand that, if you please?—For vertical loads it would be practically the same. I do not say that that theory would hold good where the section is so much in excess of the weight it has to bear; it would not make any practical difference.

9003. (Mr. Trayner.) Assuming that the column is only five-eighths of an inch thick, and that the other side of the column is an inch and three-eighths, would that inequality render that column unsafe to bear the weight that would have been put upon a column which was uniformly an inch thick?—Yes.

9004. The columns in this bridge were specified to be uniformly an inch thick?—Yes.

9005. I suppose they were so specified with a view to the pressure to be put upon them?—Yes, it is not usual to specify columns of unusual thickness, but if the question is put to me as a practical engineer whether a column that is five-eighths of an inch on one side, and an inch and three-eighths on the other, should bear an equal load as the column which is an inch all round if that load does not come within a twentieth of its crushing load, then I should say that there is no unsafety in that.
9006. I suppose that there would be a specification only for the work that was necessary for the particular office it had to perform?—Yes; very likely.

9007. If it specified for columns an inch thick, that meant an inch thick all round?—Yes.

9008. If a column were specified for an inch thick all round, it would be intended, would it not, to bear the pressure which such a column is calculated to bear?—Yes.

9009. If a column so cast was not an inch thick all round, but was five-eighths of an inch on one side and one inch and three-eighths on the other, was that a safe column to subject to the pressure which you would be inferring by specifying for the uniformity of such columns?—I so happen to know approximately the pressure to which it was exposed, and from that knowledge I say that, the section of the metal remaining practically the same or something very nearly 50 square inches, it would not materially decrease the strength.

9010. Does it in your opinion make no practical difference to the strength of the bridge that the columns, instead of being cast uniformly an inch thick were cast five-eighths on one side, and an inch and three-eighths on the other?—You must first assume that they were cast of that particular thickness; then I do not say that they would affect the strength of the bridge. I do not say that; I am talking of the vertical load.

9011. Will you just be good enough to answer the last question I put to you?—To that I answer that if the limit per column were an inch all round, that would certainly have an influence upon the strength of the bridge.

9012. Do you mean to say that it would detract from the strength of the bridge?—Yes.

9013. Would it materially detract from the strength of the bridge or not?—I cannot say that, off-hand, unless the calculation were gone into, but I would think it would to a certain extent.

9014. I also say an extent as that I suppose you would not be willing to take the responsibility if you had charge of the work?—Certainly not. If I saw any columns that were of unequal thickness, I should not pass them. Possibly that column has been passed without being detected. Accidents will happen.

9015. If the inequalities which I have pointed out to you are found in many of the columns on the bridge, do you think that would affect the stability or strength?—It depends very much upon whether all those columns appear on the same pier, and in what position.

9016. No, I mean columns not in the same pier, but different piers under the high girders?—I will not say that the strength of the bridge depends upon one pier. If, in my opinion, it is a matter of very little value whether there were 13 strong piers and one weak one, I think they would be equally unsafe.

9017. You apply there the usual rule that the strength of a chain is its weakest link?—Exactly.

9018. Will you just answer the question I have been putting to you?—If it were all in one pier I should say yes, astonishing that the bridge has been standing so long.

9019. And if distributed it would take a longer time to bring about the effect of weakness or that the effect of weakness was likely to lead to?—I should not say a longer time, it would depend upon so many circumstances.

9020. Would you say a shorter time?—Yes, it may, but I do not think the stability would be affected by time.

9021. In sample No. 1 which you have taken, is there any other defect in that piece of column beyond its thickness?—Yes, there are several holes.

9022. What is No. 1?—Yes.

9023. Is there a blow hole there?—Yes.

9024. Just tell me this: From the appearance of the fracture does that represent about half what the hole would be, the blow hole?—Yes; it may be; it may be made larger or it may be made smaller.

9025. Judging from what you see there, what do you think would have been the size of the blow hole originally in that piece of metal?—I could not give an opinion with regard to that; it may have extended ever so far.

9026. Give me the smallest size?—It might have been bigger than that.

9027. Because there is a fracture through it?—Yes.

9028. How much is there, what is the length and depth of the blow hole which is visible?—That is about three-sixteenths.

9029. That is to say three-sixteenths in depth?—Yes; it measures three-quarters of an inch, and it is about seven-eighths long.

9030. And three-sixteenths deep?—Yes.

9031. What do you fancy would have been the smallest diameter of that blow hole?—I think about half an inch.

9032. It could not have been less?—I do not think it.

9033. What is the diameter of the hole as it stands there just now; half an inch?—Half an inch; it measures very nearly half an inch.

9034. Will you measure it?—On the top it measures less; it goes in a little here (pointing to the specimen).

9035. Was that a serious blow hole?—Yes, I think so; I should not have passed the column with it upon it.

9036. That blow hole is on the surface of the column, is it not?—Yes.

9037. Has anything been put into it?—Yes; there are little globules in it.

9038. Are there not remains of some cement in it?—Yes.

9039. There has been cement?—Yes.

9040. Can you suggest for what purpose it was put in there?—I should think it has been put in to fill up the hole.

9041. To hide it?—Yes.

9042. And you say that you would not have passed a column with a blow hole like that in it?—No.

9043. Are there not two blow holes in No. 1?—There is a little one here; it must have been here (pointing to the specimen).

9044. Just below the skin of the column?—It is just broken off here (pointing to the specimen), just under the skin.

9045. So that in that little hit which you have in your hand you have a very material thinners and two material blow holes, have you not?—No doubt about it.

9046. There is enough in that little bit to have condemned the column in your mind?—Yes; if I had seen it.

9047. Now look at No. 2: is there anything wrong about that?—I see cracks in it here (pointing to the same) and some blow holes.

9048. In the inside?—Yes.

9049. How do you account for their getting there?—I suppose it was done at the fall.

9050. What fall?—The fall or whatever broke the column—the hammer or the fall.

9051. Leaving those cracks alone, is there anything about No. 2 production that is not as it ought to have been, a good casting?—Yes; there is a blow hole here (pointing to the same); it looks very much like it, at any rate.

9052. Is there some honeycomb there?—Yes.

9053. Is that enough to have made it doubtful as to the propriety of using that column alone?—If it had been of the proper thickness, the blow hole is visible on the top; but it is not visible on the surface.

9054. If the thickness had been sufficient you think the blow hole then would not have affected the strength of the column?—No; not much.

9055. Apart from the blow hole, is there anything else about it which is different from what it should have been in a good casting?—I do not admire the appearance of the iron very much, there seems to be a little cinder in it.

9056. There is a good deal of cinder on both sides...
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of that specimen; I am not prepared to say unless it was tested, whether it is all cinder or not.

9037. Is there no cinder and scum there?—It does not look a healthy casting, at any rate.

9038. Is there not to your eye the existence of a scum which should not have been there?—It certainly should not have been there; it is an impurity in the iron that should not have been there.

9039. And which affects the strength of the column in which it exists?—Yes.

9040. It materially affects the strength of the column?—It is in any quality?—It would depend very much upon the quantity; I am not prepared to say that off-hand.

9041. Where you have pointed out the honey-combing or the blow hole, is there not cinder besides?—Yes, a little.

9042. That is not as it should have been, is it?—No; very likely one occasioned the other.

9043. It affected the stability of the column or the strength of this piece (pointing to the specimen)?—It would to a certain extent, but the effect may be an infinitesimal effect. In this piece (pointing to the specimen) one would say that the thickness is enough to be affected.

9044. The thickness where that blow hole occurs is so thin, and the thickness there is so slight as to account for the existence of the blow hole that you find there?—One can hardly say that, I am not prepared to say that unless I saw it tested.

9045. Tell me whether, in your opinion as a practical man, you think that that was a dangerous blow hole situated in the thickness of metal that you see?—I could not say that it was a dangerous blow hole, but I would certainly say that it ought not to have been there. If I had seen it I would not have passed it.

9046. Is the crack that you see near the blow hole on specimen No. 2 in any way to be accounted for by the existence of the blow hole?—If this crack had not been there, and I had hit it with the hammer, very likely it would have broken off there.

9047. If you had hit that part of this specimen with a hammer the result would probably have been to produce a crack, would it not, such as you see there now?—Yes.

9048. And that would have produced such a sound as to warn you that the column was unsound?—I would think it required a knock with a hammer from within. If the man had knocked it here it might have cracked there (describing) very likely; but I should not say that it would have cracked there (pointing to the specimen).

9049. Would it have cracked so as to produce a ring that would have told you that there was a crack in it, that is to say, if you had struck it on the outside with your hammer, would the sound have warned you that there was a crack in the column?—I cannot say that off-hand. I have not tried it.

9050. 'That blow hole (pointing to a specimen) does not look so bad as that series of blow holes on the other side of it?—No, that does not look very good.

9051. It looks very bad, does it not?—It depends a great deal upon the extent of it.

9052. What is the thickness of the place that I have just pointed out to you?—I do not mean to say that that is a thing that is good at all.

9053. Is it not bad?—It is bad so far as it goes; if you say that it is good iron I say no, it is bad.

9054. Because it is not pure; it contains ingredients that should not be there?—I cannot say that, because you may find it in the best iron sometimes.

9055. Is that such a thing as, if known to you, would have made you reject the column?—Very likely.

9056. I will show you No. 3 (showing another specimen to the witness) there are blow holes in that, are there not?—Yes.

9057. They are serious ones, are they not? There is one big one here (pointing to the specimen), and a congregation of little ones about it?—Not so very big, the size of a pea.

9058. There is a congregation of small ones, honey-combings?—Yes.

9059. And those holes are in the vicinity of a considerable amount of scum or cinder, are they not?—Yes.

9060. Each of them assisted in reducing the strength of that column?—Yes, always proportionally.

9061. But in the proportion in which you find the blow holes, the cinders and the scum in that specimen No. 3, to the sound metal contained in the same specimen, was it a safe column to put up?—It depends upon the extent. If I saw all the column I should be better able to judge of them, I must confess.

9062. The proportion of bad metal is large, is it not?—Yes, in this particular spot, but it would depend upon the size. If there was a hole in a column the eighth of an inch for the purpose of inserting a bolt, which is very often done, I should not consider that that hole weakened the column materially.

9063. Not so if you had the bolt put in?—No, the bolt would not affect it, there is always a play between the bolt and the metal, on the same principle it depends very much upon the extent of the bad plate in any castings, whether or not it materially affects the strength of the column.

9064. Taking the extent of the metal in specimen No. 3 as the proportion of bad metal, that is to say, of impure metal in that specimen, in excess of what there ought to be in any columns, would that be safe?—If the same proportion were carried through.

9065. Take the proportion that there is there?—If that proportion were carried on through the whole of the column, most decidedly not.

9066. It would not be safe?—No.

9067. If those three specimens which I have shown you were taken from one and the same column, was it that a safe one to be accounted for by that a safe column to put into the bridge?—I should certainly not approve of it.

9068. Can you say nothing more than that? Do you not disapprove of it in the least degree?—Yes; I mean to say that it may not have affected the strength, for all that, materially.

9069. It would not make it stronger, would it?—Certainly not; that is plain.

9070. You said that when you went to the foundry there were 30 or 33 columns laid aside and subsequently broken up?—Yes.

9071. And you also stated that those columns were unequal in their thickness?—Yes.

9072. You also told us that they had been cast unequally for a special purpose?—Yes.

9073. I do not remember whether or not you said that that had been done within your knowledge while you were there or whether it was done before you went there?—It had been done before I went there. I was at the bridge while they were cast, but I was not aware that they had been cast.

9074. But the statement that they had been cast purposely of unequal thickness was a statement which you gave us upon information supplied to you?—Yes; upon information supplied to me by the gentleman from whom I took those columns over, Mr. Beattie, and sustained by the general inference which should not have been made there (pointing to the witness).

9075. To cast them thicker on one side than the other, I understood you to say, was for the purpose of putting something into the thicker side?—Yes.

9076. What was that?—I believe, I am not sure, but my impression is that it was to put certain bolts through; I am not sure, but that is my impression. It was to put certain bolts through, or what are called pinching screws or set screws.

9077. Is it customary, as far as your experience goes, to cast columns or pipes in that unequal way to be used for the purpose of putting in screws or bolts?—Yes.

9078. Is it not more the custom of moulders to put on a "boss" at the place where they propose putting the screws or the bolt, rather than cast the whole side of the column of unequal thickness?—I have seen it both ways. It exists in that way in the bridge.
8099. Which way?—Both ways.
8100. Which is the more usual way of the two?—If it is only for the purpose of taking a bolt I should say that the boss would be sufficient. It may be that additional strength is required for some other purpose.
8101. For the purpose of bear'sinevenient pressure, suppose you would not recommend a pipe to be thicker on one side than the other?—No, it would not be necessary.
8102. And you would not recommend it?—I should not think of it.
8103. If it is for the purpose of making it of a strength to bear binearient pressure, is it not a waste of metal to mould the whole side of the column unnecessarily thick when you can accomplish your end by putting on a boss at the place where you would use a screw or a bolt?—It all depends upon the purpose for which it is to be used. In this case I approve of the metal being thickened, because it was wanted there.
8104. For what purpose?—For the purpose of screwing on a bracket upon which the struts were such that the "bosses" would have come so near together that they would all have fallen into one. Were there any of the columns that passed your inspection which showed signs of having had the upper flasks shifted in casting?—No, I do not remember any.
8105. That should show unmistakenly, would it not, on the outside of the column if it took place?—Yes.
8106. And the result if it took place would be to render the metal unequal on the different sides?—Yes, to the detriment of the shift, but not necessarily; it may have gone with a gentle curve.
8107. Even with a gentle curve it would have produced an inequality?—Yes, an inequality in the section in the shape of the column, but not necessarily in the thickness. If it came into the shifting a half or a quarter of an inch, I should say yes; but if it is only a small amount of shifting, it may be that the metal runs in.
8108. If the shifting was sufficient to make a distinct line on the outside of the column visible to any one, would that have been sufficient to produce an inequality in the thickness?—Not necessarily.
8109. You do not approve, do you, of the shifting of the upper flask?—Of course not.
8110. And if it was there it would show at any rate, whether it affected the real strength of the casting or not?—Yes, I would not blame a man for a thing of that kind happening for once, I should not call him a careless man for it.
8111. I ask you whether you would call the work careless or not?—Yes, I speak of the work as careless; in the true sense of the word it would be careless.
8112. Have you ever seen any columns on the bridge that shows obvious external signs of a shifting of the flasks?—I do not mind any.
8113. If you saw such a thing would you recollect it surely?—I think so.
8114. Are there none of them standing at this moment?—Not that I am aware of.
8115. On the other hand, if the columns have been broken down are there not columns at this moment showing signs of a shifting of the flasks in the casting?—I am not aware of it.
8116. If you had examined those columns before the bridge was finished with care you would have seen it, I suppose?—Yes, if I had examined that particular column.
8117. Did you not go over all the columns after the bridge was finished?—Not all that had been erected there.
8118. Under the high girders did not you go over them and inspect them before the job was taken over?—No.
8119. Anybody who had gone over the bridge to inspect it before handing it over or taking it out of the contractor's hands would have seen such a sign if he had inspected it carefully, assuming that it existed, would he not?—Yes, if such a sign existed, surely it is visible.
8120. If there had been a distinct shifting of the upper flask as so to produce an external mark, any skilful man going over the piers before taking them out of the contractor's hands must have seen it, must he not?—Yes.
8121. If you had seen columns showing signs of the shifting of the upper flask before they went out of the yard to the spot, would you have passed them?—If it were an immaterial raising of the line for instance, a thing not definable in parts of an inch, and if only the line was visible, I might have passed it. I mean if only the line had been visible, and there had been an indication that there was a tendency to shift, I should pass it: but if there had been any material deviation from the centre, of course I should not.
8122. If the line on the columns showed you that there had been a shifting of the upper flask, you would not have passed it?—No.
8123. In your opinion, if anybody did pass such a column as those, and put them up on the bridge, were they doing wrong?—It depends upon the extent of the shifting.
8124. If it was a distinct shifting, such as you would not have passed, you think other people should not have passed them to be used in the bridge either?—My private opinion is such.
8125. That is to say, your opinion as an engineer is such?—Of course an engineer has a private opinion of his own.
8126. You mean your private opinion as an engineer?—Yes.
8127. Suppose it showed a shifting to the extent of two-eighths of an inch, would you have considered that sufficient to warrant you in rejecting it, or would you have passed it?—I would have rejected it.
8128. Do you consider the one under which it was mentioned?—Yes, I would have rejected it.
8129. Do you mean the one under which it was mentioned that it would not have been passed?—No.
8130. Was there anything whatever done in the way of testing those columns, excepting looking at them with your eye and touching them with your hammer?—Not that I am aware of.
8131. Did you see the specification of the Tay Bridge?—I saw the old one.
8132. Do you mean the one upon which it was built?—The one in the charge of Messrs. de Bergua and Co.
8133. Just look at it and tell me if you have seen that (handing a specification to the engineer), that is the contract under which it was originally built, or at least a specification, have you seen that before?—Yes, I think so, but I have seen so many of these papers that I am not sure whether I have seen it.
8134. Look there, under the head of "cast-iron," I mean the first specification, you have there the second, you will see "cast-iron" on the right-hand page. Do you see it at the foot of the page?—I have got it.
8135. If you will look there you will see "The iron of which the castings for the cylinders, piles, and columns are to be made shall be melted in a "cupola furnace, and shall be of such mixture of pig "that a bar cast therefrom, with a transverse section "2 inches by 1 inch, and placed edgeways on bearings 3 feet apart, will not break with a less weight "on the centre than 3,000 lbs., and bars of the above "dimensions shall, from time to time, on the demand "of the engineer, be cast and tested, at the sole "expense of the contractor, in the manner before "mentioned;" were any of the castings in the foundry tested in any way except as you have described?—Not during the time that I was there.
8136. Neither under your supervision, nor at your request, nor any other body's request, so far as you know, was one of those castings tested in the sense of the specification?—I am not sure.
8137. (The Commissioner.) But so far as you know?—I am not sure that any of the castings at Wornit have been tested. I do not know that. Q 8104.
1913. During the time that you were there the castings were not tested under your supervision?—No.

1914. (Mr. Trayner.) To your knowledge they were not tested at all?—No.

1915. As an engineer what test would you suggest those things to be cast and tested to have meant to have satisfied the test a hydraulic test or what?—I could not tell you without going into figures; I think it is a severe test.

1916. If it was put into your hand and you were asked what was the nature of the test which is presumably intended by this provision, what would you say as to the test it provided for?—Is it a hydraulic test or what?—Very likely they use hydraulic as most convenient.

1917. As being about the most accurate as well as the most searching?—Yes; it may be done in different ways.

1918. But, so far as you know, there was no testing whatever under your inspection at Wormit?—I know that there was hydraulic testing machinery, for I remember the engineer testing things that may have been cast there, but I am not aware of it.

1919. Was there testing machinery there that could have been applied?—Yes.

1920. At Wormit?—Yes.

1921. Did it not occur to you to test a single column that was going to support the structure?—I had no instructions to that effect. I do not mean that there was machinery there ready for testing, but a thing that could easily have been converted into a testing machine.

1922. There is another thing in this specification which I should like to look at on page 4: "Piers for 66 feet spans. Each pier for the 66 feet spans to be formed of three cast-iron columns placed together, two being columns for the main girders, and one a stout column set into cast-iron cylinders according to Drawing Nos. 14 and 15, excepting Piers 58, 65, 69, 73, 77, and 80, which are to be double. The flanges of length of casting for the piles and columns to be turned on the face, and to have 8 foot bolt holes, 1½ in. diameter, accurately drilled therein to or through a gauge, so that any two flanges being applied to each other, the bolt holes would be true and fair; the lengths may be properly fitted and bolted together. That did apply to the holes to be drilled in the flanges of all the 14-inch columns?—No, to the 66 feet span; to the spans in the curve alone.

1923. What was the order that you gave or expected to have fulfilled with regard to the drilling of the holes in the flanges?—To drill holes at the distance of 1 foot 7 inches centre to centre, so as to receive an inch and an eighth bolt easily.

1924. Did that amount to an order to make the drill holes an inch and an eighth, or an inch, or how much more?—An inch and an eighth, or an inch and a sixteenth, as a rule. I had no other order to give, because the drills were there, and they could not be altered; we had no other drills.

1925. What was the diameter of the drill?—It was an inch and an eighth easy, and I would think a sixteenth of an inch over.

1926. Did you ever measure it?—I measured the holes.

1927. What was the diameter of any of the holes which you measured?—More than an inch and an eighth; I do not know exactly how much more, but surely not much more.

1928. Was it within an inch and a quarter?—Yes, it was within that as far as I recollect.

1929. But I understand you to say that they must all have been exactly the same, because the drill would not permit of variation?—Yes.

1930. Were these orders about drilling the holes that were given by you verbal or written?—There was a tracing of the columns given to the foreman by my predecessor, which showed all the details of the columns, and he had that, and that was a standing order.

1931. And therefore you never gave any orders yourself?—No.

1932. And the drills to make the holes were there before you went?—Yes.

1933. What were the bolts that were used in those flanges?—There were an inch and an eighth in diameter, and I think four inches and three-quarters long.

1934. Was not that inch and an eighth bolt rather loose in the hole that you have described?—No; it went in easy.

1935. Had it any security against slipping except the nut at the head?—Yes.

1936. What other security had it?—At any rate I am not speaking from personal experience, but I know that the order had been given to the engineers before the bridge was given up to the North British Company to caulk all of these bolts, and I have no reason to believe that it was not done by a conscientious man.

1937. But have you any reason to suppose that it was done except that you have been told so?—I would not take it upon me to say that the man who was in charge of it, who was an engineer, neglected that.

1938. Who was the engineer?—Mr. Reeves, and Mr. Delpratt before him. I do not know whether Mr. Reeves went over all the piers.

1939. But what I want to know is this: so far as you knew of your own knowledge and inspection, there was nothing to keep those bolts in their places except the nut that was screwed on?—And the caulking.

1940. But the caulking might or might not have been done?—In some instances I have seen the caulking done.

1941. Did you see that in many cases, or was it just here and there?—Just here and there a pier.

1942. From what you saw you inferred that it had been done all over?—Yes, the majority of the bolts that were caulked were done shortly before the opening, in the last two or three months before the opening.

1943. You did not see it done?—No, it was not under my charge.

1944. (The Commissioner.) I thought that this gentleman was the engineer who was left in charge for the last two or three months?—I was there a year after the contractors left it, but I was not in charge of the bridge; I was in charge of some of the plant used in the construction of the bridge and some operations.

1945. (Mr. Trayner.) On the shore?—On the shore.

1946. But you are not in a position to say, whatever you may think, whether the caulking was done over all the bolts or the great majority of the bolts, or not?—No, I am not.

1947. Without that caulking would the bolts have been slack?—They might have been, but as an engineer I might not have approved of it.

1948. A bolt of an inch and an eighth, which went into its hole easily, if not secured, would be apt to get more easy as it got older, would it not?—No, I do not think so.

1949. Would it wear?—No, I do not think so, nor if it were properly kept.

1950. But with the best nut that you could put on it in a bridge subject to more or less vibration, would it not be a necessary result that as the structure got older the hole would get larger, or the bolt would get smaller?—In the course of ages of course everything wears away. The tendency of a nut is to work loose under vibration.

1951. And the result of that would be that the bolt would come out of its place ultimately with vibration?—When the nut came off.

1952. Would it not have been better to have fitted these bolts a little tighter at first?—I do not think that would have made any difference if they were not cracked. A bolt that was fitted tight and was cracked was equally unsafe with a bolt that did not fit tight and was not cracked.
9179. Then it did not make any difference in your opinion whether the bolt was originally tight or loose; in either case the cracking was the material matter to attend to?—Yes, in my private opinion.

9180. In your private opinion as an engineer?—Yes.

9181. Did you employ Edward McGovan to bolt these columns together?—I did not employ him on the large girders, because I was there only a very short time, two or three weeks. I have not the least idea, and I do not think he was there then; but I am not sure of that.

9182. Was that a piece of work to trust to workmen?—Yes, if they were trained to it.

9183. If a man is trained to be an engineer he is fit for engineering work?—It does not take a long time, I had trained McGovan myself.

9184. And you thought then, and you think now, that he was quite a sufficient man to put to that job?—Yes.

9185. Did you ever inspect any of the columns that were erected by McGovan?—Yes.

9186. Will you say that they were not some of them off the straight?—I have not made myself clear. McGovan was trained by me, and when he was working under my orders, that was on the spans to the north of the last spans.

9187. It is right for you to say that. I understood you to say that you had trained him before you came to this work?—Yes, exactly.

9188. After McGovan had been working on the high girders, did you ever inspect any of the columns that he erected?—I had no occasion to have anything to do with McGovan after that.

9189. You did not do that in point of fact?—No.

9190. Assume from me that some of the columns and the three girders are off the perpendicular to the extent of three-eighths of an inch, how would you account for it?—To the north or south?

9191. Either north and south or east and west. Assume that they are off the perpendicular to any side three-eighths of an inch?—The columns under the high girders. Yes.

9192. How would you account for that?—Do you mean at the present time after the fall?

9193. Yes?—That would be knocked out of position after the fall.

9194. If the bolts had fitted tight and had been tightly caulked would that have taken place?—Yes, I would think so, with a good blow—the bolt would have been in that matter.

9195. Have you ever seen cast metal bending to the extent of three-eighths of an inch?—Not cast metal, but bolts I have.

9196. Cast metal would break before that?—When it was stretched to the extent of three-eighths of an inch.

9197. Cast metal will not bend to the extent of three-eighths on an inch?—It depends upon the length.

9198. In one of these 15-inch columns?—No, I do not think so.

9199. What were the bolts made of?—Of wrought iron.

9200. So that if the lying over off the perpendicular is the result of the bolt giving, that would be visible on the bolt itself?—It depends upon the number of bolts. If there are seven or eight bolts in the height then the drawing may be divided over that height.

9201. I had a certain landing of four columns in one of the piers, and the next day there was three-eighths of an inch off the perpendicular. You think, do you, that that may be accounted for by the twist that it got when the girders fell?—I would not be prepared to say that unless I saw the columns myself.

9202. But assume from me that the columns are three eighths off the perpendicular, how would you, as an engineer, account for that?—Well, it may happen, for instance, that the stonework on which the bottom columns are standing had been defective. I cannot account for it unless I inspected it minutely.

9203. Would it be accounted for if the bolts had not properly fitted?—If the bolts were slack.

9204. That would account for it?—That would show it.

9205. It would account for it?—No, it would fall back, I think, into the perpendicular if it had been plumb.

9206. Supposing that it is off the perpendicular to the extent which I have put it, would that be a probable result of the bolts not fitting the drill holes sufficiently?—I could not say that off-hand.

9207. Can you off-hand account for it in any way?—No.

9208. Do you doubt its possibility?—No, I fully believe what you say.

9209. It is not my statement; it is an assumption for the purpose of this examination, do you think that the assumption is too violent to be real?—That there should be an eighth of an inch difference? I will believe everything after the bridge has fallen down.

9210. You believe that this may have happened that one landing is three-eighths of an inch off the perpendicular from that below it?—Well, I am not a very strong believer, but I understood that you had seen it.

9211. Do you think that that is a possible thing, or do you think that it is not?—I am not prepared to say, I do not believe it till I see it.

9212. You have made no examination of the bridge then since it fell?—I have been along the girders, I have been in a steamer, and I attempted to get there the last spring tide, but I was not successful. I have only been a short time in town since.

9213. You have not been landed on any of the piers since?—No; I have not.

9214. Where are you engaged just now?—I am, nominally, what I have been for the last 15 months, agent for the Aqueous Works and Diamond Rock Boring Company. I was engaged in Buckie, in Banffshire, in blasting the bottom of the sea with the diamond rock drill, but that has come to an end now, and at the present I am doing nothing.

9215. The lugs were fitted into the different columns for the purpose of holding on the tie rods or the bracing?—The bracing bars horizontal and diagonal.

9216. And to fasten the bracing rod you had two plates beside the lug?—Yes, inside the lug.

9217. And into those plates the bracing rod was put?—Yes.

9218. How was the end of the bracing rod fastened to the plate?—There was a slotted hole in the plates and in the bracing rod.

9219. And into those holes, in order to keep them together, you put on a gib and a cotter?—A gib and two coppers.

9220. The gib is a U-shaped thing?—Yes, and a cotter is a wedge.

9221a. And the U-shaped gib held the two plates together at the upper end of the slot hole?—Yes.

9221. To keep that in its place, you put in the two wedges, or coppers, as you call them?—Yes.

9222. Those are shaped like a wedge?—Yes.

9223. With a split at the small end and solid at the bend?—Yes.

9224. And I understand that you put them in in the opposite directions to each other as regards end and head?—Yes.

9225. Was it necessary, in order to have these perform their work efficiently, that the surface should be quite plain and flat?—Yes, at any rate practically so.

9226. That there should be no material inequalities of surface?—No.

9227. How did you proceed to obtain the necessary equality of surface, by planing, or simply by hammering?—I am not aware of that, because we got these coppers from Middleton.

9228. They came supplied?—Yes.

9228a. Did you yourself inspect any part of these braces after they had been fixed in the manner described on the high girders?—No, not purposely. Of
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I have seen them, but I did not go there for the purpose.

2923. Then you are not in a position to say whether they had been sufficiently tight or not?—No.

2920. Was that a piece of work entrusted to McGovm?—I could not speak to that, I would think so, part of it.

2921. I think McGovan said so yesterday?—Part of it.

2922. He said that he was not only to drive the bolts into the flanges, but he also said that he was there to fix up the bracing rods?—Yes.

2923. If he put up the bracing rods he must have used the gibes and cutters that I have been speaking of?—Yes, but not necessarily. He gave them the lightest touch. The erectors tightened them up sufficient for the erection, and the final finishing and tightening up of these cutters was done shortly before the opening.

2924. If McGovan did not do it when he was at it, who was the man that was bound to see to their being finished up before the job was taken off the contractors' hands?—Mr. Reeves.

2925. But the fastening up of these girders, I take it, was a very particular piece of the work; and that is the very reason why Mr. Reeves, the oldest engineer on the work, was entrusted with it.

2926. It was very particular work, and, therefore, for the oldest resident engineer, was the man charged with the duty of looking after it?—Exactly; at any rate, I suppose so. He was known as a careful man.

2927. If these bracings gave way through defective fastenings, what would be the effect of that have been on the stability of the girders?—It would surely not increase the stability; it would diminish the stability.

2928. If these were not properly fitted as regards the surface of the cutters to each other, and properly driven home or fastened by spreading out the slit at the end, would these cutters have a tendency to come away through the vibration of the bridge?—I would think so if they were not opened up.

2929. They were not opened up at the end of the split?—Yes. At any rate, it might be so. The friction might be sufficient to keep them; I could not say that for a certainty.

2930. The probability is that the vibration would not shake them out of their places?—I would not trust it, at any rate.

2931. Only want to get at the fact. Do you not think the probability is that the vibration of the bridge would shake them out of their places if they were not properly fastened at the split ends?—That is not what I would think, but, however, I may be wrong.

(The Commissioner.) Of course you are only giving your opinion.

2932. (Mr. Traynor.) And it is so much your opinion that, as an engineer, you would not have passed it, if it had been your duty, without seeing that those cutters were properly secured?—Of course.

2933. You had another part of the bridge which had a great bearing on its stability, and that was the column which you called the male and female attachments?—Yes.

2934. Those were cast upon the columns?—Yes.

2935. After they were cast was that a part of the column that the turner applied his lathe to?—Yes.

2936. And was the recess into which the male attachment went a cast or drilled recess?—That was drilled.

2937. So that they should fit exactly?—Yes.

2938. Tightly?—No, not so very tight, because you would not be able to get them in.

2939. Of course there must have been room to get it into the recess, but just room to get it in and no more?—Yes, just room and no more.

2940. I say you regard that as a very essential element in the formation of the column, looking to the purpose for which the columns were to be used?—No, not very.

2941. Was it unimportant?—Not unimportant. They might have been a little longer and stronger, may be. That is my opinion as an engineer, but I had nothing to do with that.

2942. But they were evidently deemed of importance because they were part of the design?—I looked upon them in this way, that they were a guide and a security to erect the columns in a proper line, and as such they were very useful.

2943. It was of the last consequence to have the columns fitting directly one over the other?—Exactly.

2944. And that was a means of testing to some extent, or of securing to some extent, that that would take place in the erection?—Yes.

2945. Without that there was there a probability, more or less great, of the columns not being placed in a perpendicular position, one below the other?—Not very much, because all the columns were placed.

2946. But it was an additional security?—Yes.

2947. Were those male and female attachments on every column?—I am aware of. They were on all the columns except the bottom length, the 18 inch columns, and there they were left out purposely, why I do not know.

2948. But with the exception of the bottom lengths, the lowest lengths on the pillars, and with the exception of the lowest columns of 18 inches diameter, all the other columns, so far as you are aware, had the male and female attachments?—Yes, on the high girders so far as I am aware.

2949. Would you be astonished to hear that there are a great many of the columns standing now where the high girders stood which show that there never was such a male and female attachment at all?—Yes, I should be very much astonished.

2950. If that is the case, how could that have happened?—I cannot account for it.

2951. Could they have been turned off?—They must have been knocked off after they left the foundry if these were done during the time when I was there.

2952. During the last 12 months or so that you had charge of the foundry?—Yes.

2953. But all the columns that you inspected had them?—Yes; I am almost certain of it.

2954. If a lag got accidentally broken off in whole or in part, you are aware that lugs wholly or partially were burnt on to the columns?—I was aware of course. I had done it myself; that is to say, I had given the order myself. I am not speaking of the columns of the high girders.

2955. But I am speaking of the columns of the high girders?—I could not speak to that. I know that in the case of one 18-inch column, as I said yesterday, I tried to burn on the lugs.

2956. That is the only one that you knew of?—Yes.

2957. Is it your opinion that a column which is burnt on is as strong as if it had formed part of the original casting?—If it was done carefully and properly.

2958. We had one moulder who told us that he had done his best, and he could not get the bottom of the lug that was burnt on to attach to the flange. Do you think that is consistent with any experience that you have had?—He may have done it in the wrong way, it may have been that there was no metal to fuse it on.

2959. Supposing that he was a man of considerable experience as a moulder, and apparently a man of some intelligence as a moulder, would you go to the length of differing from him if he said that doing his best he never could get the lug burnt on so securely to the flange as if it had been moulded?—Certainly not, if the man said that I would not contradict him.

2960. You have no experience to contradict him, have you?—Yes, I have.

2961. Have you seen any lugs burnt on at this work at Wormit except on the 18-inch pipe?—Yes.

2962. On what?—I have seen about 18 at any rate.


2964. That is the limit of your experience as to the burning on at Wormit?—So far as I can remember just now.
9275. In any of these cases did you observe any crack whatever?—Never, always excepting this one case.

9276. Then does it come to this:—That you would just as soon, so far as strength is concerned, have a lug that is burnt on wholly or partially as a lug that forms part of the original casting?—Yes, if it was done carefully. I have seen it with my eyes.

9277. So far as your experience goes the one is as good as the other?—Yes, I am convinced of it.

9278. Do you think you can ever heat the column with the remaining part of the lug that is on it up to the same state in which the molten metal is that is being poured on to complete the lug?—Yes, the part where the lug is to be burnt on. There must be a piece of the lug left.

9279. Assuming a column with a piece of the lug cast on it, and that you are about to apply molten metal to make up the piece of the lug that is gone, can you get, or in practice do you ever get, the column with the adhering piece of the lug up to the same state of heat in which of necessity the molten metal is that is being applied?—I do not know that because I have never tested the heat, but I know the result was that it was as stated.

9280. We will leave the results about the strength out of view just now?—I cannot speak as to the temperature of the respective heats, nobody could.

9281. You cannot?—No.

9282. Unless you get the metal up to the same temperature as that of the metal which you are pouring upon it, there cannot be a perfect fuse?—It need not be exactly of the same temperature, but they will both fuse. Where they join, the temperature must necessarily be the same.

9283. Then unless you have the same temperature at the point of joining, there will be no fusing?—Well, that is the effect, and the other is the result.

9284. Result and effect is the same thing?—The one is the effect, and the other is the cause. Whenever two surfaces meet together, if you leave them long enough together, the temperature must become the same; and therefore I have no doubt, on that principle, that if you pour metal on and keep it pouring long enough, you must arrive at that result.

9285. But the column itself to which the part of the lug is attached will never reach the temperature of the molten metal?—No, it is not necessary either.

9286. Whether necessary or not, in point of effect it will not reach it; for if it reached that state of temperature, it would no longer be a column, it would run?—Yes.

9287. The state of the temperature on the column will affect more or less the temperature of that piece of the lug that is adhering to the columns as part of the original casting?—Yes; but this temperature dies gradually off.

9288. Will you ever get a complete fuse until the metal which you are pouring on, and the part of the lug to which it is being poured on, have come to the same point of heat?—No, but on the same principle a ladle which holds the molten metal need not fuse for all that, although it is in close contact with the metal. You cannot see the one, but it does not matter?—I compared the ladle to the column.

9289. The ladle never fuses with the metal in it?—Exactly; neither need a column fuse.

9290. You know the diagonal bars between the uprights at the juncture of the girders, what are called the end posts in post office in what purpose were they intended to serve?—I do not know.

9291. But as an engineer what do you think was their purpose?—Well, I think as an engineer that they may have served first of all (and I think that would be the original idea in such a case) to keep the plate from buckling.

9292. What is that; to keep them from approaching each other?—Yes, or going asunder; one of the two.

9293. It was to keep them in their place relatively to each other?—I do not know.

9294. That is what you have said, is it not?—That is my opinion.

9295. Was it of importance that these end posts should be kept in their place relatively to each?—Yes.

9296. Was it of importance?—If the plate buckles, of course the strength is gone, and that plate cannot act; not the strength of the whole end post, but of that plate, practically speaking.

9297. Was it of importance to the bridge that these diagonal bars should be kept, and securely kept in their position?—Not in my opinion.

9298. Then they might have been away, in your opinion, altogether so far as the stability of the bridge went?—Yes, I think so.

9299. Therefore, in your opinion, there is no object in them except that of ornamentation?—They helped to stiffen it a little, of course; but I may explain that the reason why I expressed that opinion is that a section of the metal in the bar is entirely out of proportion to the section of the one rivet that holds it, and therefore on that principle a section of a bar equal to the section of the rivet would have been sufficient.

9300. They would have been sufficient to serve the purpose for which they were there?—Yes; that is what I should think, though I may be wrong.

9301. I was putting it too strongly when I said that the result of your evidence was that they were of no use; these were of use?—To my opinion practically they were of no use.

9302. You were often on the bridge when trains went past, were you not?—Yes.

9303. Were the end posts serving any purpose?—Yes.

9304. Both passenger and ballast trains?—Yes.

9305. And you did feel a certain vibration, I think?—Yes.

9306. From which did you feel the greatest vibration, from the ballast trains or from the passenger trains?—I do not think there was much difference.

9307. Was there any?—The want of springs in the ballast trains made up I think for the lightness of the passenger trains.

9308. Was there any difference between the vibration occasioned by the passing of a ballast train and that occasioned by the passing of a passenger train?—I cannot recollect; the difference was not sufficient to leave an impression upon my mind.

9309. Did you feel this vibration at some distance before the train reached the point of observation?—Yes.

9310. How far from you did you first feel the vibration of the bridge occasioned by an approaching train?—As soon as the train was on the span that was connected to the three others.

9311. That was so soon as it came upon the one set of connected girders?—Exactly.

9312. Some of these connections I think extended over four spans, and some of them over three spans?—Over four and five spans.

9313. Could you put roughly how many yards in advance of the train you felt the motion?—I have always found it very deceptive to distinguish between feeling a motion and hearing a sound. I think you felt somehow that a train was on the girders, but I did not feel any motion until the train was on the span immediately preceding the illustrating one that I was standing on.

9314. There was a certain rumble occasioned when it came in within the connected girders?—Yes.

9315. But whether that was produced by the vibration of the surface of the bridge or was a vibration of sound in your own ear, you could not distinguish at that distance?—No.

9316. But you could distinguish the vibration upon the bridge when the train came on the span that you were on?—Yes.

9317. Or the span next to it?—Yes, or the next to it, and in the span that I was on; but it must have been vibration because they were connected, although it was very little.

9318. Was that vibration very perceptible within the connected girders; from the time that you first felt it until it came up to you was it distinctly perceptible?—Yes.
3919. Was it perceptibly increased as the train advanced?—That vibration never increased very much.
3920. Then you felt it just as much when you first felt it as you did either when it passed you or after it had gone past?—It got a little stronger in proportion of course.
3921. Was it so slightly stronger as not to make any noticeable impression upon your mind?—So far that you naturally expect when a train comes near you to feel an increase of the trembling, and therefore you are not apt to make an observation upon that point.
3922. But your observation does not enable you to say more than this: that, as you would anticipate, so you believed you perceived that on the approach of the train the vibration did increase?—Yes, exactly.
3923. But the extent to which it was so increased, you could not put it into figures?—No.
3924. As the bridge itself did yield more or less to the passing train?—Yes, and it was expected to do it too.
3925. Did the vibration under foot upon the bridge amount to more than the vibration that you have felt on the solid ground in the case of a train passing you closely?—Sometimes it did in the case of some trains.
3926. I have been standing on embankments when trains have been passing, and I have almost felt as much vibration there. On a rocky soil you feel the vibration of a train on the solid ground just as much sometimes.
3927. I do not want to press you too closely, but if you were standing upon the solid ground, and not upon a jolted embankment, can you say whether the vibration of the earth was as great as the vibration of the bridge at any time when perceived by you?—No, I can only say it was greater.
3928. Was it so much in excess of what you had experienced on solid ground, as to enable you to put it into figures?—No; I am always speaking of the vibration in the structure, and not of the deflection of the girders.
3929. Now, since you have mentioned it, there was deflection?—Yes.
3930. It was obvious and perceptible?—Yes, naturally.
3931. To what extent?—I do not know; I could not put it in figures. I know from the Government Inspector's report that there was deflection.
3932. You are aware that there was deflection, as was expected?—Yes, when there was a load on the girders.
3933. But what it was in figures you cannot say?—No.
3934. Was there no oscillation at all from side to side?—No, not that I observed at any rate.
3935. What I want to get at is this: give me as nearly as you can the date of the last occasion on which you stood on the bridge, and experienced the vibration or deflection occasioned by a passing train?—It must have been in October 1878. I beg your pardon, it must have been in September 1878.
3936. This bridge gave way in the end of September 1879. Do you think that the vibration or deflection, which you have spoken to would increase between September 1878 and December 1879?—Not if the bridge were kept in the same condition as it was then.
3937. But given the bridge as you saw it last, would you have expected naturally an increase in the vibration or deflection in the course of the following 15 months?—No!
3938. Then if any persons found a train going across that bridge with such a vertical motion, as to be described as a prancing or a bounding motion, how would you account for that, assuming their statements to be correct?—I would account for that in a similar way (I have often thought of that), as one can account for exaggeration in the case of earthquakes, a little shock experienced by people who have never felt one before would be exaggerated into a waving motion of the earth. I have seen that repeatedly.
3939. Then your account of it is that it is exaggeration on the part of the person who describes it?—Exactly, it may be so.
3940. If the bridge was getting looser in its structure would that account for it?—Yes, there is no doubt about it; that is to say, the girders.
3941. Would the loosening of these bracing rods at the hogs have anything to do with the production of such a result?—I do not think so.
3942. Then what part of the bridge do you think must have got loosened to account for that extreme vibration or deflection if it existed at the time I have mentioned?—Well, I could not account for it. The girders must have somehow lost their original shape; I am not prepared to say.
3943. I suppose it was possible for the girders to lose their rigidity, and if it was possible what was the most likely cause of such an effect?—I do not believe it was possible for the girders to lose their rigidity, and I cannot think that they did.
3944. You do not believe it was possible for men to have felt a greater vibration in December 1879 than you felt in September 1878, or do you believe it possible?—Well, I do not believe a thing until I see it myself.
3945. Then the result of it is that you do not believe that the deflection in December 1879 was greater than it was in September 1878?—No.
3946. Can you conceive that it was possibly greater in December 1879 than September 1878?—No.
3947. If different persons described the vibrations or deflections of the bridge in or about December 1879 as producing a bounding or prancing motion in the train, do you still adhere to your opinion that was more exaggeration and not fact?—Well, I could explain to myself in this way; that if a train runs fast you feel all sorts of motions, and one is not in a proper position to judge of the movement of the soil or surface that one is moving over from the movement of the carriage that one is sitting in.
3948. You think that persons may have been in accurate observing?—Exactly; I have seen express trains going along in the shape of a serpent, with the carriages swaying as much as that on a solid road.
3949. That is a lateral oscillation?—Yes; but I have felt myself going up and down very much.
3950. You may be quite correct, but I am rather pointing at this: How could these persons, who were of course describing with particularness what they thought, have been so much deceived as you seem to think they have been? Can you account for it at all?—I have never given any thought to it.
3951. What was the speed in your judgment that a train ever attained in crossing the high girders?—The trains that I have seen went I would think about 30 miles an hour, but that is a mere guess of course. I have never timed the trains between the high girders.
3952. Were you employed by Hopkins, Gilkes, and Co. originally on this bridge?—I was employed first by Charles de Bergue and Co.
3953. (The Commissioner.) And then after by Hopkins, Gilkes, and Co.?—(Mr. Traeger.) Can you tell approximately the date when Charles de Bergue and Co. ceased to be contractors for the bridge, and Hopkins, Gilkes, and Co. came on?—In May 1876; that is speaking from memory, but I am almost positive about it.
3955. What was the condition of the bridge when de Bergue and Co. ceased to be the contractors and Hopkins, Gilkes, and Co. came?—Speaking approximately, there were 15 piers standing on the south side of the river.
3956. Brickwork?—Brickwork and girders upon the top of them. I am not sure whether the fifteenth pier was in the course of construction or not. That was at the south end. Then on the north side, just before the curve begins, there were standing five piers.
3957. (Mr. Traeger.) Five piers on the water?—Five piers in the water, and some of them had columns
on them, and some of them had girders on them too.

8388. (The Commissioner.) That is in the north side?—Yes, not to the very top, but they were in the act of being finished. I am not sure about the girders, though, and the curve on the north side of the bridge was completed to where the large bowstring span now exists.

8389. (Mr. Trayner.) I think it comes to this, that from the fifth pier, counting from the north, to the fifteenth pier counting from the south, there was more or less done, but between these points nothing was done.

—There was a good deal done.

8390. What was done?—The 15 girders were up and the 15 spans were up.

8391. But leaving out of view altogether the 15 piers to the south and leaving out five from the north, the general work entirely done by Hopkins, Gilkes, and Co.?—Except those piers that I have mentioned.

8392. (The Commissioner.) Fifteen on the south side, and five on the north?—In between there were five piers and columns erected on them. The piers were finished and sunk, and the columns were built up upon them, some to the total height, and others partially.

8393. Besides the 15 piers and the five?—Yes.

8394. There were five more then?—Yes.

8395. (Mr. Trayner.) In the contract between the Railway Company and Hopkins, Gilkes, and Co., there was a sentence about 50 lines from the bottom of the first page: ”Contractors further bind and obligate themselves that they shall forthwith enter upon the works, and that they will substantially and in good manner, and so on, ‘execute and finish the bridge’ with all the works incidental to the perfect construction and completion of the same” (this is what I was to call your attention to) “including the restoration of the work erected by the former contractors which has failed through bad foundations.” What part of the work erected by de Bergne and Company is referred to there as having failed through bad foundations?—That is the fifteenth pier from the south side.

8396. And that only?—And that only. I beg your pardon; there are some more which may have been included, but I hardly think it from the wording. There were five piers standing at the bottom of the river, but not sunk beyond those 15 piers, and they have never been used. Different spans have been introduced and those piers have been taken away.

8397. What was the matter with the fifteenth pier from the south which is referred to in this provision; what had it made it fall through bad foundation; what was wrong with the foundation?—The nature of the clay on the south side was stiff, a good sand clay, but on the other corner of the pier there was a bed of soft, soapy clay, and that caused the pier to heel over after it had been built to the full top.

8398. You mean the fifteenth pier from the south?—Yes.

8399. Was it on a different foundation from the others?—Yes.

8400. So far as you know, with the exception of the piers that were not used, that is the only part of the contract which fell within this provision about restoring the work that had failed through bad foundation?—Yes.

8401. What amount, if any, was there of iron which Mr. Hopkins, Gilkes, and Co. took over from de Bergne and Company when they came in 1874?—There was a great amount of iron, especially in the shape of 180 feet spans and 66 feet spans. All the spans in the curve for instance were made by de Bergne, except some small pieces over some of the piers.

8402. Could you give it me in tons?—I am just going to bring it into tons. I could get that by referring to my notes.

8403. If you give it to me roughly that will do; would you have the goodness from your notes to make up a detailed statement, and send it to the Court, of the iron which you took over, both as regards its character and its quality?—Yes.

8404. When I say the character of the iron I do not mean that you are to give any opinion as to whether it was in mouldings, or was in girders, or what it was in?—Yes.

8405. When you were under de Bergne and Co., what was your exact position in the works?—Under Messrs. de Bergne and Co. I was at that time superintending the sinking piers under pressure.

8406. The sinking of the stone piers?—Cast-iron piers and stone piers.

8407. Were you at that work when the contract was taken over?—I am not quite sure whether I had anything else in hand then.

8408. Did your position under Hopkins, Gilkes, and Co. change from the position that you had occupied under de Bergne’s contract?—It did not change in the least.

8409. Then when Hopkins, Gilkes, and Co. got the contract Mr. Gröthe came as the principal resident engineer?—He was there.

8410. He was there under de Bergne too?—Yes; from the very beginning.

8411. Then your relative position to him was exactly the same so long as he was there?—Exactly.

8412. And after Mr. Gröthe left who took his place?—He was there until the bridge was handed over to the North British Railway.

8413. And you were Mr. Gröthe’s principal assistant?—I was one of them; the work was so much divided that I could not call myself the principal assistant; in some respects I was, and in other respects there was a second who was principal assistant.

8414. But there were others in other departments?—Yes, in one respect I was the principal assistant because I was entrusted with the monthly accounts of the North British Railway Company, and as such I had to be acquainted with everything.

8415. (Mr. Balfour.) I see that there was a valuation by Mr. Anderson. If the Court or the Board of Trade desire it, I should think that the valuation by Mr. Anderson would probably give that valuation?—That would give every information.

8416. (Mr. Balfour.) There would no doubt be an inventory, or, at least, I should suppose so.

8417. (Mr. Trayner.) I have no doubt whatever that that will serve the purpose.

Re-examined by Mr. Balfour.

8418. You said, I think, in reference to what Mr. Trayner asked you last, that it was the fifteenth pier from the south, the foundation of which had failed?

—Yes.

8419. Was it in consequence of the foundation or river bottom being discovered to be inadequate that the change of plan took place?—I think so.

8420. From the brick piers to the metal piers?—Yes.

8421. And was that fifteenth pier the first one in which that inadequacy of foundation had been noted?—No, it was not the first one. The difficulty had appeared in a pier which they had been trying to sink to the north of that one.

8422. But at all events the necessity for taking down some work that had been up there arose from the discovery that the foundation was inadequate?—Yes.

8423. And then the plan was changed, and the work was carried out as we now see it?—I do not think that was the immediate cause of it, but something similar to that.

8424. Was there anything wrong with the work itself?—No, nothing whatever.

8425. It was not from defects in the work itself, but from something independent of the work that it became necessary to take it up?—Yes.

8426. In designing such work as this Tay Bridge do engineers provide a large excess of reserve strength.
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beyond what the work is expected to be called upon to bear?—Yes.

3935. Can you give us any idea of what excess or reserve of strength was provided in the case of the Tay Bridge?—As a rule four and five times that amount in the wrought iron and in the cast iron a good deal more, I think.

3936. How much more?—Six times, I think, but that can easily be made out.

(The Commissioner.) That is rather the scientific part upon which we are engaged at present.

3937. (Mr. Balfour.) Then I will not pursue it, sir. (To the witness.) You know that that was so?—Yes.

3938. And such reserve of strength, I suppose, is to provide for all contingencies, including the risks of possible bad pieces which may have escaped observation?—I suppose so; otherwise there would not be any good in it.

3939. You did your best, I suppose, while you were there to detect all the bad work?—Yes.

3940. But some within the columns may possibly have escaped?—Yes.

3941. You were asked as to the effect of such things as you have seen on the three pieces shown to you; do you think that the mere existence of such defects as those occurring in one flask or pipe of a pier would be so much more of such pieces in the whole length of a pier?—No, I do not think so; of course it would not be a right thing, but as to the strength and stability I do not think it would make a material difference.

3942. Of course if you had a pier built of bad columns altogether then that would be a bad pier?—No doubt.

3943. But do you think that the occurrence of such things in a pier which consists chiefly of sound columns would jeopardise it?—No, not generally speaking.

3944. As far as anything that you have seen?—No.

3945. Of course you know nothing about what these pieces are yourself?—No.

3946. Can you say from looking at them whether they are parts of 15 inch columns or of 18 inch columns?—I could see by measuring the columns.

3947. But from the examination that you made just now you cannot say?—No.

I will not ask you any more about it because it is better to leave out the scientific questions at present.

(The Commissioner.) There are some questions that I should have liked to ask Mr. Campbell, but I think it is better to reserve those for the future.

3948-9. (Mr. Balfour, to the witness.) Passing to the actual character of the work, do you know that instructions were given to have all the bolts caulked?—Yes.

3949. That done under the direction of careful men?—Yes, so far I am aware.

3950. And by careful men?—Yes.

3951. Under Reeves and Delpratt?—Yes.

3952. Did you see Reeves and Delpratt going about and examining the work?—I often met Mr. Reeves on the bridge, for I had occasion to cross the bridge while he was working there.

3953. He is now in Portugal, I believe?—I think so.

3954. Was he a careful man?—Yes.

3955. And skilled?—Yes.

3956. Was he a man likely to pass uncaulked rivets?—I should not think so.

3957. With regard to Mr. Guvian you said that he had been trained under you; what training do you refer to?—I got him as a labourer, it must have been somewhere near 1874, and I put him in with the foreman and let him go through all the work that had to be done, and very soon I got advice from the foreman that he was a very clever and intelligent lad; he was not much above 20 years old then, and I have had all along great satisfaction from him. He was never more than a labourer, but some labourers are more to be trusted than others, who are called smart men, and he was one of them. I have lost sights of him since.

3958. He was first a leading man and then a foreman?—Yes.

3959. Was he trained to the particular kind of work of which he was afterwards put in charge by a skilled foreman until he himself became possessed of skill?—Yes.

3960. And when he put in charge until he had shown to your satisfaction that he had the requisite skill?—He was not under my charge, he was under Mr. Delpratt.

3961. Did you see that he had the requisite skill when he was under your charge?—I have no doubt that he had.

3962. In regard to the bracing rods, did you examine any of the ends of the bracing rods, or was it not within your department?—Not exactly; I looked at them going up and down the piers and they were not all permanently tried, and I did not pay particular attention to them.

3963. Who would be the best person from whom to get an account of the state that they were left in?—They would be Mr. Reeves, Mr. Delpratt, and the foreman.

3964. What are their names?—I believe Orran was one of them, and Robertson.

3965. And Dixon?—I do not know all those men by name, because I had directly nothing to do with it.

3966. But can you tell us who, so far as your knowledge goes, would be the best men to give the Court an account of that matter?—I think Alexander Robertson, who was foreman blacksmith at the bridge, would be able to give some information as to the caulking of some of the piers at any rate.

3967. You were asked about the moulding of the piers; I will not go through the detail again, but do you think that a moulder of ordinary skill using ordinary care would have any difficulty in casting on a lug so as to be solid and strong?—No, it is not given to every moulder to do that.

3968. A moulder of competent skill?—Yes, if he is an intelligent man who knows how to beat his column properly.

3969. Was the casting on of the lugs at the Wormit Foundry confided to men competent for the work?—Yes, the foreman always did it himself.

3970. Fergus Fergusson in your time?—Yes.

3971. Was he competent for that work?—Yes, most decidedly.

3972. But you say that it is not a thing that you would have confided to every moulder?—No.

3973. You were asked some questions about the difference of temperature between the two parts of the metal, the metal which was proposed to be added and the metal to which it was to be added; when the two edges of the two portions of the metal came into close contact would they give and take heat so that the heat of the two would become the same?—It must keep the laws of nature.

3974. The laws of nature make it necessary, do they not, that at the edges where they come into contact the transmission of the heat must make the temperature similar?—Yes.

3975. And if the temperature was high enough they could fuse together?—Yes.

3976. And you saw that that was the case with the lug's?—Yes, at any rate as far as you can test it with a sledge hammer.

3977. Was a blow from a sledge hammer a very severe test?—Yes; but I would not take that as being a test, because the chances are great that you knock the lug off.

3978. You were asked some questions as to the persons observing vibration; are the results of different people's impressions of such a matter very different in your experience?—Yes.

3979. Depending to some extent upon imagination, I suppose?—Yes, and nervousness.

3980. And in passing through such a place as the high girders, do you think that the flashing appearance of going past the cross-bars would have some effect.
upon many people?—It would give them a wrong idea of the velocity or likely.

9443. It is not a common appearance in railway travelling?—No.

9444. And therefore it would naturally affect some observers?—Yes.

9445. In your experience, would it be easy for an ordinary observer at all events to separate the motion of the bridge from the motion of the carriages?—No; I do not think a competent person could make anything of it.

9446. As regards the lateral motion, are you aware that the braces of the journals very often wear, especially where curves have to be gone round?—Yes.

9447. And that was the case coming by the Newport line?—Yes.

9448. There are very sharp curves there, are there not?—Yes.

9449. Where the braces of the journals wore, would that necessarily give a side motion of the body of the carriage upon what was below?—Yes, I think so.

9450. And might it quite readily be mistaken by a person travelling for a motion of the structure of the bridge on which they were travelling?—I suppose so; at any rate, I can understand fully well that one was mistaken for the other.

9451. I think, you told us you had not made any observations as to speed?—No.

9452. (Mr. Tweymore.) You said to me a little while ago that there was a change made in the plans of the bridge, giving up brick piers, and adopting iron ones?—Yes.

9453. In your opinion, what was the cause of it?—I think the immediate cause of it was that a pier was floated out to the north side of the river, which, according to the old plan, was No. 45, and a violent gale springing up and scouring away the sand round it, and the pier was upset, and, I believe, the loss of that pier started the notion that larger bases were required, and the larger bases could, of course, be used; but if they were built up in the same solid style of brickwork, that would mean expense that was not necessary, and I think when the opportunity was given that brickwork was given up and iron put instead of it; but that is a thing without my knowledge.

9454. (The Commissioner.) With respect to the lateral motion, in answer to Mr. Balfour, you have said that it might be generated, as I understand, in coming round the curve?—Yes.

9455. (Mr. Balfour.) My question was whether the braces of the journals might not be iron by the trains having to come round the curve. I did not suggest that motion was generated coming round the curve.

9456. (The Commissioner, to the Witness.) I thought he understood that you mean that the wheels themselves would get out of gauge a little?—Yes.

9457. Which would get out of gauge, the rail itself or the wheels?—The wheel in the axles, the axles and their bearings.

9458. Which is it that you mean?—The axles working in the bearings would get a little out of gauge, a very little would do it. I think one often feels it in railway travelling, and I have always ascribed it to that.

9459. But would it be any more so on the bridge than another railroad?—There was a pretty sharp curve, and there is an incline too.

9460. But you have seen an equally sharp curve on other lines, have you not?—Yes; I do not mean to say that you would not feel the same motion on any other line.

9461. Is not this curve just before you come to the signal-box on the south side?—Yes.

9462. And where you go very slowly?—Yes; but they go pretty quickly near the curve down the north side.

9463. You come from Meaux, de Bergue's to this work, did you not?—Yes.

9464. Was Meaux, de Bergue's the first place to which you went?—The first place I went to was Cardiff, to Mr. de Bergue's.

9465. When did you go to him originally?—In the beginning of 1873.

9466. Then it was from the beginning of 1873 that you first began to learn anything of engineering, was it?—No, I beg your pardon, I got my diploma as an engineer in 1871.

9467. Then where did you get your diploma?—I got a diploma from the Public Works Department in Holland.

9468. Then your first work upon anything of the kind was with Mr. de Bergue in the beginning of 1872?—Yes, in bridge building.

9469. And when you came your first work was in sinking the pier?—Yes.

9470. Then after that you were put to lifting the girders, were you not?—Yes.

9471. And you continued to do that until these two girders came down?—I beg your pardon, I had left off by that time; they think so.

9472. Then these two came down when Mr. Grösche had the superintendence, did they?—Mr. Delpratt had the superintendence, but I understood that he received all orders as to detail from Mr. Grösche.

9473. Then you had ceased having anything to do with the girder when those two came down?—Yes.

9474. You were then at the foundry?—Yes, and other works.

9475. But chiefly at the foundry?—Yes.

9476. Had you any experience at all in moulding when you were at Mr. de Bergue's?—No, not as manager.

9477. Nor, of course, any practical experience?—I have seen a great deal of work, and got information myself.

9478. In moulding?—Not in practical moulding; but, of course, every civil engineer is supposed to know the material that he has to work with.

9479. But, as I understand you, after you went to the moulding works, the person who was responsible for passing the columns was yourself?—Yes; I was responsible to Mr. Grösche, of course.

9480. You were the head?—I was the manager of the foundry.

9481. You were responsible for the sufficiency of these columns?—Yes.

9482. And, as I understand, the only mode in which you tested them was by looking at them from the outside to see whether they were sound or whether you could see any defects?—Yes; and by satisfying myself that the means employed in melting and casting were such as to ensure proper setting.

9483. But I understand that you did not often test them with the hammer?—Not unless I had suspicions.

9484. But, even if you had suspicions, I understand that you would not have been able to test whether or not they were of proper thickness?—Not if the difference in thickness was very little.

9485. You would not be able to know whether or not they were of the proper thickness?—I do not think so; I had never had reason to try that. I do not know.

9486. You say that it would require a skilled person to do it?—No, I do not mean to say that; I say I am not sure whether I could detect the difference in sound and pitch between a casting of five-eighths of an inch and a casting of one inch three-eighths. I have never made any experiments by which I am able to distinguish the pitch.

9487. Then the columns which were sent out from the foundry might be as far as you knew have half of them been of unequal thickness?—My conviction is quite the other way.

9488. But they might have been so, unless they showed it on the outside?—They could not show it from the outside very well.

9489. And you took no other means to ascertain whether they were of unequal thickness?—No, I had no instructions to do that.
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4989. And you took no means of ascertaining it?—
As a matter of fact all the means that I had to
ascertain that they were good sound castings was my
own satisfaction that the means employed for moulding and
casting were such as to ensure equal thickness, and I
made as many experiments as I could, inspecting
carefully every column that was broken up.

4990. That is to say you inspected it externally?—
EXTERNAL, that was broken up for faulty casting or
moulding that gave me a clue.

4991. Did you never find any of unequal thickness? —
No, with the exception of those that were brought in
from the river.

4992. How many did you see of those that were
brought in from the river?—I think one distinctly,
but I am sure those must have been more than one
which of different thicknesses.

4993. Those were actually put up to bar the girders?
—They have been put up.

4994. And externally they showed no appearance
whatever of being of unequal thicknesses?—Not so
far as I ever heard.

4995. Therefore to come back to the point upon
which I asked you before, a great number of those
columns might have been of unequal thickness, and
you would not have detected it?—It is possible.

4996. You said that if those inequalities to which
your attention has been directed had occurred all in the
same group of piers they that would have undoubtedly
been a case of weakness?—Yes, as it is very large
the want of material is a means of weakness. It is only a
question of degree; I should think it very serious if
they were all in one group of columns.

4997. I did not understand quite what you meant
when you said that if in the section there was the
same amount of metal there was pretty nearly the
same strength in the column?—I mean where there is
such an excess of metal in proportion to what is
actually required.

4998. Would the column be equally strong if it
were twice the thickness on one side of what it was on the
other?—If the strength of the column in the thinnest part were sufficient to carry the weight.

4999. That is to say that the strength of the column
would be equal to the strength of the thinnest part?
—Yes, if the section of the column at the thinnest part was the weight of any structure.

5000. If the column at one side is only five-eighths
of an inch thick it would be the same as if the whole
column was only five-eighths of an inch, would it?
—No, it would be stronger. What I mean to say is this—that within the limits it would not make any difference
because there is such a large excess of section to what it is wanted to have to carry.

5001. That is to say, your assumption is that there
was a great surplus strength?—Yes.

5002. Supposing there had not been that surplus
strength the inequality would be a serious thing, would
it not?—Yes, I have always been speaking of the vertical strength, I do not mean any lateral force
acting on such columns, I should not say that it
would not affect the strength.

5003. You said that the tendency of the bolts is always to work loose, with vibration?—Yes.

5004. Surely it would be from the friction either of
the bolt or the hole; from the bolt getting smaller or
the hole getting larger?—The fittings are not
so tight but what there is also room for a slight
motion.

5005. That is not an answer to my question?—You
are right.

5006. My question is this—you said that the tendency
of the bolts is always to work loose in vibration—what did you mean by that, namely, the working loose in vibration;
it means, does it not, that the bolt was working smaller, or that the hole was getting larger?—No, the
screw through the vibration, I mean the bolt working in the hole—a very little will do it—it makes it to go
up and down.

5007. That causes a friction between the two
surfaces?—Yes.

5008. And that would diminish the surfaces, would
it not?—Yes, it will cause a friction; it makes a little
hammering underneath the nut in a little degree, and
that hammering in a little degree repeated slackens
the nut.

5009. That gives a looseness to it?—It need not be
in the ordinary sense loose with vibration; the bolt
may be quite tight for all that the vibration would do.

5010. I did not understand what you meant by saying
that the ladle does not fuse when you take metal
in it; certainly the ladle does not fuse when you take
metal in it; the metal is very hot, and if you left the
metal for a considerable time no doubt it might fuse
—It wears away. What I mean is that it is perfectly
possible to have fused metal in contact with cold metal.

5011. It is very difficult to fuse cold metal by
putting it in contact with hot metal?—Yes, for that
place is filled with fire-clay.

5012. An iron ladle will not fuse at once?—Wrought
iron does not fuse so soon.

5013. There would be no cohesion between the fused metal and the ladle, would there?—To a certain
extent there is always.

5014. But not such a cohesion as you would require
in a lug?—I mean to compare the cast column to the
ladle, that ladle being as it were the ladle carrying the
fused metal.

5015. Had you not some doubt, and Mr. Grothe too,
as to whether it was proper to burn on the lug?
—When a repair takes place one is always anxious to
make it as strong as it was, but it is an exceptional
time.

5016. It was an exceptional thing to both of you, was it not?
—No, I mean to say it is not in ordinary
repair.

5017. When you say therefore that the thing when
repaired is as strong as before, it is more in the nature
of an experiment that we had to try it?—Every burn
is an experiment in itself.

5018. You were in doubt as to whether or not it would
be successful, were you not?—Yes.

5019. And therefore you tested it with one of them?
—Yes.

5020. And in that case it was successful?—Yes, I
tested it with 10 or 12.

5021. I thought you put on one bar, did you test it
with the others?—Yes, it wore away. What I mean is that it is perfectly firm?—Yes.

5022. How did you test it?—By knocking it with
a hammer, not with that particular single sledge hammer, but
with a hammer.

5023. And you were convinced that they were all
perfectly firm?—Yes.

5024. That did you yourself, did you?—No, the
foreman did the burning on and I tested them and
looked over them.

5025. (Colonel Yolland.) I think I understand from
you that the unequal thickness of the metal at the two
sides of the column does not in your opinion very
materially decrease the strength of that column as far
as vertical pressure is concerned?—With this
limitation, that when the vertical load that is to be put on

5026. I mean as far as the vertical pressure is
concerned?—No.

5027. When the vertical load is put on such a
column it is comparatively small compared to the
section?—Yes.

5028. Supposing that it has to carry one-fourth
part of the weight of a big girder?—Yes.

5029. Do you think that there is no material
difference in the actual strength of a column with
half an inch of thickness on one side and one a
half inches of thickness on the other when compared
with a column of lesser thickness of one inch through-
out?—Yes, of course there is a difference in the
strength, no doubt about it.

5030. Then in the next place, assuming that such
columns are at times subjected to a lateral or hori-
zontal strain, would not the difference in the thickness
of the metal there from half an inch on the one side
to one and a half inches on the other, make a very
MINUTES OF EVIDENCE.

Mr. G. W. Campion.

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9531. Why?—I believe it was to secure the better fitting of one flange to the other.

9537. I suppose that you also had to plane the inside of the column, the tube, so that the male should fit into the female?—Yes.

9538. Supposing that you had no male and female so that they did not fit in, you would rest one on the top of the other and there would be no necessity to groove it?—Exactly, that is the reason.

9549. And to plane it on the inside?—Just so.

9560. Do you know whether in order to save a labour they cut off in any of those cases those males?—I do not know of any case, but I have seen males which were not exactly the same length as shown on that drawing.

9561. You do not know whether or not they were cut off somewhat?—No.

9562. In order to save the labour, which it would save?—No; one would fit into the other, but I do not see why it should save labour—they were never cut off in the fitter's shop, certainly not by my knowledge— I should have seen it if it had been cut off.

9563. If you had examined them all?—Yes.

9564. You understand what I mean?—Yes.

9565. You did not see anything of that kind, did you?—No.

9566. And you cannot tell us why the bolt holes were cut instead of being drilled on the 18-inch column?—The only reason that I can suppose for it was because there was no machinery to drill the holes with.

9567. Otherwise they ought to have been drilled?—That is a question for the engineer to settle.

9568. You are an engineer, are you not?—I mean the engineer of the works.

9569. You would have drilled them, would you not?—If I had made the design of it I would have had every hole drilled.

9570. In which a bolt was put?—Yes.

9571. (Mr. Barlow.) I think I understand you to say that if you had one defective column in a pier, one defective column amongst all the columns used in the pier, would hardly be injurious?—It would depend upon the nature of the defect.

9572. Say a defect such as we would lead to the fracture of the column?—Of course it would diminish the strength, but, under ordinary circumstances, I do not think it would decrease the bearing power.

9573. Do you mean that a fractured column might exist in one of those piers without material injury to the strength of it?—Yes. I have seen fractured columns supporting girders which had been burst right through at the time of the accident, and there was a weight upon the half-span, and the structure stood a considerable gale, and the column was cut right through crosswise.

9574. When was that?—In February 1877.

9575. What led to the fracture?—The falling of two of the large spans.

9576. And yet the work was able to go on with that fractured column?—The pier stood severe gales with that fractured column, but it was taken out.

9577. Which was that?—It was a 15-inch column, about the second tier from the top, I think.

9578. Suppose the top column of the 18-inch columns was to be broken, what would happen? Does not half the weight of the girders rest upon these three columns (pointing to the model) and rest upon them in such a manner that one-half of the weight of the girders would rest upon columns?—Yes.

9579. Suppose that top column to be broken, what would happen?—If it was cracked right across, under ordinary circumstances, it would break the weight. I do not mean to say that I should like to keep it in that way, but I say that it may not shift. The fracture may just be such as to keep it tight; there is no side strain.

9580. But suppose the fracture was oblique instead of being quite flat?—The tendency then would be for the girder to slip out.
TAY BRIDGE DISASTER:

Mr. F. Beatte sworn.

Examined by Mr. Balfour.

5959. You are a civil and mechanical engineer, and at present manager of the bridge works of Messrs. Marwood and Co., of Birmingham?—Yes.

5960. And you come here to give evidence to-day?—Yes.

5961. Were you in the employment of the original contractors for the Tay Bridge?—The Tay Bridge Company.

5962. Under the chief engineer, Mr. Grisbie?—Yes.

5963. What office did you hold?—I was one of his principal assistants.

5964. Were you the general mechanical engineer for the construction of the bridge?—I came in that capacity.

5965. That is your correct designation?—Yes.

5966. When did you come?—In the latter part of 1873.

5967. From the works which the contractors, Messrs. Charles de Bergue and Co. were carrying on in Manchester?—Yes.

5968. Did you continue at the bridge in the same capacity after Messrs. de Bergue and Co. ceased to be the contractors, in the employment of Messrs. Hopkins, Gilkes, and Co.?—Yes.

5969. I believe till within about 12 months of the bridge being opened for traffic?—About 12 months. I cannot recollect the exact date, but I believe about 12 months before the bridge was opened.

5970. What length of experience have you had in your profession?—About 25 years.

5971. Have you devoted particular attention to bridge engineering?—Yes, all my life.

5972. What has been your experience of bridge engineering?—I first of all had about five years' experience in the firm of Thomas Dunn and Co., of Manchester, who were large bridge builders.

5973. Can you name any important work that you were concerned in?—They were engaged principally upon bridges for foreign countries, and for the Brighton and South Coast Railway, and several other suburban lines in London.

5974. And did bridges over rivers?—Yes; and over railways and over canals.

5975. What other experience have you had?—After leaving Thomas Dunn and Co. I entered the service of Messrs. de Bergue and Co. in 1867, about six or seven years before coming to the Tay.

5976. What experience had you had in bridge building before then?—I was principal draughtsman and manager of the works there; the whole of the bridge works and the whole of the miscellaneous work conducted went entirely through my hands.

5977. What kind of bridge works were being carried on after you went there?—For Messrs. de Bergue and Co. we erected very large works for Russia; they were principally for Spain and Russia; they were works of a similar character, iron bridges and piers.

5978. With the weight of that girder on the top, would not the tendency make it slip out?—Yes, I think so.

5979. And it would be the same with the one on the other side, would it not?—Yes.

5980. It would be liable to the same tendency?—Yes.

5981. Take the column below that, would not that second column, if it had a fracture like that, also be liable to destruction?—Yes.

5982. And the one below that again?—Yes, no doubt.

5983. And so in the case of any one of those columns which appear on the outer line of those supporting girders?—Yes.

5984. How many of those columns are there in the part that has gone down; there are 13 spans gone down, are there not?—I believe there are 14 columns to each pier.

5985. And 13 spans?—Yes.

5986. How many does that make?—That is about 180.

5987. Any fracture in any one of those columns would have the effect of bringing the bridge down, would it not?—I think so; but it depends very much upon the fracture.

5988. Take an oblique fracture?—Yes; I think in the case of an oblique fracture a train might pass once safely, but the chances are that the second train might bring it down.

5989. Had you anything to do with the filling of those columns with concrete?—No, I had not.

The witness withdrew.

Mr. G. W. Comyns sworn.

March 18th.

5990. Did you come to the Tay after you went there?—For Messrs. de Bergue I should never have advised the firm to do it unless I knew the line and had surveyed the works of all the various bridges and works of seven years before coming to the Tay. 9625. I suppose the risks of fraudure and the like after leaving Thomas Dunn and Co. were concerned in?—They were engaged principally iron bridge works and the whole of the miscellaneous work.

5991. They were engaged principally iron bridge works and the whole of the miscellaneous work?—Yes.

5992. Had you anything to do with the filling of those columns with concrete?—No, I had not.

5993. That was a department in which you had Great experience?—Yes.

5994. Were the mechanical appliances which were used in the construction of the Tay Bridge for the most part designed by you?—They were.

5995. And manufactured under your supervision?—Yes.

5996. I believe you have taken out a number of patents for such appliances?—I have.

5997. That you have?—Yes.

5998. Any fracture in any one of those columns?—I believe it was; no doubt.

5999. Of belief it was:—it any rate it would be liable to the same tendency as the one below that again?—Yes, no doubt.

6000. That is your correct designation?—Yes.

6001. Hopkins and Company to the time of your leaving the Tay Bridge?—Yes.

6002. That is your correct designation?—Yes.

6003. Which office did hold?—I one of his principal assistants.

6004. Have they been successfully worked?—They have.

6005. In addition to your other duties did the management of the foundry at Wormit devolve upon you?—Yes.

6006. Did you continue to have that management as long as you continued in the employ of Messrs. Hopkins, Gilkes and Company?—Yes.

6007. Will you tell me for what reason was a separate foundry built there instead of bringing the castings from elsewhere?—In the first place owing to the alteration of the plan a number of the cast-iron cylinders and caissons which were formerly used for the construction of the pier were abandoned, and it was decided to use wrought-iron cylinders in their place. This threw upon the hands of either the railway company or the contractors about 500 or 600 tons of cast-iron cylinders. This cast iron had been obtained by the former contractors, Messrs. de Bergue and Company from Falkirk, and was composed entirely of Scotch iron.

6008. That you know?—Yes; Scotch pig and iron, and Scotch scrap; it was brought from there; I believe it was so—at any rate it was not Cleveland iron.

6009. It was delivered and was there as Scotch iron?—Yes, and paid for as such.

6010. You have no doubt of that?—No.

6011. Using it upon the spot, was that one of the great considerations?—Yes; in the first place it would prove a source of great convenience to the contractors to be able to cast the columns exactly as they required them, and this consideration was with reference to the scrap iron, and that it could be used in the form of scrap for the re-casting of the columns of the bridge.

6012. I suppose the risks of fracture and the like would be diminished if you had a foundry near the work?—Yes, we should have it under our supervision.

6013. Were you satisfied from the result of your experience, that it was an expedient thing to have a separate foundry there for the purpose?—Yes, I was. I should never have advised the firm to do it unless I had thought so.

6014. Was it upon your advice that they started it?—Yes, entirely so.
9628. Who was the first foreman moulder or founder that you had?—The man whose name is Strachan.
9629. Was he a man of great skill and experience?—Yes; I took a great deal of pains to get a suitable man, and he was recommended to me very strongly as a man of good character. He had good testimonials, and as I had had not the least previous experience of him I could only judge of him by that, and, after consultation with Mr. Grothe, we selected him to be foreman.
9630. You used care in selecting a suitable foreman?—Yes.
9631. Did he know his business well?—I found him to be an experienced moulder.
9632. In fitting up the foundry and in the plant was good material and good workmanship used?—We spared no expense in any of the appliances for the equipment.
9633. What was the first casting that you made there?—The first castings for the bridge were the bottoms, the base plates for the 145-feet span.
9634. For the piers of the span?—Yes.
9635. Will you describe what sort of castings these were in size and character?—This 145-feet span was originally designed to have four columns. When I speak of base-plates, I mean on all the castings which were concerned with it at each corner of the circular base to receive four columns.
9636. Were those all heavy castings?—Yes, they weighed about five or six tons each.
9637. Did they come out good castings?—I believe all without exception.
9638. When they cast into the bridge?—They were.
9639. Had they any special appliance in the way of adjustable parts?—Yes; they had four columns. Then those spans were not vertical, they were inclined planes, and therefore the faces of the base plates required to be inclined faces, and the pattern used for casting those bases had to be chilled, making the base surfaces to any suitable angle. Although the bases were of the same size yet the piers were not of the same height, and therefore the angles of those bases varied in each pier, and it was necessary to have them adjustable.
9640. Was that a thing requiring care, and was it carefully done?—Yes.
9641. What were the first columns that you cast at the foundry?—Fifteen inch columns, the ordinary 145 feet spans or the 120 feet spans, some of the small ones.
9642. Before the casting was proceeded with, were accurate moulding boxes made for the purpose?—Yes; very accurate ones indeed.
9643. Were they made under your direction?—Yes.
9644. Did you pay particular attention to their accuracy?—Yes.
9645. Will you describe the kind of patterns that were employed?—The pattern for casting the 18-inch columns was a cast-iron shaft turned perfectly true all over, and turned up to an equal diameter all over.
9646. Had you good sliding flanges?—Yes, at either end and so that we could cast a column of any measured length.
9647. Then were there pockets and lugs?—Pockets and lugs; preparations were made on these castings for them, so that we could cast one, two, or three as the case might be.
9648. Then each column had a projection at one end and a recess at the other?—Yes.
9649. Those were afterwards to be turned and bored so as to fit on the other?—Yes.
9650. So as to get a perfect bearing on each other?—Yes.
9651. What arrangement was made for making holes for the bolts on the flanges?—We had a special machine for that, a special boring machine which had at either end eight drills set accurately.
9652. Did that bore all the holes of each column simultaneously?—It bored all the holes for one flange only.
9653. It bore simultaneously eight holes in the flange?—Yes; that column was carried on a sliding bed. After those eight holes had been bored at the one end the bed was slid along to the other eight, and the other eight holes were bored.
9654. Were the holes in the flanges of all the columns of good bore or from any cause cast in your time?—I believe there were about a sufficient number of 18-inch columns for about four or five of the large piers cast during my time.
9655. They had the holes cast?—Yes.
9656. And not bored?—No.
9657. Why were the holes of the 18-inch columns not bored, like the holes of the other columns?—In the first place we had no convenience to do it, no machine.
9658. Could you not have got a machine or made one?—If I had been a contractor I could have done so.
9659. Was it not thought material?—No, it was not thought material. I may say that I had a discussion, or rather a conversation, with my immediate chief upon the subject.
9660. What was his name?—Mr. Grothe; and I believe he had a consultation with the engineer of the bridge, but I will not be sure about it.
9661. The matter, however, was considered?—Yes; it was in some way or other, and I was authorised to go on casting the piers.
9662. In your judgment were the holes that were so cast sufficient for the purpose for which they were intended?—If they were made true.
9663. Were such as were made under your supervision made true?—I never saw any untrue.
9664. Whom did you mean by the engineer of the bridge?—I understood it was Sir Thomas Bouch.
9665. Now did your subsequent experience lead you to doubt the sufficiency of that method of making holes by casting instead of drilling?—No.
9666. In those large columns?—No; I may say that I do not think that I saw any of those large columns erected at all, I believe, at the time I left the employment of the contractors; none of those 18-inch columns had been erected.
9667. As long as you were there did anything lead you to doubt the sufficiency of the method?—Not at all.
9668. Upon whose final decision the resolution to cast them was arrived at, you cannot tell?—I cannot, I do not know.
9669. Of what were the core bars made that were used?—They were cast-iron core bars.
9670. And of as large a size as was practicable?—Yes.
9671. Were they coated with anything?—Haybands in the usual way, and dried in ovens.
9672. In short, were all your appliances for the castings of the best kind known to practice and science?—I was not restricted in any way with regard to any expenditure in the foundry to make it complete and perfect for the proper casting of the column; I did my best.
9673. You had had great experience in that kind of work before?—Yes.
9674. What kind of water was used in making the cores?—Salt water; water from the river.
9675. Was there any other source of which you obtained water?—There was a spring or well close by, which moulders could avail themselves of if they thought proper.
9676. Was there any disadvantage in salt water as compared with fresh water for that purpose?—Under the circumstances I would rather use salt water.
9677. For what reason was the majority of the iron that was used was Cleveland iron, which contained a greater percentage than the other does of phosphorus and sulphur, and it is well known that salt has a great affinity for extracting both phosphorus and sulphur from molten metal?—It would rather improve them than otherwise.
Mr F Beattie.
9679. You would not have used it if it had not been—
I do not restrict its use.
9680. You apprehended no harm from it?—No; the only harm would be that after the castings the moulders would suffer a great deal from the sulphur rising and causing an unpleasant smell.
9681. They did not take the sulphur?—No.
9682. What was that smell?—A sulphuric smell.
9683. Did that show that the salt was combining with the sulphur, as you would expect?—Yes, I believe so.

9684. Regarding to the appliances with which the columns were fitted, was there anything at all in carrying on the work of casting?—No, none.
9685. Was any special care taken in placing the cores so as to ensure that the cores should be concentric in relation to the outside?—I always insisted that special care should be taken to ensure concentricity of cores.

9686. To ensure the concentricity of the core with the result of equality in thickness in the casting?—Yes, I was continuously instructing them to use the greatest possible care.
9687. You were alive to the importance of having the pipes of equal thickness all round?—Yes.
9688. And you desired to produce that result?—Yes.
9689. Had you sometimes trouble with the mould in that matter?—I had upon some occasions.
9690. And with what result?—I only ascertained it afterwards when the columns come into the hands of the turners. I may say that I do not believe that anybody can ascertain by outward inspection whether a column is true all round.
9691. Did you give any instructions to the turners upon the subject?—Yes, I gave certain instructions to the turners.

9692. What instructions did you give them?—In the first place I should have to describe the lathe they used. The lathe was an ordinary lathe, having a slide rest at each end. The column when placed in the lathe would rest in a carriage, a fixed carriage on the bed of the lathe, and it would be the turner's duty to centre that column from the outside diameter, and when he had got it centred perfectly true to the outside diameter to set the lathe in motion, and he would then discover whether the core of the column was concentric with the outside or not, by pointing the end of his cutter or any other means, and he could see whether there was any eccentricity in the column or not.
9693. We have been told that there have been flanges on the ends of the columns?—Yes.
9694. Would the fact of the flanges being there disable the turner from ascertaining whether the core was of equal thickness?—In the first place the flange itself would be true with the outside of the column but not with the core, so that if he centred it from the flange it would be the same distance from the shaft of the column. The flange of the column is about 4 inches or 8 inches in diameter from the shaft.
9695. Do you think that when he put on his lathe and proceeded to make it revolve and apply his tool, any eccentricity would have appeared?—Yes, that is to say after he had centred it from the outside, trying the lathe by his slide rest, any eccentricity would be detected with ordinary care.
9696. In practice did you ever find that the turner did detect eccentricity?—Yes.
9697. And reported it to you?—Yes. If it was exceedingly trifling he would have general instructions to record it as being a correct column, but if it exceeded a certain degree, then he reported it to me.
9698. What was that limit?—A quarter of an inch.
9699. Did you correct that degree of eccentricity?—I did not correct it; it might be for a reason which I will explain; I must now allude to the thickness of the columns. The specified thickness of the columns was one inch; and, having on several occasions tested myself the column in the lathe to see whether there was any want of concentricity, and having on several instances discovered that there was a want of concentricity, I gave general instructions to the foreman, the second foreman, Fergus Ferguson, entirely on my own responsibility, to increase the thickness of the columns from one inch to an inch and a half, or thereabouts, and I cautioned him to have them thinner, but rather the other way. At that time I considered that the column should be an inch and an eighth in thickness, and if it was one quarter of an inch out of concentricity, we would by that means only have a minimum thickness of seven-eighths of an inch on the one side against an inch and three-eighths on the other.

9700. Within those limits, giving that as the maximum eccentricity that you would pass, do you think that that is as strong as a column an inch all round?—I think it was even a stronger column.
9701. In saying that do you mean stronger both for bearing vertical dead weight and for bearing lateral pressure?—As a girder: with a load in the middle, or treating one of those columns as a girder with a load in the middle, one of those columns of unequal thickness, I believe it would carry more weight than a column of equal thickness all round.
9702. In saying that do you mean merely that it would carry more weight pressing vertically down, or that it would also bear lateral strains?—Yes; when I speak of columns I mean lateral strains.

9703. It might be good enough to bear something pressing down upon it, and yet possibly it might not be so good otherwise?—There would be no doubt about it, because it would have a greater sectional area of metal.
9704. For any strains to which the column forming part of a pier would be subjected, would it be equal in your judgment?—I believe it would exceed the strength of one column one inch in thickness all round.
9705. Did you consider that if the eccentricity exceeded what you have described as to give a divergence of an eighth of an inch, then it would become too much?—I believe it would be a doubtful point, and I would rather not go beyond that.

9706. Did you give instructions that beyond an inch should be tried?—If I was on shore, frequently I was upon the river, I was to be sent to; and if not, the column was to be put aside till I returned; it was to be reported to me.
9707. Did you repeatedly receive information that an eccentric column had come out?—Yes, for that and other causes, many times during a week.
9708. Did you apply your own inspection and judgment to the case of the columns?—Yes.

9709. What did you do with the columns, where the eccentricity exceeded what you have said?—Broke them up immediately.

9710. You have mentioned Mr. Fergus Ferguson once or twice; will you kindly tell us what sort of a man was Mr. Fergus Ferguson?—After Mr. Strachan left us we endeavoured to get another good man, and we had some very good testimonials of Mr. Fergus Ferguson, and if I was to be asked my preference of the two men I should say that the young man was the preferable moulder: I always found him exceedingly careful, obedient, and diligent.

9711. And an able foreman?—Yes, thoroughly so.
9712. He remained I think for a long time in the employment of the Company?—I believe when I left the employment of the firm he was there still, and I believe he remained there.

9713. Do you believe that the means which you took were adequate to secure that there should not be an excess beyond the eccentricity you have mentioned?—Yes, if any column was under the divergence which I have mentioned, then I say that actual deception must have been practised on me.
9714. Would it have been easy to have taken you in that matter; must it have been a deliberate deception?—I say that a man simply looking at a column and tapping it with a hammer would not have been able to detect a slight difference in the thickness; and if this man who had to turn the columns delibe-
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rately attempted to deceive me, I believe he might be successful. He might turn a column and take it away and put it down as a finished one.

9715. Had any of the turners any interest in deceiving you?—No.

9716. Who were your turners? What kind of men were they?—One man, who was the principal turner, was Fender; he was there the whole time while I was there; I engaged him and left him there.

9717. What sort of a man was he?—He was an extremely good turner, a very diligent man, and very attentive to his duties.

9718. Mr. Fender was the responsible man to whom you looked?—Yes, he was the man that I looked to.

9719. Have you any reason to doubt that there was not, until you were leaving, any eccentricity?—I never had any reason to suspect anything of the kind.

9720. About how many columns did you direct to be broken up because of unequal thickness in them, that you were the person who sent them to me?—I can tell you within half a dozen, I believe. I think we attached between 30 and 40 for that particular purpose.

9721. Did you find while you were there that there were other defects in the castings with which you had to deal, I mean in the casting of the columns?—I gave general directions to the foreman, and also to the turner to report to their foreman whenever flaws of any kind manifested themselves of such a serious character that at a glance the column was unfit to use: and in that case those columns were broken up without consulting me.

9722. As to those columns in which the flaws were doubtful, what directions did you give?—When there were any such or such that you did not think would create a doubt in the mind of the foreman whether he was to break up the column or not, in most cases they were to report to me.

9723. Were scab columns frequently reported to you?—Yes, they were.

9724. What did you do upon that?—I examined them, and if I found the scab anywhere at all serious, or any other serious flaw such as a blow hole—if it was of any serious extent, if it for instance was beyond an inch or so in extent, I mean upon the surface—if it was beyond a mere blemish, I had it broken up immediately.

9725. Will you tell us what dimensions of scab you would have passed?—If I should see a small scab about an inch or an inch and a half long and probably about an eighth of an inch deep upon the surface, I should not consider that that would injure it to any extent, but I should consider it a blemish, and I do not believe I should pass one of that size.

9726. Would you pass a scab of such a size that would not have exhausted the excessive thickness that you detected?—No, it would not; it might be on the thin side.

9727. So that in that case you would have thought it not safe to pass it?—I would not pass it.

9728. What sized blown holes would you pass?—I do not believe I ever saw above two or three blown holes at all.

9729. Did you look for them often?—Yes, repeatedly.

9730. What sort of blown holes would you have passed?—If I saw cracks on a column to any extent, even a little jutting of the size of a pea, I should consider that the flaw would extend deeper than I could see, and I would not pass that column.

9731. Did you often find the workmen filling up slight flaws with anything in your time?—Yes.

9732. Can you give me the name of the composition?—I believe it is quite a local name, Beaumont egg. I do not know what it is composed of.

9733. It is the thing that you found the workmen were using for the purpose of filling in flaws?—Yes, it is a composition that appears to be indigenous to Scotland, as far as my experience is concerned.

9734. Did you find that that had been used to any extent?—I found it on two or three columns, but this was in the time of the first foreman, Mr. Strachan’s time. I found that one or two columns had been filled in.

9735. What had been filled in?—Small, previus, small blow holes.

9736. How did you find that out?—In the course of my examination I detected it. Every column that was cast passed through my hands several times.

9737. When you found it out what did you do?—I discharged the whole of the men engaged in that dressing.

9738. Then of course after you had once detected this were you vigilant in every case to see whether it was there again?—Yes.

9739. Did you ever detect it again?—It never passed under my knowledge again.

9740. Did you ever find out any filling with cement?—No, I believe there was one instance of that occurred, but it was a very long while after that.

9741. Who detected it?—I believe it was pointed out to me by the turner, but it is five or six years ago now.

9742. What did you do in consequence of that?—I could not find out who had placed it there.

9743. Did you let them hear about it?—Yes, I made inquiry of it, and they all denied it.

9744. No doubt you spoke very strongly of the unpropriety of it?—Yes, I reminded them of the time before when I discharged the men.

9745. Was McGonigle a moulder under your charge?—I recollect the name now.

9746. He was not foreman, was he?—I believe he was during the interval when Mr. Strachan left.

9747. Between him and Ferguson coming?—I believe he took charge of the shop for a short time for that interval; I believe it was about a fortnight.

9748. And was he a good man?—He was a good moulder, but not fit to be a foreman.

9749. Did you during that time pay particular attention to the work that was turned out?—Yes, I took it under my personal supervision; I was foreman myself at that time.

9750. What kind of metal was employed in casting the columns?—The pig iron was Cleveland No. 1.

9751. How would you describe it?—Cleveland foundry pig.

9752. Is it a good type of iron—what is its quality?—For the purpose of the columns, personally I would not use it to the same extent as we used it there as a mixture.

9753. What else did you mix it with?—We had 500 or 600 tons of Scotch scrap iron, and we used it in proportion of 2 to 1, 2 of pig to 1 of scrap.

9754. Was that 2 of pig and 1 of scrap maintained all the time?—I believe it was rather more scrap than pig.

9755. Did you give any instructions later to exceed the third of scrap?—Yes, and for this reason, because personally I would have preferred to have had a mixture also of some other Scotch pig along with the Scotch scrap and the Cleveland iron, making a third each.

9756. When you say “personally,” what do you mean?—I mean my private opinion.

9757. Did you therefore augment the proportion of Scotch scrap?—When I found the rest of the iron to be entirely Cleveland pig, I did.

9758. Did the combination which you thus worked with in your opinion produce good columns?—It did; I desired to satisfy myself of it and I made some test bars. At the commencement of the opening of the foundry, in order to satisfy myself, I cast I believe on one occasion of founding eight or nine test bars of the size prescribed in the specification.

9759. (The Commissioner.) What is that?—I am not sure of the size, but I believe three feet long; I believe the bars had to be three feet bearings and the sections two inches by one inch—I believe so—I tested them privately for the purpose of finding whether they were fit for the purpose for which they had been made?

9760. (Mr. Ballour.) Of what metal did you make the test bars?—Of the same running, two proportions of Cleveland and 1 per centage of scrap.

9761. Two-thirds of one, and one-third of the other?—Yes, the same that the columns are composed of.

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9762. You made the test bars out of the running of your cupola?—Yes.

9763. With what result?—I tested them according to the conditions in the specification, and I imposed the same weight mentioned in the specification. I do not know that the weight was then, nor do I know the exact result beyond the fact that the result was satisfactory to me. 

9764. (The Commissioner.) Take it at 3,000?—Yes, I believe it was about that.

9765. (Mr. Balfour.) Did you find that subjecting the test bars to the specified tests, they stood those tests?—They did, they have stood more than that.

9766. They not only stood those tests but they would have stood more, did you increase the test beyond that specified?—I put on one bar, I distinctly remember that, a load of 35 cwt., and the load imposed in the specification is 3,000 lbs., which is less than 30 cwt.

9767. And you went materially beyond that?—I broke it at about 35 cwt.

9768. Was that a severe test for metal for that purpose?—I considered it was, it must be very good metal to stand that strain according to the universal and accepted formula for testing metal for bridges and for structural purposes.

9769. For structural purposes were you satisfied that it was adequate metal?—Yes.

9770. Did you ever stop any of the men from using any metal for the purpose of mixing at Wormit?—I did on one occasion. I stopped McGovan from using it on one occasion.

9771. What were the circumstances when you did so?—We had a few castings, that did not belong to the North British Company, and he disobeyed my instructions and broke up some castings that did not belong to us, and I stopped him from doing it.

9772. Was that simply because he was proposing to cast other people's property?—Yes, that is what he actually did.

9773. Had anything to do with effecting a saving of your property; was it dictated by a desire to save the putting of good metal into the columns?—No, we only had two metals there of our own, the Scotch scrap, and we desired to use the Cleveland pig, which came from our own firm.

9774. Did you say anything about those castings?—Yes, they were castings of a peculiar kind.

9775. Did you say anything about keeping those castings and not breaking them up, so that, you might get a good price for them after the bridge was finished?—No, they belonged to the railway company; they were not ours, but they must remain till the bridge was done.

9776. My question was this: did you say at any time anything about saving them in order that the contractors might get a good price for them when the work was finished?—I think it is hardly probable; I think it is impossible that I could have said such a thing.

9777. Did any of the moulders or persons connected with the foundry, ever speak to you about sluggishness in the iron?—Yes, two or three occasions.

9778. What were the complaints?—None of the moulders ever spoke to me; the foreman came to me.

9779. Was that Ferguson or Strachan?—Once Strachan, and either once or twice Ferguson.

9780. Kindly mention what they said and what you did?—On the commencement of the mould, when preparing to run the metal on, on one or two occasions the foreman asked me to come into the foundry to look at the metal; and on one occasion I was not satisfied with the result. I believe this was the occasion on which Strachan called me in.

9781. What was wrong with it?—There was a good deal of dross and it was very sluggish.

9782. What did you do?—I directed on that occasion the contents of the cupola to be thrown out in the sun.

9783. And thrown in again?—No, not to be cast in the moulds.

9784. What was done with it afterwards?—After it cooled it was broken up and re-melted.

9785. What was the sluggish and dirty condition of that metal due to?—It might have been a bad portion of pig iron at that time. I did not know exactly what to attribute it to.

9786. It was not a successful flow?—No. 

9787. Did you on any other occasion have your attention directed to anything?—I believe on two occasions afterwards it was simply complained of.

9788. With what result?—I considered that the complaint had been very much exaggerated and that I directed the moulds to be cast.

9789. Did you see it done?—Yes, I saw it done.

9790. Was it a kind of metal that gave a little more trouble to the workmen than many others?—The moulders personally had very little to do with any amount of trouble in melting the metal.

9791. But in dealing with it after it was melted?—That gave them more trouble in what they call feeding every column after it was cast; they are able then to be fed with a bar of iron; they have to feed them continually, and keep adding fresh metal until they have got it quite solid, and they can feed it no longer.

9792. That is adopted to make the grain of the metal closer and more rigid.

9793. Did that give them more trouble in feeding than some similar metal?—I believe it would.

9794. And they would not like that?—No, I do not think they would.

9795. With proper care was there any difficulty in feeding the metal so as to make good castings?—No, I may say that on one occasion, where my attention had been directed to the metal when I had not time to cast the columns, I recollect that I would look at them every morning to see if there was anything wrong in the nature of cold shut, and I may say that when I examined them then I saw nothing in the nature of cold shut, neither did I see a single cold shut the whole time I was at the Bridge.

9796. Were you satisfied from examination?—Yes, I was satisfied that the metal was pure and that it properly annealed and joined.

9797. That it properly combined on the top of the mould?—Yes, and properly joined.

9798. That it properly combined on the top of the mould?—Yes, and properly joined.

9799. Has a person of skill like yourself any difficulty in deciding whether there has been a cold shut?—No, it is apparent.

9800. Is it apparent without breaking up the columns?—Any decided cold shut is, there is a mark on the outside.

9801. I suppose it would be also apparent, and perhaps more if the columns were broken so that you could look at the fracture?—Yes, you could see that there had been no well in it.

9802. You told us, I think, that you broke up in consequence of eccentricity 30 or 40—how many columns from other defects were broken up in your time?—Altogether for other causes upwards of 100, making 150 altogether.

9803. And that gave you, I suppose, an ample opportunity to observe the quality of the metal as exhibited by those fractures?—Yes.

9804. Must you have seen them if there had been cold shuts in any of them?—Yes, I could see without it.

9805. Did you ever see any cold shut in the fractures?—No, I never did.

9806. Are you satisfied that such things were not occurring in your time?—I am satisfied of that.

9807. You said something about the scabbing which occurred sometimes—what led to that?—Carelessness in moulding.

9808. In what did that carelessness consist?—If they did not use proper facing sand, the sand would wash away from the bottom.

9809. Was the scabbing in any respect due to an inadequacy either of the sand, or of water, or of any of the other equipments of the foundry?—No.

9810. But to carelessness on the part of the moulders?—Yes, careless moulders.
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9809. Is that a thing that happens to other workmen in moulding? — I believe it occurs in every foundry of the globe.

9810. Did you get it pretty much eradicated latterly? — As soon as my measures got more stringent with the moulders, the scabbing was of less frequent occurrence.

9811. What do you mean by saying more stringent measures? — What more stringent measures did you adopt? — Principally I mean cautioning the moulders to be more careful in using foundry sand.

9812. What was the caution that you gave? — I told them on several occasions that in my opinion the scabbing was due to the way in which the columns had been broken off, but there was not sufficient evidence that proper sand had not been used.

9813. Had they a supply of proper sand? — They always had. If ever the stock of any kind ran short the duty of the foreman was to notify it to me and it was supplied at once.

9814. Had you dressers always working on the castings? — Yes.

9815. What were the duties of the dressers? — To clean the castings.

9816. Had they instructions to report defects to you? — To the foreman, and he to me.

9817. Did you receive reports of defects from the dressers? — There was no foreman dresser, and they were sent to the foreman moulder.

9818. Can you tell me whether any of the defects which were pointed out to you had been discovered by the dressers after the columns were out of the moulders' hands? — The columns were taken out of the sand the following morning, and then they went to the dressers' hands direct in order to save time. If the column is a bad one and there is an apparent flaw upon it there is no use in wasting time in dressing the other part of it. The instructions were that, directly a flaw was perceptible to draw the attention of the foreman to it.

9819. Did you enforce your orders to the men to report the flaws? — Yes.

9820. Will you tell me what occurred? — At the time that the first foreman left, Strachan, at the same time that the men were dismissed for cementing, I refer to the same occurrence; I dismissed several of them, I forget how many.

9821. Were there any lugs burnt on to the columns in that time? — Several.

9822. What made them necessary, or why was it done? — In the time of Strachan as far as I recollect, there were only two burnt on, and that was done without my knowledge.

9823. Did it come to your knowledge afterwards? — Yes.

9824. How did it come to your knowledge? — It was told by Strachan after it was done.

9825. Did you examine into it? — Yes.

9826. Did he explain why he did it? — Small pieces had been chopped off, other small pieces had been knocked off, the small pieces had not been formed as they should have done.

9827. Had the pieces that were knocked off gone down as deep as the hole which held the blistering or had they not? — I did not see them myself, I was told that they were there, but I did not know it.

9828. When you examined them was there any inadequate junction between the added metal and the original metal? — I cannot tell where the fracture was, whether the joining was right.

9829. You could not tell what had been added and what had been original? — No.

9830. Had the metal formed a perfect junction? — It had.

9831. That no doubt was a matter to which you paid particular attention? — Yes.

9832. Did you apply any tests to see whether the junctions were adequate? — One of those two junctions I examined most minutely for about half an hour.

9833. So that if there had been any sort of crack, must you have seen it? — Decisively; in fact, I examined it with a microscope.

9834. Even with a microscope, could not you tell? — Not in those two columns; I should have no hesitation in saying that they were perfectly strong, I counted them as being such.

9835. Would you have done so if you had thought them inadequate? — No.

9836. Were there any other cases of burning on lugs that you know of? — In the time of Ferguson, the moulders, there were five or six.

9837. But those were not permanent columns at all, were they? — No.

9838. They were lifting columns, were they not? — They were temporary columns, that would have to go on the tops of the piers for lifting purposes after the girders had been lifted.

9839. They were temporary lifting columns to go on the tops of the piers? — Yes, after the girders were lifted into their places they were removed and taken out.

9840. They were never built into any portion of the structure? — No.

9841. Were lugs sometimes broken off them? — Yes, these temporary columns were perfect columns at first, but owing to their having been very much handled about moving from one place to the other, the lugs had got broken. Portions of the lugs had got stripped off from time to time, and it was these things that I am alluding to now when I say that in Ferguson's time six of them were burnt on.

9842. Were they burnt on in Wornout Foundry? — Yes.

9843. And went out not to be built into the bridge, but to help to build the bridge? — Yes, as accessory to the building of it.

9844. When they were being used for building it, were any breakings or other things put in the lugs that were used? — Yes, when the columns were braided together in the ordinary way.

9845. To stand a strain? — Yes.

9846. Were you satisfied that in the case of those a proper junction was formed? — Yes, there was no crack, it was just as important to have one of those lifting columns, one of those temporary columns, as it was one of the ordinary columns; it had to bear the weight of the structure in lifting.

9847. Then you did not pay as much care to them as to the others? — Yes.

9848. Will you kindly give us your opinion as to this point. If the lugs were properly and carefully burnt on, were they in your judgment quite adequate to go into the structure? — If it was properly done.

9849. Did you find that Strachan first and Ferguson afterwards were quite capable of burning on lugs properly? — Yes; both men perfectly understood how to do it and did it themselves.

9850. They did not trust that to the moulders? — No, they did not; that they assured me of.

9851. Had you any idea, from your knowledge of this bridge, that there was any weakness in the bridge from inadequate lugs? — No; I was not aware of it.

9852. Nothing has ever been brought to your knowledge to lead you to suppose that? — Every column that was used in the bridge went through my hands, so to speak, at least three times.

9853. And if there had been any cracks that passed into the bridge, you must have seen them? — I must have seen them.

9854. Had the common moulders any opportunity of knowing whether the columns that you left in their hands were broken up or put into the bridge? — They did not know what became of them.

9855. A column might have been bad when it left the moulders' hands and gone to the hammer afterwards? — They would not have known what became of them afterwards; their duty was moulding and not examining afterwards.

(Mr. Halfacre.) The columns are the chief matter. If there is any other matter which the Court desires me to go into of course I should do it.
Mr. F. Beattie. No doubt that is the chief matter.

9856. (Mr. Balfour.) I have so gathered, and I have therefore directed particular attention to it, but perhaps without going into particular detail as to other parts of the subject. I may ask you generally, have you a general cognizance of the rest of the work besides the columns?—Yes.

9857. Including the girders?—Yes.

9858. Were all those properly riveted together?—They were.

9859. And properly fitted?—They were.

9860. Then without going into detail as to them can you say whether all the work that was done under your charge was sound and good work?—It was done thoroughly and sound.

9861. Have you the least reason to suppose that any of it was such as made the bridge dangerous or unsafe?—Not the slightest.

Cross-examined by Mr. Tramnell.

9862. Had you anything to do with the columns that went to support the high girders?—Yes, I must have had to do with them, with a considerable portion of them.

9863. They must have passed through your hands as castings made in the time when you were superintending the works?—Yes.

9864. But are you able to say that in any one pier the columns forming it wholly or partially had passed under your particular supervision?—I believe that the whole of the columns as far as the bigger piers were concerned, as far as the fifth or sixth piers were cast under my supervision.

9865. From the south?—I believe so.

9866. Then that would include pier No. 34 from the south?—I forget how they were numbered now. They were numbered from the south. (A plan was handed to the witness.)

9867. I believe the 34th pier would be the 6th of the fallen ones; so that was not within your cognizance?—It might have been. I cannot say exactly how many columns I had already cast.

9868. It was very material, I understand, that you should have your column uniform in thickness?—Pretty uniform in every way.

9869. They were specified to be uniform in thickness?—They were specified to be an inch thick.

9870. And I presume that they were not unnecessarily so specified?—I presume not.

9871. There was a purpose in specifying them to be an inch thick?—They are always specified of equal thickness.

9872. And there is a good reason for that I suppose. You like your column as nearly uniform in thickness all round as you can get it?—Yes.

9873. Accordingly I understand that you took very considerable care in adjusting the cores in such a way as to bring about that result?—Yes.

9874. And the result of your examination, so far as it was given, was to satisfy you that, so far as the cores were concerned, that result had been attained?—Mainly.

9875. In all that you passed practically so?—Practically so in all that I passed. What I want to know is this, you had the column fixed upon the carriage and the appliances of the turner applied at each end, so that you could ascertain with exactness that the core had not wandered from its place at either end?—Yes.

9876. And in that way it followed that if the core was not displaced at either end, it must of course have preserved itself upon the same level all through?—Yes, it would be upon the same axis.

9877. So that any defect in the uniformity of the thickness, if there was any, could not have arisen from the floating of the core or the shifting of the core, that was the result of the examination in the turner's shop?—The result of the examination was this, that if it was found that there was a want of concentricity between the two circles it would show that the core had been displaced.

9879. And then you did not pass the column?—Not if it exceeded a certain limit which I put down.

9880. But when you had by the placing of the column on the carriage in the turner's shop discovered that there was either exact or perfect concentricity, that showed you that the column was equal or uniform in thickness, so far as the column was affected by the position of the core?—Yes.

9881. But you know that there are other causes that might tend towards producing inequality of thickness which that test would not show?—I am not aware that there are others.

9882. None at all?—If it would show that there was unequal thickness, it would show, in my opinion, that the core had been displaced in the mould.

9883. But do you think there is no way of accounting for unequal thickness excepting the shifting of the core?—There is no other way of accounting for a uniform equal thickness throughout the column.

9884. What do you mean by a uniform unequal thickness?—If the core in a mould had got displaced bodily a quarter of an inch to one side, the inequality would extend from one end of the column to the other. The interpretation put upon it might be that it might have been a lug.

9885. Might the core present what you call signs of concentricity at both ends, and yet be bent between those ends?—The core might be bent; the core might not be level and true.

9886. And that would produce, to the extent of the untruths, inequality in the thickness?—Yes; it would.

9887. I will show you three specimens of metal (handing them to the witness). Just look at those as if they were parts of a column. You see there is a great inequality in the thickness there. In the first place, without application of calipers or anything else, there is a very obvious difference in the thickness?—There is a difference in the thickness.

9888. Assuming that these are all from one column, is there not a very marked want of uniformity in thickness there?—There is a difference in thickness.

9889. Just tell me what it is in thickness?—(After measuring the pieces.) One piece is seven-eighths of an inch thick.

9890. Is that the thickest?—It is not the thickest portion of it.

9891. Tell me the thickest portion of it that you have before you; it is an inch, is it not?—Its average thickness is fifteen-sixteenth of an inch.

9892. Is it at any place an inch thick?—No.

9893. By how much does it fall short of an inch?—About the sixteenth of an inch.

9894. Now, will you take the thickness of the piece that I have shown you, and tell me how thick that is?—About five-eighths of an inch.

9895. On these three pieces you see there is a difference of between five-eighths of an inch and fifteen-sixteenths of an inch?—Yes, a difference of five-sixteenths of an inch.

9896. If this formed one side of a column the opposite side of which was an inch and a half in thickness, would that show a considerable want of uniformity in the thickness of the column?—Yes; when you speak of one side it is only one point of those sides.

9897. The point opposite these?—Yes; it only occurs at that one point.

9898. I am referring only to that point to ascertain that at that place there was a want of uniformity. Now what I want to get from you is this, could you suggest to me that something which produced such an inequality as I have said existed?—I should say the shifting of the cores.

9899. Would anything else produce it?—Not that I know of.

9900. Would that be affected in any way by the shifting of the top flange or the upper box?—If the top box was lifted it would make it thicker at that
portion; it would not alter the other portion, it would thicken the upper half.

9901. Since these are before you, I may as well ask another question; taking No. 1, do you see a blow-hole there on the surface?—Yes.

9902. That obviously has been filled with lime or cement, is that blow-hole of serious moment?—That is only a portion of the hole.

9903. That is a blow-hole which apparently has been filled up with some cement.—It has had something in it.

9904. Is it a blow-hole which you would have passed?—I do not think so.

9905. A blow-hole of that size in a column of that thickness where the blow-hole occurs is a thing that you would not have passed?—No, I do not think I should. If that blow-hole had been covered over with varnish, I think it would have been very difficult to have detected it.

9906. That may be; I am not finding any fault with anybody, but I am merely asking you the question as a skilful engineer; you see in the same specimen there is the sign of another blow-hole?—There is an indication of one here.

9907. Is it a serious one?—That hole would go through, I think.

9908. Would it go through?—I would be a very serious one?—It would depend upon the size of it.

9909. But you think that blow-hole at the corner would have gone through?—I do not know that it would go through, except at a very little place in the middle perhaps.

9910. You see the lustre on the metal there, do you not think that it went through?—I should think this was a very minute hole where it went through.

9911. But still; minute or not, it was in your opinion through?—I think it was.

9912. That is a serious defect in a column with the thickness that you see there, is that so?—I say if the blown pipe is only the size that I believe it was, I should not call it a serious defect.

9913. Would you have passed a column of that thickness with a blow-hole such as that indicates?—I could not tell until I see the hole.

9914. Now then look at No. 2, does that show any blow-holes or honeycomb?—It shows a little honeycomb.

9915. To any serious extent?—I would not go so far as to say it was serious.

9916. Would you go so far as to say you would pass it?—I should not able to see that; that is entirely a latent defect.

9917. I will ascertain by-and-by whether you have any way of testing it, but supposing that you came to know of it by testing, would you have passed it?—I do not think so; not if I ascertained that actually existed in the interior of the column.

9918. In this specimen that we have here do you see signs of blow-holes?—Yes, there is a slight blow-hole there.

9919. Is that serious?—No; I would have passed that.

9920. Do you find any signs of cinder or scum there which should not have been in good metal?—Very slight.

9921. Do you call that slight?—It is very slight.

9922. Is it not through the whole thickness of the metal? Is it not from side to side?—There is a little there.

9923. Is it not from side to side?—No, it is only in the centre there.

9924. Do you think that if there was that imperfection in the metal to any extent, and you had been aware of it you would have passed it?—I do not say that at all. I say, on the contrary, that had I known that to exist in the interior of, the shell I would not have passed it.

9925. In specimen No. 3, do you see signs of the same thing, the presence of scum or cinder which should not be in good metal?—There is a little cinder in this; part of it is due to cinder, and part to blowing.

9926. You would not have passed that if you had known it, I suppose?—Not to the extent that it is there.

9927. If it was at all in the same proportion throughout the column as it is in the specimen just before you, you would never have thought of passing it?—You mean if that flaw had existed in other places?

9928. Yes; in the same proportion throughout the column as it exists in this piece?—No, I would not have passed that.

9929. These are hidden defects; how do men in your profession discover these defects that are below the surface?—In the case of columns for structural purposes, the only way in which we can guard against it (I do not say that we can discover it) is to exercise the greatest possible care in moulding to see that your metal is properly mixed, and that you adopt all the precautions that a good moulder generally would do. Even with all that care, it may happen sometimes that a casting gets honeycombed, or gets scabbed, or gets dirt in it; and these things will occasionally exist inside a casting, and practically remain undiscovered.

9930. There may be a serious defect, which materially affects the strength of a column, go into the structure without the possibility of engineering science discovering that it is there?—I believe that that possibility exists in every casting that is made for any purpose whatever.

9931. And you do not know then, I suppose, of any way in which these latent defects could have been discovered when they exist?—No, I will not undertake to say that they could have been discovered even by a method of hydraulic pressure.

9932. What you are pointing at is this: men in your position may by attention to the moulding prevent the existence, or probable existence, of such faults, but they may exist without the possibility of detection?—They may.

9933. If there was much of that kind of work in the columns supporting the high girders, they were not, I presume, of the strength you expected them to be under the specification?—As I have already explained in my examination, I increased the thickness of the columns; I made them of a greater strength than was specified.

9934. You expected the columns to bear a certain pressure?—Yes.

9935. Whether at the specified size or at the increased sizes?—Yes.

9936. And you expected that these columns that were to be subjected to that test, whether of the original weight or the increased weight that you made yourself, would bear those weights?—Yes.

9937. If there were many columns under the high girders with defects such as I have pointed out in the specimens, do you think that the columns would have borne the test that you constructed these to stand?—The columns would be weaker to the extent of these flaws.

9938. And upon whether the flaw was greater or less the stability or instability of the pier depended?—The strength of the column.

9939. And upon the strength of the column depended the stability of what was put upon it?—I should think so.

9940. So that much work of that kind within the high girders rendered the bridge at least not so stable as you and others had intended that it should be?—It would have been stronger without the flaws, certainly.

9941. Cannot you put it as I am doing?—Not quite. What I say is this, that in a column alone you had one of these flaws existing, such as you here show me on these samples, it does not necessarily follow that that column would be a weaker one than the column of the specified strength, because in order to provide partly for flaws and partly for any inequality of thick-
ness, I insisted and in fact I ordered the foremen to
make the columns of greater thickness.
9942. You are aware now that some of those speci-
men last year, of which I have shown you reached even the
specified thickness?—These do not.
9943. And they were considerably within your
instructions as to increased thickness?—Yes.
9944. If there were several columns like the
specimens that I have shown you on one pier, were
those called and told to bear the weight they ought
to be able to bear?—You mean a column in
which one side was say five-eighths of an inch
thick and the other side an inch and three-eighths?
9945. Yes,—I believe that the column would be
weaker, but not to the extent of the decrease in thick-
ness; it would be to some extent weaker, but to some
considerable extent.
9946. Is there no appreciable difference in the
strength of a column which is uniformly an inch thick and a column which is only five-eighths of an inch thick on the one side and an inch and three-eighths on the other?—When you speak of five-eighths of an inch on the one side and an inch and three-eighths on the other, it is only at two particular
points of the circle that it is so. If these circles were
drawn out to their true size, and then if the true
concentric circle was drawn round them, you would
see at a glance how much metal was deficient on the
one side and how much it was in excess on the other.
9947. But if the defect was only what
found in the columns discovered by breaking it up and
not discoverable externally, would you now answer the
question whether a column such as I have described is as strong as a column equal in thickness all round?—According
to the measurement that you have given me it would not be quite as strong, but I believe it would be
within one or two per cent. as strong when it is subjected to a purely dead load.
9948. Would it also be as strong to resist lateral
pressure as to resist vertical pressure?—In some cases it
would be stronger, and in some cases it would be
weaker.
9949. In what case would the column be able to
resist the greater pressure?—When the thickest side
of the column was in tension, when the force came in
the centre of the thinnest side of the column.
9950. But applying the force from the other side,
what would be the result?—In this case it would be
weaker.
9951. Would it be much weaker?—In proportion
to the difference of the thickness regarding the column
as a bearer.
9952. But as a skilled man you would never have
knowingly approved of columns being put under these
high girders, either as a rule or even as a thing of
frequent occurrence, that were disconformed in thick-
ness to the extent that I have shown you on these
specimens?—I have already shown you the limit that
I put upon it; it was a total difference of a quarter of
an inch between the two thicknesses.
9953. Taking the two thicknesses together?—Yes.
9954. (The Commissioner.) That is to say, as
I understood, if you assumed that the thickness was an inch and an eighth, and you allowed a quarter of an
inch, viz., one-eighth of an inch less on the one side,
and one-eighth of an inch less on the other side?—They
assumed the true thickness to be an inch and an eighth.
it would go to the limit of seven-eighths of an inch
on the one side, and an inch and three-eighths on the other.
9955. You would go to the extent seven-eighths of
an inch on the one side, and an inch and a quarter on the other?—An inch and three-eighths on the other.
Of course, I wanted to put that section of a column
as it were, in comparison with a column of an inch
maximum thickness.
9956. (Mr. Traquair.) As a matter of fact the
columns were not subjected to any test except your
careful inspection by the eye and your hammer in
hand?—Yes; a superficial examination you may say.
They were not subjected to any mechanical test.

9957. Neither by hydraulic or otherwise?—No.
9958. Am I right in understanding that there were
something like 150 columns altogether destroyed for
defective working while you were there?—Yes, that
would be from the opening of the foundry in July 1874.
9959. What proportion did that 150 bear to the
whole number of columns cast during the same
period?—I should think in the proportion of about
twelve to one; I should think about one-twelfth—from
two-twelfths to three-twelfths.
9960. Whichever way you like to put it; but I
think, if you count up the number of pillars in the
piers, you will find that it is about one-twelfth?—I
am rather at a loss to know exactly how many columns
I did cast.
9961. I am quite willing to take it as being from
one-twelfth to one-fifteenth?—They were broken up
week by week.
9962. And these formed, I suppose, a large part of
the scrap that was subsequently mixed up with the
Cleveland pigs?—At that rate there would be some-
thing like one or two columns only a week broken up;
two columns a week probably. That would be a very
small proportion of the scrap that was used.
9963. But it was used as scrap for mixing with the
Cleveland pigs?—No, it was regarded as pure Cleve-
land iron.
9964. And there was added to that one-third of
scrap?—Afterwards one-third of the original scrap
used in every casting.
9965. You would have preferred, you say, to
have had one-third of Cleveland and one-third of
Scotch metal and one-third of Scotch scrap?—Yes.
9966. Why?—Because I think they flux better
together.
9967. Did you suggest that to anybody at the
time?—I did.
9968. But the suggestion was not acted upon?—It
was not acted upon.
9969. To whom did you make the suggestion?—To
Mr. Grobe.
9970. Your immediate superior?—Yes.
9971. Was that a matter of expense?—I believe
it would have cost about the same money. Cleveland
pig was cheaper, but the cost of carriage would have
made the cost approximate almost to the cost of Scotch
pig.
9972. Was there any reason assigned for your
suggestion, which seems a reasonable one, not being
followed?—Yes, I believe that my opinion as to the
mixture was not agreed with by the contractors.
9973. I think it is only fair to the previous
witnesses to put this to you with regard to this scrap; this
was some scrap lying near the copulas that McGeovan had
ordered to be mixed up and used?—Yes, there were
some castings lying upon the top of the bank and
thereabouts for a length of time.
9974. You ordered him to stop using them?—Yes.
9975. Did you not say to him that he was to let
these alone, and that you would get a better price for
them when the bridge was finished?—I have not the
least recollection whatever of making use of such
an expression.
9976. He says you did say so; do you positively
deny is or is it want of recollection?—I say that I
have not the slightest recollection of ever having made
such a remark, neither do I believe that I did say it.
9977. Then your notion is that it is an invention of
his?—My notion is decidedly that it is an invention
of his.
9978. Can you conceive any reason that he had for
making such an assertion?—No; but I cannot
conceive any reason whatever for my making such a
ridiculous speech.
9979. You can see no reason for his telling a false-
hood, and you can see no reason on the other hand for your having said it?—No; not at all. I confess I
do not quite understand what he means now, because
we were using Scotch scrap at the time.
9980. Those tests that you did apply were tests
to ascertain the bearing power of the iron?—Yes,
9981. Without going into any great detail, will you
tell me exactly the process that you adopted; you
have the cast iron bar of the proportions that you have
given us, how do you place it?—I place it on supports.
9982. And you hung upon it weight?—I hung upon
it which had been previously weighed.
9983. Until you got to the breaking point?—Yes;
I measured the deflection of the bar also.
9984. Can you give us its deflection where you had
the specified weight of 8,000 lbs. upon it?—I could
have done it had I had my notes; at any rate I know
that it bore the weight prescribed in the specification.
I satisfied myself at the time, and then having satisfied
myself of that I dismissed the matter from my mind.
9985. And having tested the bearing power of the
iron, you subjected the columns which were made of
that iron to no further test than you have already
told us?—No, I subjected it to the test in the specification.
9986. The specification gives the test simply to be
a test of 3,000 lbs.?—It gives the test for a bar; it
does not mention that any of the columns have to be
tested.
9987. But as a matter of fact you subjected the
columns to no test other than that which you have
already described to us?—No.
9988. Scabbing does not seem to have taken place
since were you yourself intending, a matter of
frequent occurrence?—No. The only scabbing
that was brought to my notice was that it occurred
in the case of columns to a small extent, and where
the foreman was doubtful whether he should pass the
columns or not; in the case of any more serious scabbing
he would have already, I presume, broken them up.
9989. But so far as your knowledge goes the scab-
ning was not frequent or extensive?—(Three or twice
a week.
9990. Out of the number reported to you what propor-
tion did you pass, and what proportion did you
cast?—Cast should say half and half, but I will
not be sure about it, it is a good while to recollect;
perhaps about every other one I might have passed.
9991. That is just half?—That is about half.
9992. And the blown holes were not frequent?—
No, I saw only very small, minute holes.
9993. I think you said that there were only about
two or three altogether?—Only about two or three altogether.
9994. As to the burning on of the lugs, I suppose
you preferred to have the lugs moulded on part of the
original casting?—That was the intention.
9995. And as an engineer prefer to have it so?
Yes.
9996. But your experience has taught you that at
least at the Wornit Foundry a careful man applying
himself carefully to the job, may produce by burning
on as secure a lug or part of a lug as if it were original-
cast?—He may produce part of a lug, but he will
not burn on a whole lug.
9997. But you would prefer, I suppose, to have it
on the casting rather than trust to the chance of the
care taken by the man who is doing it?—Yes, I would
rather have the casting perfect.
9998. In short, there is a risk in the one case of not
getting a perfect junction which does not occur in the
other?—Yes, that may be so, but then if a burning on
is not done perfectly it is very readily detected after-
wards.

Re-examined by Mr. Ballfour.
9999. In answer to Mr. Trayner you made some
reference incidentally to the hydrostatic test, did you
not?—Yes.
10,000. You said you thought it would not have
revealed such defects as Mr. Trayner showed you in
these pieces of metal?—It would have revealed the
presence of a blown-hole, but not the presence of
clinders.
10,001. You told us, I think, also that you could not
judge quite how large that blown hole had been in the
entire piece of metal?—No, I could not.

10,002. You would require in order to appreciate
the relation of these defects to the entire circle to see
the whole, I suppose?—I should require to see the
whole.
10,003. So as to see that there was or was not such
a strength of metal at the other parts of the circle as to
make this not very material?—Yes.
10,004. Is there anything in the pieces of metal
which have been shown you which leads you to the
conclusion that these defects would jeopardise the
structure?—No, there is not. I may put it in this
way, that in the proportions of columns that I have
mentioned where I increased the thickness, if two or
three flaws had existed in a column of that kind I
would have believed it to have been just as strong as an
ordinary column of one inch in thickness.
10,005. Even as such structures are designed there
always a great reserve of strength beyond what they
are likely to bear?—There should be.
10,006. And you added this additional reserve in
the manner that you have explained?—Yes; I added
it entirely on my own responsibility.
10,007. (The Commissioner.) You told us that you
went there at the latter part of the year 1873, but you
did not tell us when you left the works?—About 11 or
12 months before the bridge opened. I forgot the date.
10,008. I think you said they had given up their contract,
Messrs. Hopkins, Gilkes, and Company took it off their hands?—I have given no
evidence to that effect.
10,009. I think you said that they had taken over
the whole of the 600 or 600 tons?—I said that
Messrs. Hopkins, Gilkes, and Company continued me in the
same capacity that I occupied with Messrs. de Bergue and
Company.
10,010. They took over, I presume, the standing
plant?—Under a valuation they took the plant and
material.
10,011. And they took all the pieces that were there?
—They took all this iron over with them.
10,012. Now, as to these base plates which McGovan
was breaking up, those were some portion of them that
they took over, were they not?—No, they were not.
10,013. What were those then?—They were some-
thing in connexion with some experiments. As far as
my recollection serves me there were some base plate
castings in connexion with some experiments that
had been made, and it was not at all clear to me that they
had been taken over. The whole of the iron that had
been taken over, and that I intended to use, consisted of
circular cylinders and circular caissons, and it was
entirely one character that we used.
10,014. Do you mean that the work over the cylin-
ders and caissons and did not take over the base plates?
The base plates had no connexion with the caissons.
10,015. Did they not take over any of these base
plates?—They belonged to some particular work that
had been executed a long while previously by Mr. de
Bergue for the north side, where the character of the
columns and the castings was entirely different from
the class of iron that the scrap was composed of, and
I was almost certain that they never had been included in
the valuation.
10,016. Why were you almost certain of that?—
Because I had a great deal to do with the valuation.
10,017. Then you must have known whether they
were taken or not?—It is my impression that they were
not.
10,018. And that Mr. de Bergue left them at the
works?—I believe that they belonged to the railway
company.
10,019. Was that the reason why you prevented
McGovan from breaking them up?—Yes; I did not
know what the iron was or where it came from.
10,020. Was there any other piece of iron on the
ground that belonged to the railway company?—I did
not think so.
10,021. Only this small quantity of base plates,
which you stopped McGovan from breaking up?
Since that had been used for a special purpose; they
had been employed there before I arrived at the bridge.
TAY BRIDGE DISASTER:

10,022. Can you explain why trial was not included in the contract when they took over the rest of the iron amounting to 600 or 600 tons?—As far as my memory serves me they had not been included in valuation, and being doubtful on the point as to what iron they would compose of, and moreover Mr. Strachan having commenced to break them up without having received instructions from me, I prevented his going on any further with them. I do not suppose there were more than two or three tons altogether.

10,023. Did you stop him from breaking them up, because he had begun to do so without orders?—That was one reason; he had only broken up no iron but what was brought before him. The iron was lifted up from below, and placed before him in a heap.

10,024. You told us that Mr. Strachan was an experienced man and a person of good character; did you continue always to entertain the same opinion of him?—No; before this incident in relations to McGovern took place Strachan had left us.

10,025. He left you immediately before?—Yes; I may say that I was not satisfied with him at that time.

10,026. You were not satisfied with the work?—Not with the attention that was bestowed upon it; I do not want to say anything against the man.

10,027. But you have given him a high character, and want to know whether you had reason to believe that he was a trustworthy man. You have explained to us very carefully how, during the time that you had superintendence over the foundry, you examined every one of the columns before it was sent off to the works?—I examined every column, not only once, but two or three times.

10,028. In the turner's hands?—Every one that the turner directed my attention to as being a defective one.

10,029. Then did you explain to the turner—Fender—how he might be able to ascertain whether or not the column was thinner on one side than it was on the other?—Yes, I did; I did one myself, and showed him how. I do not mean to say that I turned one; but I showed him how to do it.

10,030. He has not told us that. On the contrary, he has told us that he did not know at all how, without breaking a column up, to ascertain whether or not it was thicker on the one side than the other; therefore, he must have forgotten the instructions which you gave him?—Fender frequently either came to me, or sent for me in there, in order to inspect columns that he was doubtful whether to go on with or not.

10,031. Supposing, for instance, that this same care in looking at the column when it had passed into the hands of the turner had not been given to it, there would be no means of knowing externally whether or not the column was thicker on one side than the other, would there?—I do not think I could have detected it myself.

10,032. Then if no such means were taken by the gentleman who succeeded you, viz., Mr. Campell, they might be turned out without his knowing whether they were thicker on one side than they were on the other?—Any great discrepancy in thickness might have been ascertained by sounding with a hammer, but any discrepancy to the extent of three-eighths of an inch, or a quarter of an inch, I do not think I could.

10,033. Could any discrepancy reduced to five-eighths of an inch have been detected?—I should not undertake myself to detect the difference in thickness merely by sounding with a hammer.

10,034. Except it was very thin?—Except it was something very decided.

10,035. Unless it was something like a quarter of an inch?—Unless it was about half an inch, perhaps.

10,036. You told us that you examined carefully, for half an hour with a microscope, this lug which had been cast by Strachan?—Yes.

10,037. What was your reason for doing that?—I wanted to see if it had been done perfectly.

10,038. Was it a new thing to you?—Not at all.

10,039. Why did you examine it so carefully?—Because there is a risk of cracking the column.

10,040. There of always a risk, is there not, when you put on a lug, of cracking a column?—There is a certain risk if it is done perpendicularly. If it is done properly there need be no risk.

10,041. But if it is done perpendicularly? Either it must leave the flange, or it must leave the column, or the column must crack, must it not?—Yes, to some extent it must.

10,042. (Colonel Yolland.) Were there many columns that you examined which had cracks in them from the burning on of the lugs?—I never saw a crack in a centre column from first to last, not a single crack of any description.

10,043. Do you consider that it was good workmanship to allow the outer 18-inch column to be secured together simply by bolts through holes that had not been drilled holes?—If the holes agreed with each other, they would be equally as true as drilled holes.

10,044. But, supposing that they did not agree with each other?—Of course, the bolt would not go in, and they would have to be chipped or filed to make them to do so.

10,045. The holes would require to be chipped to make them agree?—Yes, chipped or filed.

10,046. Then the attachment would not be so complete as if equal sized holes had been bored through the flanges of the 18-inch columns?—They would not; but it may be that the flange of these 18-inch columns was made thicker.

10,047. Were they made thicker?—I believe they were made an inch and a half thick.

10,048. And the holes through them were cast. What size?—About an inch and a half diameter; they were made for an inch and an eighth bolts, if I recollect rightly.

10,049. (Mr. Barlow.) I think I understood you to say that with the best care and attention that you can give to cast iron, you cannot altogether rely upon bringing out these columns without serious flaws in them?—There may be a latent defect in the column, that does not exist or show itself on the surface or yet, in the bore there may be a piece of cinder in the iron, and there may be two or three bore holes; I have known castings that have been subject to the hydrostatic test, and the water has never forced its way through, and yet when such a column has been fractured, it has shown certain blown-holes that have been thoroughly concealed. I have seen that in water pipes.

10,050. And it is, therefore, a very uncertain and unreliable material to use where it is placed in a position like these outer columns, for example?—Yes, without great excess on the side of safety.

10,051. Have you found in any of the columns a tendency to break during frost, either in the work or after their erection?—I do not know a case in which one has broken through frost.

10,052. Had you anything to do with the filling of those with concrete?—I had nothing to do with the erection of the bridge at all.

10,053. How was the contractor paid for his work? Was it a lump-sum contract, or was he paid so much a ton?—According to a schedule of prices.

10,054. Then when you increased the metal from an inch to an inch and an eighth, was that a benefit to the contractor?—It would be in that sense, looked at in that way.

10,055. (Colonel Yolland.) Was it so understood?—I informed my chief of what I was doing.

10,056. (Mr. Barlow.) It would increase the weight, of course?—Of course, it would increase the weight a little.

The witness withdrew.
Further examined by Mr. Trayner.
(The official photographs of the Bridge were shown to the witness.)

10,055. (Taking No. 4 pier and the view looking east, do you see that distinct line traversing the right side of the column?—Yes.
10,056. What do you think that was?—I think it was a shifting of a box.
10,057. Plainly obvious on the outside of the column?—Yes.
10,058. (The Commissioner.) That you have no doubt about?—It may be something different, but from the photograph I would say it is quite possible that it is caused by a shifting of the box.
10,059. (The official photograph of pier No. 6, looking west from the south side, was shown to the witness.)
10,060. What is that?—That is very much the same.
10,061. And that is very obvious?—Yes, at any rate, on the photograph.
10,062. And it would be on the column, would it not, if it is on the photograph?—That is not quite certain, it might possibly be something in the glass.
10,063. If these are accurate pictures in the two that I have shown you, there are obvious marks of the shifting of the box?—It may have been caused by the shifting of the box.
10,064. It is more likely to have been caused by that than by anything else that you can suggest?—Yes.

The witness withdrew.

(The Commissioner.) What evidence do you propose to produce to-morrow, Mr. Balfour?

(Mr. Balfour.) We shall offer evidence of speed, but it cannot be long. The Court have heard that Mr. Gröthe and Mr. Reeves and Mr. Delpratt are all abroad, and after having heard the two engineers who are in this country, Mr. Beattie and Mr. Campbells, the Court would not think it necessary that we should bring more subordinates. If the Court desired it, I should offer one or two more, but I doubt if they could add anything to the evidence.

(Mr. Balfour.) If that is the view of the Court it is entirely my own, I confess.

(The Commissioner.) Of course we express no opinion as to whether Mr. Gröthe and Mr. Delpratt should come forward or not. That is a question for you to consider.

(Mr. Balfour.) Certainly, sir, but they are not accessible to us at this moment.

(The Commissioner.) The only question is whether you should produce a few more subordinates, and of what character.

(Mr. Balfour.) Merely some of the men very much such as the Court have already heard, but I should doubt whether their evidence would add anything.

(The Commissioner.) You are not anxious for other evidence.

(Mr. Trayner.) I should be disposed to leave that absolutely in the hands of Mr. Balfour, as he must be the best judge of what would best meet the case presented by the Board of Trade.

(Mr. Balfour.) I do not think any information that I have would add materially to what is already before the Court, but of course the North British Company wish to present every official who is accessible to them.

(The Commissioner.) Then we shall be going on to-morrow with the evidence as to speed.

(Mr. Balfour.) It will really be that, and I think it will be practically limited to that; I think it will really be evidence of two classes both comparatively short. We propose to call some evidence on the part of constant travellers, that is to say, some persons who will come, as Provost Robertson did, to say what they observed and felt, and then we shall have some of the drivers and officials of the company to enable the Court to understand the capabilities of such engines. We have a witness who could speak to the condition of the permanent way, but I do not think that is drawn into question.

(The Commissioner.) No, it is not in question.

(Mr. Trayner.) The Court having requested me to communicate to the Town Council, after the examination of the witnesses, that we did adduce, and to inquire whether they desired any further evidence to be led on their suggestion, I have this letter from the Town Clerk: "Referring to your wish expressed to me yesterday, to know whether the Town Council in reference to their resolutions communicated to the Board of Trade had any further evidence to suggest in the inquiry now proceeding, I have to state that, at a meeting of Council called for to-day, and fourteen members only being present (fifteen being a quorum), the meeting in Committee after deliberation, instructed me to convey through you to the Board of Trade the thanks of the members of the Council present for the additional opportunity afforded the Council of suggesting evidence, and to intimate that in the meantime they had no further evidence to produce or suggest."

The Court have heard that Mr. Balfour, as he must be the best judge of what would best meet the case presented by the Board of Trade.

Adjourned till to-morrow at 10 o'clock.

NINTH DAY.

Wednesday, 3rd March 1880.

DUNCAN MACDONALD KNOLEDGE.

Examined by Mr. Balfour.

10,064. Can you give me a general idea about how often you crossed the Tay Bridge both by the Newport trains and by the through trains?—Yes; very frequently.
10,065. From the time it was opened to the time it fell?—Yes; from a few days from the first start after it was opened.
10,066. Are you one of the magistrates of Dundee?—I am.
10,067. Did you frequently cross the Tay Bridge both by the Newport trains and by the through trains?—Yes, very frequently.
10,068. Can you give me a general idea about how often you crossed during a week, or month, or otherwise?—I should say on the average at least two or three times every week.
10,070. Did you pay attention to the speed?—I did. 10,071. Both by observing it without your watch, and also with your watch?—Yes, both ways.
10,072. What did you remark or observe with regard to it?—I was told before I crossed a day or two that...
the trains passed in about five minutes. I did not expect that, and therefore curiosity led me to time it, and the first time I timed it I was going from the north to the south.

10,073. (The Commissioner.) From station to station? — No, nor was it from cabin to cabin. I made it necessary to look until I saw the water below, so that I counted from one side of the water to the other side, which is a little less than from cabin to cabin.

10,074. (Mr. Balfour.) What was the result of your observations? — In going across the first day I timed the train, and it was a little over 7 minutes from north to south.

10,075. Now give us your observations from south to north? — On coming from the south to the north I timed it as I stated, from the moment I saw the water under me until I saw the hand. I never saw it under 5 1/2 minutes except on one occasion.

10,076. And how often did you time it from south to north? — I said in my precognition at least half a dozen times; but in reflecting over it I think I should say a dozen times.

10,077. You say except on one occasion. What was that one occasion. What was the speed that you observed? — I forget whether it was a Newport train. I am not sure whether it was not a Saint Andrews train, but on the Newport line, and I calculated that we were a second or two within the 5 minutes.

10,078. Now, was there any very material increase of speed within the high girders as compared with the rest of the journey? — I do not think there was.

10,079. But was there some increase? — I should say very slight, I think. The train seemed to me at least's train, but on the Newport line, and I calculated that we were a second or two within the 5 minutes.

10,080. Now, was there any very material increase of speed within the high girders as compared with the rest of the journey? — I do not think there was.

10,081. Did you ever perceive any vibration or oscillation, either vertical or lateral? — No, nothing to cause any observation.

10,082. How would you describe the run across the bridge as regards comfort comparing it with the rest of the line? — I always felt it, and I very frequently spoke of it as being the easiest and smoothest part of the line.

10,083. (The Commissioner.) Do you mean between the high girders? — No, the whole bridge.

10,084. (Mr. Balfour.) Then was there anything that ever occurred to you to excite either any apprehension or misgiving as to its stability or safety? — Never.

Cross-examined by Mr. Trayner.

10,085. Do you reside in Dundee or on the other side? — In Dundee.

10,086. Your trips across were business trips, I suppose? — Yes.

10,087. Just going and coming on your business? — I am not in business; but I have in the first place friends, a brother and sister-in-law at Newport, whom I frequently visit, and I am in the habit of going down frequently to Saint Andrew's, Carnethie, Edinburg, and the almost all the towns on that line.

10,088. On all the dozen occasions that you have mentioned, did I understand you to say that you had timed the train with your watch in hand? — Yes, with my watch in hand.

10,089. You do not mean a stop watch? — No.

10,090. But a watch with second hands? — Yes.

10,091. The general result was five and a half minutes? — It was never under that except on one occasion.

10,092. That is taking it generally; give me the highest that your watch indicated? — Do you mean from end to end?

10,093. I mean from where you took your own point of observation from point to point? — I do not think I ever saw it higher than six and a half minutes.

10,094. (The Commissioner.) From south to north? — Yes, from south to north.

10,095. (Mr. Trayner.) You never saw it higher than six and a half minutes? — Longer I mean.

10,096. And the lowest was a second or two within the five and a half minutes? — Yes, under five minutes.

10,097. Can you come a little nearer and say how much under the five minutes it was; a few seconds might mean a different thing? — I should say under five; not more than five seconds less.

10,098. What speed did that indicate? — I am not exactly sure, but I think five minutes would indicate 24 miles calculating the bridge at two miles, but the distance is less.

10,099. You are taking it from a point inside the bridge to a point inside the bridge? — Yes.

10,100. Have you formed an opinion as to what the highest speed was that you travelled at from point to point according to your observation? — I cannot exactly say, but judging by observations of distances on the land I do not believe it ever could exceed 26 miles or less, 25 or 26 miles, that was my feeling at the time. Of course, as you are aware, we are very apt to be deceived in passing anything. When coming out of the girders or going into the girders the speed then appeared to be less, although in reality it could not possibly be.

10,101. It might be a little more or it might be a little less? — It might, I paid particular attention to that, knowing for instance that people are deceived. When coming out of the girders or going into the girders the speed then appeared to be less, although in reality it could not possibly be.

10,102. (The Commissioner.) You account for it by the rapidity with which the train dashed past the high girders? — Yes, that is apparent to everybody who travels in a railway carriage.

10,103. (Mr. Trayner.) You said that you made these observations in consequence of having heard something? — No, it was not quite that, when the line was opened, of course, it was the talk of everybody as to the facilities of the line.

10,104. You said that a day or two before this, when you made your experiments, you had heard people speaking of the speed of the trains? — Yes, but I must make myself understood better; it was on a Saturday that the line was opened, I think it was on a Saturday, and it was on the following Saturday that I crossed for the first time, and people had been talking to me as to the very great convenience it would afford; and people had been saying that trains now would pass and did pass in about five minutes; and curiosity led me to time it.

10,105. Were those observations that you made within a short time after the bridge had commenced to be used? — The very first day I timed it, the first day I did time the train, and I continued to do it occasionally up till nearly the last; I am not sure that I did it on the very week preceding before I travelled for the last time on Monday to see.

10,106. Did you ever hear during that time that others had complained that the speed was excessive? — I never heard that until after the fall.

The witness withdrew.

Examined by Mr. Balfour.

10,107. I believe you are an architect in Dundee? — Yes.

10,108. Are you proprietor of an estate at Furry Bank, near Cupar Fife, where you and your family reside? — Yes.

10,109. Did you go daily between Ferry Bank and Dundee along the Tay Bridge, from the opening of the bridge down to the day before it fell? — Yes.

10,110. Passing once at least each way? — Yes.

10,111. That was by the through trains? — Yes.
10,112. Did you also frequently cross by the local, or Newport train?—Yes, occasionally.

10,113. Had you good opportunities of noticing the speed at which the trains were run, both the through and the local trains?—I had.

10,114. Will you kindly tell us what was the result of your observations with reference to the trains coming from the south to the north?—I formed the opinion that they always drove across the bridge very carefully both ways, from north to south as the other way. My conviction was that they never occupied less than five minutes in crossing the bridge proper.

10,115. Did you ever time a train with your watch?—No, I never did by watch.

10,116. Are you satisfied that you correctly timed the trains?—Yes, I was satisfied that I did this—generally by the 4.5 train from Dundee in the afternoon. The train which left for Newport at 4 o'clock was always despatched very punctually. With the 4.5 train we had invariably to slow, and sometimes it came to a full stop at the north cafin long before we were allowed to go on the bridge, because the train which had left five minutes sooner was not clear of the bridge, and we had to wait often two minutes, and, of course, we wondered what the delay was, and we always made it a practice to look out for the Newport train to get off the bridge. Then I found that the speed coming down the other way was just the same as we went going over. Practically there was no difference, so far as I could judge, between the trains going either way.

10,117. Why was there anything in the speed at any time either way to excite apprehension in your mind?—Not the slightest.

10,118. Did it occur to you that the speed was reckless or dangerous?—Never.

10,119. You have travelled over the bridge, it would seem, as long as the bridge was a bridge—all the time. Did you observe any difference in regard to the speed during the latter part of the time as compared with the earlier part of the time?—None whatever.

10,120. Then did you feel any vibration or oscillation, either vertical or lateral?—Not so much as upon the other part of the line beyond the bridge.

10,121. At no time between the opening and the fall of the bridge?—Never.

10,122. Was there any difference in that respect between the early period of the bridge being open and the latter part?—I thought it was rather improved. I thought there were more careful and more punctual latterly than they were at first.

10,123. What do you mean by more careful and more punctual latterly than at first?—They got more

10,124. Did you mention something about the baton, down to what speed did they slow the train in order to get or deliver the baton on the south side?—It came down very slowly, and there was a man always ready to catch the baton from the signalman as the train passed.

10,125. Do you mean that you did not at any time observe any oscillation or vibration?—There were those little usual waverings which I set down as due to the giving of the springs and the ordinary movement in railway trains.

10,126. Was there anything that was different on the bridge from other bridges?—It never struck me that there was any difference.

10,127. Was there anything connected with your experience to excite apprehension or misgiving?—There was never anything whatever.

10,128. From having crossed the bridge daily, you must have crossed in all kinds of weather?—Yes, sometimes the weather was a little squally and cold.

10,129. Is your evidence given with reference to your whole experience?—Yes.

10,130. Over the whole time, including all changes of weather?—It is.

Cross-examined by Mr. Traill.

10,131. You went over in the afternoon you say by the 4.5 train?—Yes.

10,132. And came from the south to the north in the morning at what time?—About nine o'clock.

10,133. By the through train?—Yes, by the through train.

10,134. Is it your opinion, from your experience, that there was no vibration whatever in the bridge, and that the only vibration you felt was that occasioned by the carriage?—I can only say that there was no vibration unusual to the ordinary vibration, not that I could distinguish, more than on an ordinary line.

10,135. Is it your conviction then that any oscillation or vibration was due to the carriage and not to the bridge in any degree?—That is my conviction.

10,136. But persons who were standing on the bridge when a train went past I suppose would be better able to say whether or not there was vibration on the bridge itself than you could in a carriage?—Undoubtedly.
10,152. Did you ever time it with a watch?—No; in fact the time was too short.
10,153. Do you know what travelling at a speed of 40 miles is?—Yes.
10,154. Were you ever travelling at anything near that on the bridge?—No.
10,155. Are you certain of that?—Yes, I am certain of that.
10,156. Were you sensible of any vibration on the bridge?—No; the only difference I have felt sometimes was that an old carriage was not so pleasant to travel in as a new one. There was the ordinary shaking.
10,157. Were you conscious of any lateral vibration or oscillation, or any movement from side to side?—No; my experience is the reverse—that there was not anything of the sort.
10,158. Is the result of your experience this, that you found nothing connected with the bridge to excite any fear in your mind or misgiving?—Never.
10,159. Had you perfect confidence in the bridge till it fell?—Yes.

Cross-examined by Mr. Trayner.
10,160. I suppose your attention was never particularly directed to the exact rate of speed of the trains, or to the vibration?—No, the vibration I should have felt.
10,161. If there had been anything excessive in that way, you would have felt it?—Yes.
10,162. There was nothing in the vibration to call your special attention to it?—No.
10,163. And, at the same time, there was nothing special to call your attention, either by way of public complaint or otherwise, to the rate of speed?—No, I never had any complaint.
10,164. And you never went at a speed of 40 miles an hour?—No.
10,165. What is the highest rate you ever went at?—I went by the “Flying Scotman,” the express train.
10,166. Did you ever come across the bridge at the same rate of speed as that did?—No. I sometimes noticed a deflection of the girders.
10,167. Can you give us any opinion with regard to the highest rate of speed that you attained with that morning train which you have mentioned, when it was a little quicker than others?—How should I possibly? I cannot, because I never timed it; but, by my common observation, I should think it was not more than 30 miles.

The witness withdrew.

HENRY ROBERTSON SWORN.

Examined by Mr. Balfour.
10,168. You are a merchant in Dundee?—Yes.
10,169. And reside at Dairsie, in Fifeshire?—I am a resident in Eden Grove, near Dairsie.
10,170. Did you travel along the Tay Bridge, between Dundee and your residence at Eden Grove, daily?—Yes.
10,171. During what time?—From the opening of the bridge till the 25th December—Christmas-day.
10,172. Did you travel daily during that time?—Yes.
10,173. Besides going by the trains to Dairsie, did you sometimes go by the Tayport trains or the Newport trains?—Occasionally.
10,174. Had you an opportunity of seeing the speed at which the trains travelled?—Yes.
10,175. Did anything strike you about it?—Nothing particularly; but occasionally, when I have gone to Glasgow or Edinburgh, inquiries were made of me as to how long the trains took to pass over the bridge, and out of curiosity, so that I might be able to answer that question, I timed a train two or three times by my watch, between the signal-box on one side and the other, from cabin to cabin.
10,176. With what result?—Between five and six minutes, both ways.
10,177. Did you find any difference, or any material difference, between the two?—It did not strike me that there was any difference of time, but I did not time it for that purpose.
10,178. Five or six minutes was your observation of the time both ways?—Yes.

Cross-examined by Mr. Trayner.
10,179. Did it appear to you that the speed was too great?—No, I did not think so.
10,180. Had you any doubt or misgiving as to the safety of the bridge?—None whatever.
10,181. In saying that do you include the whole period down to the last time that you travelled?—Yes.
10,182. Did you ever find any vibration or oscillation of the bridge?—Nothing to alarm me in any way in Fifeshire, not so much as on many parts of the permanent way.
10,183. On the solid land?—Yes.
10,184. Was there any movement in the trains which in your judgment was attributable to the bridge?—I did not attribute it to the bridge.

The witness withdrew.

JOHN ANDERSON SWORN.

Examined by Mr. Balfour.
10,190. You are a passenger engine-driver in the employment of the North British Railway Company?—Yes.
10,191. How long have you been an engine-driver?—About 16 years.
10,192. When the Tay Bridge was opened were you put upon a part of the line between St. Andrew and Dundee?—Yes, I was.
10,193. So that you had daily to pass along the Tay Bridge?—Yes, from the first day it was opened up to the later time.
10,194. From 1876 till it fell?—Yes.

10,195. How many times did you pass it?—The first summer we passed about ten times a day; that was before the Newport route was opened, but latterly, after the Newport route was opened, we went from four to eight times every day. There were a couple of engines on them.
10,196. Were you the only driver who passed it for the first year?—Yes.
10,197. I mean on the St. Andrews route?—Yes.
10,198. After the Newport route was opened did you go by that route?—Yes, by Tayport and Newport.
10,199. Before that you went by St. Fort?—Yes.
10,201. From May 1879 you went by Tayport and Newport?—Yes.

10,202. At what hours of the day did you pass?—In the morning train that was at 6.20 from St. Andrews, due at Dundee at 7.10, and the 7.35 from St. Andrews, due at Dundee at 8.45.

10,203. Was that the one that passed Newport about half-past?—Yes.

10,204. Did you drive that train and others during the day?—Yes.

10,205. Did you drive the evening trains also in that direction?—The four o’clock train was our last train to St. Andrews. Coming from St. Andrews we have cross lines to Leuchars.

10,206. When you were passing from the south to the north, what was the rule with reference to slowing down at the south cabin?—Before the Newport line was opened the speed was restricted to three miles an hour, and after the Newport line was opened it was restricted to two miles an hour at the south cabin.

10,207. Did you obey that direction?—Yes.

10,208. And slowed down to the specified speed?—Yes.

10,209. And you had to receive a baton, had you not?—Yes, and give one up.

10,210. Will you tell us what speed did you cross the bridge or go along with it?—Generally I remarked that the time from cabin to cabin it took me was from five minutes to about five and a half minutes from south to north.

10,211. Did you time it with a watch?—Yes.

10,212. Often?—Mostly every time we crossed.

10,213. What kind of engine did you drive?—It was a tank engine from St. Andrews.

10,214. Was it a good engine?—A splendid engine.

10,215. Did it get up to the speed which it was designed for quickly?—Very sharp.

10,216. Can you tell us over what part of the bridge did you go quickest?—Only on account of warnings. Will you tell us what speed across the whole bridge was pretty even, barring 500 or 600 yards from the south cabin, and cutting off 600 or 700 yards coming to the north cabin.

10,217. The rest was pretty uniform from merely getting up steam smartly with that kind of engine?—Yes.

10,218. Was there any material difference in going through the high girders from the rest?—In no degree; not in one part.

10,219. Can you tell us at what speed in miles per hour do you think you ever went through the high girders?—It would be something below 25 miles per hour.

10,220. You say that about five and a half minutes was sometimes the time it took from end to end?—Never below that.

10,221. And sometimes above that?—Yes, six minutes.

10,222. Did you ever go through the high girders at anything like a speed of 40 miles an hour?—No, not on any part of the route.

10,223. Could such a speed as that have been got out of that tank engine?—No.

10,224. What length of trains, or what kind of trains had you usually?—In the morning with the passenger train we had nine or ten carriages.

10,225. How many vans?—In the case of the one that I am speaking of it was seven carriages and two vans, or eight carriages and two vans.

10,226. And a good many people?—Yes, full carriages; they were always full in the morning.

10,227. And in the afternoon?—There were scarcely any in the afternoon.

10,228. Were they heavy trains?—Yes.

10,229. Have you gone over in all kinds of weather?—Yes.

10,230. Did you ever feel my movement upon the bridge in going over?—Not in the least.

10,231. Up and down, or side to side?—No.

10,232. Did Mr. Smith, the station master at Dundee, ever speak to you about any complaint that had been made by Provost Robertson?—I saw Mr. Smith and Provost Robertson on the platform, one day, just before starting by train for the south, and Mr. Smith told me that Provost Robertson was speaking to him about the speed being too high, but that was all.

10,233. Was that the speed of your train or of whose?—I cannot say, I do not think it was exactly my train.

10,234. When was that?—It was sometime in the summer, I recollect the day it was.

10,235. Was that the only occasion upon which anybody over spoke to you of the speed of the train?—It was only one occasion.

Cross-examined by Mr. Trayner.

10,236. Was that complaint that was made by Mr. Smith to you with reference to the train that you had just brought over that morning?—No, it was some train previous to that day.

10,237. What was the longest train you ever timed a train going across the bridge?—From south to north?—Yes, something nearly six minutes.

10,238. What do you mean by that?—I measured the time by the five minutes handle.

10,239. Had you no second?—I had, but I had my duty to look after besides.

10,240. I suppose you took out your watch at one cabin and put it into your pocket, and then took it out when you reached the other?—Yes.

10,241. And in the meantime you were attending to your necessary duties as driver?—Yes.

10,242. Were you yourself the driver of the 8.35 train from Newport?—No, there are two of us.

10,243. Who was the other?—John Braud.

10,244. Did you take it on alternate mornings or how?—Yes, or every other week.

10,245. Was there not a boat that crossed about that time?—Yes.

10,246. Which was the soonest into Dundee generally, you or the boat?—If the boat got away sharper she was the first into Dundee, but if we started both from the station when she left the pier, we were in Dundee first.

10,247. Were you sometimes detained, or did you sometimes leave Newport after your advertised time?—We were pretty sharp up to time—we had no junctions.

10,248. But you were sometimes late, were you not?—Sometimes perhaps we were a minute or two late.

10,249. Sometimes the boat was away from Newport when you started?—Yes.

10,250. When was the boat advertised to leave?—I do not know—it was just about the time we started.

10,251. But sometimes the boat got away sharper to time than you did?—Yes.

10,252. What was the highest speed you ever went across the bridge at?—I have generally tried not to exceed 25 miles.

10,253. Your orders were not to exceed 25 miles?—Yes, I had a supplement to that effect.

10,254. You tried, of course, to reach your regulation speed of 25 miles?—Yes.

10,255. I suppose it was against your orders to go below the regulation speed?—We sometimes failed to do it.

10,256. But you tried to keep up to it?—Yes.

10,257. It required the regulation speed to enable you to go from one station to the other in the advertised time?—Yes.

10,258. On those occasions when you were a minute or two late at Newport, have you not sometimes got into Dundee at your right time?—No.

10,259. If you were late in starting, were you also late in arriving?—Yes, from Newport.

10,260. Did you notice that particularly?—Yes, from Newport.

10,261. Are you in a position to say from actual observation that you never made up any part of a
minute's time lost at Newport by the time you reached the station at Dundee?—I am quite sure.

10,252. How are you quite sure?—Because I had my watch to look at the time.

10,253. Did you always look at it when you reached the station at Dundee?—Yes, either my watch or the station clock.

10,254. Was the highest rate of speed that the tank engine could get up?—It was to go across the bridge.

10,255. No, I mean anywhere. What was the highest rate at which you could drive the tank engine with an ordinary train?—It depends upon the gradients and the load.

10,256. Take a level line?—When the train consisted of eight or nine carriages on a level, I do not think I could manage that on a level.

10,257. You could get that, could you not?—If it was a quiet day I might.

10,258. How often did Mr. Smith speak to you?—Only once; on that occasion with the Provost.

10,259. Tell me, if you please, so far as you can recollect, what it was that Mr. Smith said to you?—I think the words were something to this effect: he said, "John, ex-Provost Robertson is complaining to me just now about some trains he came across with some days past that their speed is about 40 miles an hour." I said nothing to Mr. Smith, but smiled to myself; I considered it was perfect nonsense.

10,260. What did Mr. Smith say to you?—That was all.

10,261. You said nothing?—Nothing that I remember.

10,262. You did not think it was proper for him to say that, had you your own doubts about it?—Yes.

Re-examined by Mr. Balfour.

10,263. You thought that you knew better than the ex-Provost?—I think so.

10,264. You were asked about the boat, had you anything to do with that?—No.

10,265. Did you ever try to race the boat?—No.

10,266. Or if it went away first did you try to get in before it?—I never made any difference.

10,267. (The Commissioner.) Do you know what time it was from cabin to cabin?—I considered it to be about two miles.

10,270. You said that you did not get up to your full speed from 500 or 600 yards after passing the south cabin, and that you went at a slower speed 500 or 600 yards before you got to the north cabin?—Yes, 600 or 700 yards before coming to the north cabin the speed was shut off at the summit of the hill to descend into the girders.

10,271. Before that?—Yes.

10,272. Did you ever shut off steam until you came within 600 or 700 yards of the north cabin?—No.

10,273. (Mr. Barlow.) I suppose you have had to drive across iron bridges before?—Yes.

10,274. Any large ones?—No, not a large span.

10,275. Have you ever, or can you ever upon your engine feel any vibration which was due to the bridge itself different from the rest of the route?—On narrow bridges.

10,276. Did you ever when you were upon your engine feel any vibration or oscillation which was due to the bridge itself?—Not on the Tay Bridge.

10,277. On any bridge?—Yes, I have felt it.

10,278. But not on the Tay Bridge?—No.

10,279. But you have felt it on other bridges?—Yes.

10,280. You are sure of that?—Yes, quite sure.

10,281. And yet you did not feel it on the Tay Bridge?—No.

10,282. What did you attribute it to?—Mostly on account of the length of the spans; it was a wooden bridge that I referred to.

10,283. I was speaking of a large iron bridge?—No.

10,284. You felt, you say, no vibration in crossing this bridge?—No.

10,285. I understand you distinctly to say that you only shut off steam when you got to the summit of the bridge?—Yes.

10,286. Up to that point you had been going at full speed?—Yes.

10,287. And when you got to the summit you shut off steam?—Yes.

10,288. But up to that point you were going full speed?—Yes.

The witness withdrew.

Examined by Mr. Balfour.

10,293. Are you a passenger engine-driver in the employment of the North British Railway Company?—Yes.

10,294. How long have you been so?—Twenty-eight years.

10,295. Have you been driving on the branch between St. Andrews and Dundee for the last 16 months?—Yes.

10,296. Did you go there three months after the Tay Bridge was opened?—Yes.

10,297. Then between three months after its opening and its fall were you driving across it every day?—Every day.

10,298. How many times a day?—It was four times when I ran to Burntisland.

10,299. I did not ask about that. For the first three months that the bridge was open were you driving between Burntisland and Dundee?—Yes.

10,300. Were you crossing the Tay Bridge from the time it was opened?—Yes.

10,301. How often during the first three months?—Four times a day.

10,302. Then, after that you were put on the St. Andrews branch, how often did you cross then?—Four times a day one week, and eight times a day the other.

10,303. (The Commissioner.) Twice each day would that be. Do you mean when you say four times that you went twice north and twice south?—Yes.

10,304. When you speak of eight times you mean four times north and four times south?—Yes.

10,305. So that you traversed it four times one week and eight times the other?—Yes.

10,306. (Mr. Balfour.) Since the Newport line was opened did you drive the trains passing Tayport and Newport?—Yes, the whole time.

10,307. Morning and afternoon, as well as midday?—Yes.

10,308. Did you often drive the train which left Saint Andrews at 6.20?—Yes.

10,309. In your turn with the last witness?—Yes.

10,310. That is John Anderson?—Yes.

10,311. Were you the man that drove the three morning trains?—Yes.

10,312. With regard to the regulation about showing down at the signalmen's cabins, did you act upon that regulation?—Yes.

10,313. Will you just tell us on coming from the south to the north at what speed did you cross the bridge?—I do not think I ran more than from 22 to 24 miles from cabin to cabin.

10,314. Did you go at a little higher speed in the middle?—We should get a little more speed at the high girders than at each end.

10,315. That would be the highest speed on the high girders?—Yes.

10,316. Can you give us an idea of how quickly you would be running when at your top speed there
on the bridge?—I do not think I ever exceeded 24 miles.
10,321. (The Commissioner.) You mean between the high girders?—Yes.
10,322. (Mr. Balfour.) How long did you take from cabin to cabin in going from south to north?—I do not know that I ever did it below 34 minutes or 5 minutes. I have seen it take 7 on a coarse morning.
10,323. Have you timed it often with your watch?—Yes, I had my watch in my hand.
10,324. When did the morning train from Saint Andrews, which left 7.55, pass Newport?—At 8.33. There were eight carriages and two vans to that train.
10,325. Was it well filled with people?—Chock and block; every morning full.
10,326. That was the train by which people came over to their business in Dundee?—Yes.
10,327. Did you ever on any part of the bridge, either in the high girders or elsewhere, go at anything near 40 miles an hour?—No; but I could not get it.
10,328. Could you have got it out of your tank engine?—No; I could not get it.
10,329. Did you ever feel any movement in the bridge?—No.
10,330. Up or down, or from side to side?—No; it was very smooth on the whole of the road.
10,331. Had you any fear for its safety?—No; never had any fear.
10,332. Did anybody ever complain to you about running too quickly?—No.
10,333. At no time?—At no time.

Cross-examined by Mr. Traynor.
10,334. Not the station-master?—No.
10,335. He never spoke to you?—No.
10,336. Nor your locomotive foreman?—Yes; he spoke once.
10,337. When was that?—One time that he was going with us he said that there were some complaints about the Saint Andrews speed going hard.
10,338. He would say something else than that, would he not?—No.
10,339. Did he not ask what speed you were running at?—No.
10,340. He did not give you any instruction to be careful in future?—Yes; he said we should be canny and not get too high speed upon it for there were complaints.
10,341. When you timed the train, did you do it often?—No; I did not do it often, perhaps once in a day, or perhaps once in two days.
10,342. You do not mean to say that you continued timing it once a day or every two days all the time you were running from Saint Andrews to Dundee?—No.
10,343. How many times did you time it; a dozen times altogether?—I could go as far as a hundred.
10,344. You timed it a hundred times?—Yes.
10,345. I suppose you took out your watch at the one cabin, and put it back in your pocket, and looked at it when you got to the other side?—Yes; I stood with my watch in my hand all ready for it.
10,346. And attended to your duties as driver as well?—Yes.
10,347. Which did you attend to most; the watch or the engine?—I did not look at the watch until I came to the cabin.
10,348. You took your watch out of your pocket and looked at it at one cabin and held it in your hand and looked after your engine, and then looked at it at the other end?—Yes.
10,349. Did you judge by the minutes or by the seconds?—Yes; by the big hands.
10,350. You never felt, as I understand, any motion in the bridge?—No.
10,351. You said that it was the smoothest bit of the road?—Yes.
10,352. Was there less motion on the bridge than on the land?—Yes.
10,353. (The Commissioner.) You stopped in passing the south cabin, I suppose, to pick up the baton?—Yes.
10,354. You slowed down to what speed?—Two miles.
10,355. Did you put on full speed after that?—Yes; when we got the baton we put on steam for a mile, then we put off steam again for the next cabin.
10,356. You did not shut off steam till you had to do it to come up to the next cabin?—No.
10,357. How far from the next cabin did you shut off steam?—About a mile.
10,358. After you had passed through the high girders?—Yes; before we passed through the whole of the high girders we shut off steam, the third or fourth pier from the north side.
10,359. When you came to the steep incline?—Yes.
10,360. You shut it off then, and not till then?—No; we put it on at the south end until we were within 400 or 500 yards of the north end.
10,361. There is an incline before you get to that downwards; you did not shut it off there?—No.
10,362. I suppose you would increase your speed for going down the incline?—We had to put on our hand brake to check the train for the cabin.
10,363. Only for the cabin?—Yes.

The witness withdrew.

Ronald Baxter sworn.
10,364. Are you passenger train engine-driver in the employment of the North British Company?—Yes.
10,365. How long have you been in their employment?—Twenty-eight years.
10,366. Did you drive regularly over the Tay bridge from the time that it was opened to the time it fell?—From the opening till the fall of the bridge.
10,367. On what train were you?—The trains that ran from Dundee to St. Andrews.
10,368. After the Newport branch was opened in May 1879, did you come by it from Dundee to St. Andrews and back?—Yes.
10,369. Before that you went by St. Fort?—Yes, both between Dundee and St. Andrews.
10,370. How long did you go between Dundee and St. Andrews before the Newport branch was opened?—I was not driving then.
10,371. Where were you employed before the Newport branch was opened?—I was in the goods yard as pilot driver.
10,372. How often in the day did you cross the Tay bridge?—About eight times a day in one week, and six times in the other.
10,373. Is that from the time that you were put on the Newport branch?—Yes.
10,374. Seldom before, or not at all. I thought you said that you were travelling on the Tay Bridge from the time it was opened?—No; only from the time that the Newport branch was opened.
10,375. It was eight times a day in one week, and six the other?—Yes.
10,376. What hours of the day did you drive?—One week we ran six times, and ran up to 7.35. I forget now.
10,377. Your trains varied, you interchanged with other drivers?—Yes.
10,378. Were Anderson and Brand driving at the same time?—Yes.
10,379. Were you the three drivers?—There were four and William Coutts.

10,380. Will you tell us at what speed did you cross the bridge?—At from 23 to 24 miles an hour.

10,381. Was that going from south to north and from south to north?—Yes.

10,382. Why do you say it was from 23 to 24 miles an hour?—We considered that the speed ran at the time.

10,383. How long did you take to cross the bridge?—From 6 to 7 minutes.

10,384. Going from south to north and from north to south?—Yes.

10,385. Had you timed it by a watch often?—Not very often.

10,386. Were you going rather quicker through the high girders than at the beginning and end of the bridge?—I do not think so.

10,387. That was the middle of your run?—Yes.

10,388. And would be the quickest?—It would be rather the quickest time.

10,389. Was there much difference?—No.

10,390. Did you ever go either through the high girders, or along any other part of the bridge, at a speed of 40 miles an hour, or anything like it?—No.

10,391. Having been driving for 28 years you know what a speed of 40 miles is?—Yes.

10,392. You know the regulations with regard to slowing at the signal cabins, to get and deliver the staff?—Yes.

10,393. Did you act upon these regulations?—Yes.

10,394. And slowed down?—Yes.

10,395. Did you ever feel any motion of the bridge in crossing?—No.

10,396. Either up and down or from side to side?—No.

10,397. Have you been driving there in all sorts of weather?—Yes.

10,398. Did anything ever happen to make you think that the bridge was unsafe or shaky?—No.

Cross-examined by Mr. Trayner.

10,399. You said that you were driving a pilot engine in the goods yard before?—Yes.

10,400. Were you?—Yes.

10,401. What distance did you need to drive with your pilot engine, in the goods yard, as a rule?—Sometimes we drove longer than others.

10,402. What distance did you go with a pilot engine?—Perhaps not a quarter of a mile sometimes.

10,403. What was the longest distance you drove with that pilot engine?—Half a mile.

10,404. Were you not a driver of a passenger train, before you were put upon the bridge route?—No.

10,405. How long had you been in the service of the company, on a pilot engine, before you were put upon the bridge route?—Perhaps 4 or 5 months.

10,406. Where had you been driving before that?—At St. Margaret’s.

10,407. Where did you drive from?—Generally from Portobello to Fallow Hill.

10,408. What distance is that?—Fifteen miles.

10,409. Was that where you were chiefly occupied as a driver before you come over here?—Yes.

10,410. From Portobello to Fallow Hill is up hill almost the whole way, is it not?—Yes.

10,411. Between Portobello and Fallow Hill you rise something like 800 feet, do you not?—Yes; it is pretty steep.

10,412. Fallow Hill is as high as Arthur’s Seat, is it not?—Yes.

10,413. How did you test the time coming across the bridge?—By my watch.

10,414. How often did you time it by your watch?—I cannot say—I tested two or three times.

10,415. I suppose you looked at your watch when you passed one cabin, and looked at it again when you got to the next cabin?—Yes.
10,449. What is the length of it?—From 200 to 300 yards, I suppose.
10,450. What is it across?—I think the Erne.
10,451.—Have you felt much movement there?—Yes.
10,452. More than upon land?—Yes.
10,453. What kind of motion did you feel upon that bridge?—Up and down.
10,454. Did you feel any motion from side to side?—No.
10,455. You felt nothing of that kind on the Tay Bridge?—No.
10,456. Did you ever come across with a train from Newport to Dundee, leaving Newport at 8.35 in the morning?—No.

Re-examined by Mr. Balfour.

10,457. You told us about driving up to Fallow Hill. Did you drive down from Fallow Hill to St. Margaret's also?—Portobello.
10,458. So that you were accustomed to driving both up and down inclines?—Yes.
10,459. (The Commissioner.) Did you observe any difference in going from cabin to cabin when you went from north to south, or from south to north?—Yes.
10,460. You mean that they were about the same time to you?—Yes.
10,461. Are you sure of that?—Yes.
10,462. Are you quite sure of it?—Yes.
10,463. In going from north to south when you passed the south cabin, you reduced the speed to two miles an hour?—Yes.
10,464. Then you got up steam immediately after you got the baton?—Yes.
10,465. And you kept on the steam until when—until you had passed through the high girders?—Just emerging out of the high girders going south.
10,466. I say, going north, was it that you shut off steam?—At the summit of the hill.
10,467. With respect to the girders, was that when you were in them or when you had passed through them?—Within them.
10,468. How far within; how many spans?—Generally at the summit of the hill.
10,469. Within how many spans did you shut off steam?—I should say about a quarter of a mile.
10,470. That does not give the number of spans?—I could not say.
10,471. You could not say at what span you turned off the steam?—No.
10,472. Did you usually do it at the same span, or at any span when you did it?—I cannot tell you.
10,473. Cannot you tell us where it was?—No.
10,474. (Mr. Brown.) When you passed over those wooden bridges, did you feel a depression as you passed between the pier heads at each time?—Yes.
10,475. Passing along the road on the land outside made with ballast did you sometimes have a bit of bad road?—No.
10,476. You never had a bit of bad road on your line?—No.

The witness withdrew.

WILLIAM COUTTS SWORN.

Examined by Mr. Balfour.

10,477. You are a passenger engine-driver in the North British Railway Company's service?—Yes.
10,478. How long have you been driving engines?—Nine years.
10,479. Have you been running as a passenger engine-driver by the Leuchars, Tayport and St. Andrews route to Dundee?—Yes.
10,480. How long?—Since the bridge opened.
10,481. Was it since the bridge opened or since the Newport line opened?—I was running between Tayport and St. Andrews when the bridge was opened.
10,482. Then you did run between St. Andrews and Dundee by the St. Fort route?—No.
10,483. Then have you only been running between St. Andrews and Dundee since the Newport branch was opened?—Yes.
10,484. Then that is since May 1879?—Yes.
10,485. Did you run until the time that the bridge fell?—Yes.
10,486. Did you take your turn of driving the trains on that route with the previous witnesses, John Anderson, John Brand, and Ronald Baxter?—Yes.
10,487. How often in the day did you pass the bridge?—When I went first, six times each way.
10,488. That is twelve times both ways?—Yes.
10,489. And later?—From six to eight times.
10,490. Do you mean from six to eight times each way?—Three each way when it was six, and four each way when it is eight.
10,491. So that you were first going twelve times, and then from six to eight times?—Yes.
10,492. How long used you to run from cabin to cabin?—From the south to the north five and a half minutes and six minutes.
10,493. Have you timed it with a watch?—Often.
10,494. Did you take more time or the same time coming from north to south?—About the same time, about a minute more may be.
10,495. (The Commissioner.) What was the longest time you took from north to south or from south to north?—Six minutes.
10,496. (Mr. Balfour.) Did you take longer time to go from north to south or from south to north?—From north to south.
10,497. Which way did you take longer to go when you were going from the south to the north or from the north to the south going to Dundee or from Dundee?—From Dundee we took the longer time.
10,498. Was there much difference in the time you took in going?—Half a minute.
10,499. On an average?—Yes.
10,500. Have you any idea as to what speed most of your run was made at across the bridge going from south to north?—About 22 or 24 miles an hour.
10,501. At what part of your run was your speed highest on the bridge?—About the middle of the bridge before we shut off steam.
10,502. At what point did you shut off the steam?—At the top of the summit.
10,503. Did you slow down to the specified speed at the cabins to take and deliver the baton?—Yes.
10,504. About what weight of trains had you coming across?—Ten and eleven carriages.
10,505. And the tank engines?—Yes.
10,506. Did you ever hear any complaint about some people thinking that the speed was too high?—Yes.
10,507. What was that?—Mr. ex-Engineer Robertson complained of it.
10,508. What did he do or say?—He complained about the speed.
10,509. To whom?—Mr. Duncan of East Newport spoke about it to me.
10,510. Who is he?—The station-master there.
10,511. What did he say?—He asked whether I was running beyond my speed across the bridge, and I said no.
10,512. Had you an order in regard to your speed across the bridge?—Yes.
10,513. From whom did you get it?—From Mr. Roberts, the locomotive foreman.
10,514. Did you feel any movement in the bridge?—No.
10,515. Either up or down, or from side to side?—Nothing.
10,516. Had you any doubt about its being safe and sound?—No.
10,517. To the last?—To the last.
Cross-examined by Mr. Balfour.

10,518. Did you ever drive the train that left Newport at 8.55 in the morning?—No.

10,519. What was the order that you got from Mr. Roberts about the speed?—Not to exceed 25 1/2 miles per hour.

10,520. Do you mean the printed order that is in your book?—Yes, and notice stuck up for-by that.

10,521. But after the station-master at Newport spoke to you, or about that time, did Mr. Roberts speak to you himself?—Yes.

10,522. Did he tell you that there had been complaints?—Yes.

10,523. And he warned you to take care that you did not go beyond regulation speed?—Yes.

10,524. Regulation speed was 25 miles an hour?—Yes.

10,525. (Mr. Balfour.) Not exceeding 25 miles an hour, I think?—Not exceeding 25 miles an hour.

10,526. (Mr. Trayner.) You never reached that figure in your driving?—No.

10,527. What is the shortest time you have taken between cabin and cabin?—From south to north do you mean?

10,528. Yes?—Five and a half minutes and six minutes.

(The Commissioner.) They cannot both be the shortest time.

10,529. (Mr. Trayner.) Which of these is the shortest time that you took, five and a half minutes or six minutes?

—Yes.

10,530. Did you never take less than that?—No.

10,531. Was it exactly five minutes and thirty seconds?—Yes, as far as I could remember.

10,532. But as far as you could judge at the time?

—Yes.

10,533. You were looking at the big hand of your watch, I suppose?—Yes, the big hand.

10,534. Not the second hand?—No, not the second hand.

10,535. And you were not crossing the bridge with your watch in your hand, looking at it all the time?—No.

10,536. You had your engine to attend to?—Yes.

10,537. So that you looked at your watch at the one cabin and you looked at your watch at the other cabin?—Yes.

10,538. And as near as you could judge the lowest was five and a half minutes?—Yes.

10,539. What time were you advertised to take to go from West Newport to Dundee?—Ten minutes.

10,540. If you took five and a half minutes between these cabins, could you do the rest of your journey in four and a half minutes?—No.

10,541. Then were you always behind time?—Yes, if I was behind time in leaving Newport, I was the same in Dundee.

10,542. Then did you do it in the 10 minutes or within the 10 minutes?—Yes.

10,543. You left West Newport sometimes exactly at the proper time?—Yes.

10,544. And you reached Dundee sometimes exactly at the proper time?—No, never.

10,545. Then you never did your journey in the advertised time of 10 minutes?—No.

10,546. What was the longest excess of time beyond the advertised time of 10 minutes that you took for that journey from West Newport to Dundee?—Two minutes and two and a half minutes.

10,547. Then you never did the journey under 12 minutes or 12 1/2 minutes?—No.

10,548. Then it could not be done in 10 minutes from West Newport to Dundee at the rate of speed that you took?—No.

10,549. (The Commissioner.) You said in answer to Mr. Balfour that you shut off the steam at the top of the summit; was that in the high girders?—Yes.

10,550. Opposite which of the high girders?—The third or the fourth pier from the north.

10,551. That is what you call the top of the summit?—Yes.

10,552. You did not shut it off until you got to the third or the fourth pier from the north; is that so?—Yes.

10,553. And up to that you had been going at full speed?—Yes, at full speed.

10,554. (Mr. Barlow.) Was the permanent way on the bridge in good running order?—Yes.

10,555. All the way through the bridge?—Yes.

10,556. Was it as good as the permanent way on the land before you came to the bridge in the cuttings and banks?—Yes; I should say so.

10,557. Was it any better?—It might be better after we got on to the bridge.

10,558. Not liable to get out of order by a shower of rain or anything of that sort?—No.

10,559. And it was maintained to its level and gauge always?—Yes.

10,560. And you never had any danger of your train leaving the rails there, I suppose?—No, never.

10,561. You felt no shock or oscillation in passing?—No, never.

(The Commissioner.) You will observe that they only turned off the steam when they were within three or four piers from the north and of the high girders, that is to say, when they came to the steep incline.

10,562. (Mr. Balfour, to the Witness.) You told us where you shut off the steam, just describe where it was that you shut off the steam?—At the top of the summit, I would say.

10,563. How near is it to your coming out of the high girders on the north side?—I could hardly say.

10,564. What made you know that it was at the top of the summit?—I ought to know the top of the summit.

10,565. Do you know when you are needing to pull?—Yes.

10,566. Do you mean that you shut it off whenever you got to the highest place?—Yes.

10,567. Whenever you began to go down did you put on any brake or did the guard?—We put on a brake to draw up at the cabin.

10,568. When did you first put on a brake on the engine?—Just as we came out of the high girders.

10,569. Was that after you shut off the steam?—Yes.

10,570. Then how long did you shut off the steam before you put on the brake?—The brake has never long been applied after we shut off the steam.

10,571. How many girder lengths?—I could not say.

10,572. Just as soon as you could?—Yes.

10,573. Then whenever you ceased to be going uphill did you shut off the steam?—Yes.

(The Commissioner.) And it was three or four girders before you got out of the high girders?—I am not just sure about the spans.

10,574. You said so, and so have all the other witnesses. You see there is a great difference in the inclination. There is an inclination of 1 in 120 before you come to what they call the top of the summit, and an inclination down towards the north 1 in 74 is what they call the top of the summit, that is quite clear from the evidence.

(Mr. Balfour.) It may be so. If there was any doubt we might ask the others when they put on the brake.

(The Commissioner.) I put that question to the others simply with that view, and I found that it was only when the gradient came to 1 in 74, and not before that.

The witness withdrew.
Examined by Mr. BALFOUR.

10,578. Are you locomotive superintendent in the employment of the North British Railway Company?—Locomotive foreman.

10,579. What are your duties?—To see after the engine drivers and the rolling stock, and all the steam machinery in the Dundee district.

10,580. Are you acquainted with the rule relative to the running on the Tay Bridge?—Yes.

10,581. That is about the speed not exceeding 25 miles an hour?—Yes.

10,582. At the time that the bridge was opened was that rule intimated by the general manager?—Yes.

10,583. To whom?—To the traffic superintendent, I think.

10,584. Was it printed and appended to the supplement to the working tables issued to all the drivers and guards?—Yes.

10,585. Can you say that such driver and guard was apprised of that rule?—Each driver was; the guards were not.

10,586. Did you afterwards supply the drivers with slips of this rule?—Before supplying them with the appendix.

10,587. Was the rule also posted up in the engine sheds?—In the engineer's room.

10,588. Do you know that the drivers who had to go along the bridge were quite familiar with the rule?—Yes.

10,589. Had you occasion to go along the bridge at any times?—Yes.

10,590. Did your duties lead you there?—Yes.

10,591. Have you gone both from north to south, and from south to north?—Yes.

10,592. Often?—Often.

10,593. How often?—I could not say; but very often.

10,594. Have you gone both by through trains and by the Newport trains?—Yes.

10,595. At different hours of the day?—Yes.

10,596. Do you recollect Mr. Smith, the station-master at Dundee, mentioning anything about a complaint as to the speed?—Yes.

10,597. What was that?—That Provost Robertson had complained to him about some trains running too fast over the bridge between the high girders.

10,598. Did you do anything in consequence of that?—Yes.

10,599. What did you do?—I spoke to the drivers, and I put up a written notice against it.

10,600. What did you say to the drivers?—I asked them if they had been doing anything over and above the regulation speed.

10,601. What was the result of your inquiry?—I could not find anything.

10,602. Did you repeat the notice in any way?—Yes.

10,603. And you called special attention to it?—Yes.

10,604. What more did you do?—I put up a written notice on my own responsibility.

10,605. Recalling attention to the rule?—Yes, to the locomotive superintendent's notice.

10,606. You have had a good deal to do with locomotives, I suppose, and you know something about speed?—Yes.

10,607. On any of the occasions that you ran over the bridge was the 25 miles an hour speed exceeded in your judgment?—It never struck me that it was.

10,608. Did you ever time it with a watch?—No.

10,609. If it had been materially exceeded, could you have known?—Yes.

10,610. We have been told by various witnesses that the engines on the Newport Branch were tank engines. Is that correct?—Yes.
10,635. Could they get up a 40 miles speed in any part of that bridge?—Yes.

10,636. If they slowed down to two or three or four miles at the ends?—No.

10,637. They would be at the bridge at the other end before the speed was got up?—Yes.

10,638. What speed do you think a big engine with a 7-foot wheel could get up if slowed down on the south side to two or three miles per hour by the time they got to the middle of the girder, and then slowing down again to pass the north cabin at three miles per hour?—It would depend upon the load a great deal.

10,639. Take an ordinary train load?—With eight coaches it would be possible to attain a speed of 26 or 28 miles an hour.

10,640. At the extreme?—At the extreme.

10,641. And with one of those engines got up speed slowly, would that speed be only for a short time?—For a very short distance.

10,642. Whereas a tank engine got up a lesser speed quicker, but cannot attain to the same high speed in the middle?—Quite so.

10,643. Then does it appear to you consistent with possibility that either the tank engines or the through journey engines could get up to a speed of 40 miles per hour upon any part of that bridge if they delivered and took a bolster at each end?—No.

10,644. Nor anything near it?—No.


10,646. What kind of men are they?—Very good men.

10,647. Experienced, careful drivers?—Experienced, careful drivers.

10,648. Have you found them to be men who obey their instructions, and keep their engines in good order?—In very good order.

10,649. They are not the kind of men to over-drive or misuse their engines?—No.

10,650. Examine by Mr. Travenor.

10,651. I believe that one of the purposes of those tank engines is to have an engine that will get up its highest possible power in the shortest possible time?—Yes.

10,652. What was the highest possible speed which a tank engine could attain on a dead level with an ordinary train of seven or eight carriages?—I think 32 miles an hour would be the outside limit on a level.

10,653. And of course it was put to its highest speed, and approaching an incline it would go down that incline at a greater speed than 32 miles an hour?—If it was allowed to do so it would.

10,654. I am assuming that you are taking the most out of the engine that you can get. The increased speed would, of course, depend upon the extent of the declivity?—Yes.

10,655. Both in length and gradient, or incline?—Yes.

10,656. What is the highest speed which you think it possible to attain with a tank engine crossing that bridge from cabin to cabin, coming northward, if it reached the south cabin at a speed of 2 miles an hour according to regulation?—It might attain a speed of 28 miles an hour, or perhaps 30 miles an hour; but the engine would be very badly used if it was driven at that speed.

10,657. But I understand it to be your opinion, from what you know of the engine and from actual observation, that under the conditions given, the engine and train could not possibly attain a higher speed on the bridge than 30 miles an hour?—Thirty miles an hour.

10,658. It would naturally attain its highest speed in the high girders?—Yes.

10,659. At one point in the high girders do you think it would attain its highest speed?—About the eighth span from the north end.

10,660. How far is that south of what you call the summit of the bridge?—Four spans.

10,661. Do you know what is the state of the bridge immediately to the south of the summit; is it level or is there an incline?—There is an incline.

10,662. Which way?—Down.

10,663. Northwards?—Yes.

10,664. The incline there is one in what?—One in 74, I think.

10,665. No; that is when you get on the summit, coming down from the summit of the bridge to Dundee, is it not?—Yes.

10,666. What is the incline immediately before you reach the summit on the south side between the fourth and the eighth spans?—One in 200, I think, but I am not certain.

10,667. (Mr. Travenor.) Coming down that would not the speed of the train still increase until it reached the summit; would put the train coming down that incline still be going as its highest speed until the speed was checked by the brake being put on by shutting off the steam at the top of the summit?—Yes.

10,668. Immediately before you reach the summit approaching from the south side is there a part of the bridge that is level, or is the summit that is the incline of one in 74 approached by the incline of one in 130?—I am not aware of it.

10,669. If a train is going down an incline at its highest speed it will keep its highest speed until it is checked by putting on the brake or by shutting off the steam?—Oh, no.

10,670. If it is going down an incline it will not go slower?—It will not go as fast in some places.

10,671. Why?—Because the brakes might be heated; they might want lubrication and one thing and another.

10,672. Do you think that in any of the inclines on the bridge, considering the shortness of them, anything of that kind would arise, such as heating of the brakes?—No, but they might be heated before they came there.

10,673. But I am assuming that the engine is all in good order, and that there is no heat about the brakes when it leaves the south cabin, what I am anxious to get at, if you can help me to it, is the point at which the highest speed was attainable in the bridge if it was not checked, and I assume that it would be checked, and that it would be checked at the summit. Between the south cabin and the summit, at what point would the train attain its highest speed?—Immediately before coming to the summit.

10,674. These engines you said would soon show by their condition whether they had been ill-used?—Yes.

10,675. But is it the case that in the case, of an occasional use of the engine at a high speed, the highest speed that it could reach would not show in the way you have described?—It might not.

10,676. Your answer referred to the habitual use of the engine at its highest speed?—Yes.

Re-examined by Mr. Balfour.

10,677. There is a very sharp curve, is there not, coming round from Newport to the Tay bridge?—Yes.

10,678. Have such sharp curves as that any effect in wearing the brakes of the journals of the carriages?—Yes.

10,679. What effect has that?—To wear them shorter.
10,680. Would the wearing short of the traverses of the journal have any effect in the movement of the carriages?—Yes.

10,681. What effect would that be?—To cause them to oscillate.

10,682. So that anything within them would feel a side to side movement?—Yes.

10,683. When the journal was shortened there would be an interval left, so that there would be lateral play?—Yes.

10,684. Do you know that in point of fact there was such shortening of the traverses of the journals of the carriages which came round there?—Yes.

10,685. How do you know that?—Because I have had to send carriages to the shop for that purpose, and I have had letters from the locomotive superintendent, calling my attention to such coaches running that way.

10,686. You had, in short, to renew the traverses of carriages running in that way?—Yes.

10,687. There would be a side to side motion of that kind in such carriages when they had worn down?—Yes.

10,688. Do you think that was a movement which a person not very familiar with the matter might mistake for the oscillation of the bridge?—Yes.

10,689. Do you think any one could very well tell when in a carriage what the side to side movement was due to, unless he was skilled in the matter, or even then?—No. A skilled person could toll.

10,690. In your experience of the bridge was their either up and down or lateral motion?—I felt nothing in the train.

10,691. Have you been on the bridge when trains were passing?—Yes.

10,692. Have you felt any movement then?—Yes, I have felt a slight vibration.

10,693. Have you been on other iron bridges when trains passed?—Yes.

10,694. Was there anything that struck you as remarkable or unusual in the vibration that you felt on the Tay Bridge?—Nothing.

10,695. Was there anything to give you the least idea of insecurity?—No.

Further cross-examined by Mr. Traill.

10,696. When did you make your observation of these vibrations? was it near the time of the opening of the bridge?—No.

10,697. Did you make any observation as to the vibration near the time when the bridge opened?—No.

10,698. The first time you chanced to observe it was then?—My attention was called to it by Mr. Montgomery, the locomotive foreman at Perth.

10,699. Did he call your attention to the fact that there was vibration?—He said, I feel the train coming; it makes a little.

10,700. And you felt that it did shake a little?—Yes.

10,701. Was that long before it fell?—Yes, last summer some time.

10,702. Did you observe it after that time, or did you just make the one observation?—I had felt it several times.

10,703. You made some observation after that, because Mr. Montgomery's suggestion was the occasion of your first observation?—Yes, just so.

10,704. Did you notice whether the vibration on any later occasion was greater than the vibration noticed on the first occasion?—I did not notice.

10,705. You could not say yes, or no?—No.

10,706. (The Commissioner.) In order to make it quite clear what you meant, I will ask you this—you said, I do not think that it is possible to get the speed up to 40 miles an hour with an engine with wheels like that?—Yes.

10,707. You mean upon a level?—On a level.

10,708. You do not mean down an incline?—Not down an incline.

10,709. Down an incline you might get any speed out of it, almost, might you not?—You could get a greater speed out of it.

10,710. Then when you said 40 miles an hour you meant on a level I suppose?—Yes.

10,711. Then if the steam was not shut off until they got down the incline, I suppose the speed would be considerably increased beyond what it was upon the level?—Yes.

10,712. And if there was an incline downwards before you got to the summit that speed would be increased considerably before you got to what you call the summit, that is to say, the fourth pier, would it not?—Yes.

10,713. If there was an incline downwards before you get to what you call the summit, the speed would be considerably increased over what it had been at the level?—Yes.

10,714. (Colonel Yolland.) Do you know where about the summit is, is it not about the fourth or fifth span from the south end of the broken down part of the bridge?—No, I think it is between the third and fourth piers, or about the fourth pier from the north end.

10,715. Do you descend a portion of the bridge coming from the south in order to reach what you call the summit?—No, I think you would be going up all the time to what I call the summit.

10,716. (The Commissioner.) Then that is not in accordance with the plans that have been laid before us, that there is a decline before you reach what is called the summit.

10,717. (Mr. Bartlow.) The real summit is at the next pier. That is all the difference. (To the Witness.) Did you ever walk across the bridge?—I did.

10,718. And if there was an incline afterwards you did not call the summit, the speed would be considerably increased over what it had been at the level?—Yes.

10,719. (Mr. Bartlow.) The real summit is at the next pier. That is all the difference. (To the Witness.) Did you ever walk across the bridge?—I did.

10,720. Where?—On the Bathwell and Hamilton line and the City Union line in Glasgow.

10,721. Did you ever walk across a large bridge?—Yes.

10,722. Did you feel the vibration of that bridge when a train passed?—Yes.

10,723. Did you feel the vibration of this bridge when a train passed?—Yes.

10,724. Was there any difference?—There was more vibration I think than on this one.

10,725. (The Commissioner.) Let there be no misunderstanding about this, what you call the summit is the fourth pier from the north end?—Yes.

10,726. And you are not aware how the incline is southward of it, but you think it goes up?—I think it goes up.

The witness withdrew.

(Mr. Balfour.) We propose to tender also one or two guards to speak as to the speed.

WILLIAM DUNGAN sworn.

Examined by Mr. Balfour.

10,727. Are you a passenger guard in the North British Railway Company's service?—Yes.

10,728. Were you guard of the trains running from St. Andrews to Dundee over the Tay Bridge?—Yes.
10,731. Not on those driven by others.—No.
10,732. Did you ever take notice of the time that the train occupied in crossing from south to north, between the cabins on the bridge?—Yes.
10,733. Often?—About eight or ten times.
10,734. What did you take the time with?—My watch.
10,735. Is there a watch supplied by the Railway Company?—Yes.
10,736. For observing times?—For taking times between stations only.
10,737. Would you just tell us what was the result of your observation from south to north?—The shortest time that ever I took was, I would say, about eight or ten seconds within the five minutes.
10,738. And was what the longest?—I do not mind exactly, but it would be about six minutes, I would say, or perhaps over that.
10,739. Varying from under five to six minutes?—Only once under five minutes.
10,740. What was the average?—I would say nearly six minutes.
10,741. On the other occasion, when you did not time it with a watch, did it appear to be about the same speed?—Yes.
10,742. Were you aware of the rule that the speed should not exceed 25 miles an hour on the bridge?—Yes.
10,743. Did you think that rule was kept, or not?—Yes, I thought it was kept.
10,744. Were you ever travelling at a rate of anything like 30 miles an hour on any part of the bridge?—I have never thought so.
10,745. I suppose you know what a 40-mile speed is?—Yes.
10,746. And if you had been travelling at a rate of 40 miles an hour at any part, would you have noticed it?—I think so.
10,747. At what part of the bridge did you attain the highest speed?—About the centre of the high girders.
10,748. Can you tell us at what part of the high girders the drivers that you were with shut off the steam?—About the centre of the high girders.
10,749. Did the drivers put on any brake?—Not immediately when they shut off steam, but shortly after it.
10,750. Did you as guard put on any brake?—Yes.
10,751. Where?—To the south of the distance signal coming north.
10,752. But not till then?—Not till then.
10,753. Then you were quite out of the high girders by that time?—Yes.
10,754. Then was the order of the three things—first the shutting off of the steam about the middle of the high girders, then the braking by the driver, and then the braking by you near the distance signal?—Yes, outside the distance signal.
10,755. Was the highest speed attained before the steam was shut off or afterwards?—Before the steam was shut off, I consider.

10,756. From the time the steam was shut off was the speed getting slower?—Yes.
10,757. Did there appear to be any danger to you in crossing the bridge as you did?—No.
10,758. In any respect?—In no respect.
10,759. You were not sensible of anything that led you to think that it was wrong in any way?—Nothing.

Cross-examined by Mr. Traill.

10,760. Where you at your highest speed just at the time when the driver began to shut off the steam?—I always considered so.
10,761. What led you to time the trains?—Through Mr. Smith, the station-master, making a remark to me about a party complaining of their having run too quick across.
10,762. And how often did you do it?—Eight or ten times, I believe.
10,763. Has your watch a sound clid?—No.
10,764. Let me see it?—The witness withdrew.

(The witness showed his watch to the learned Counsel.)

10,765. It is a large dial, and the seconds are well and distinctly marked on it round the dial. You took your time from cabin to cabin, I suppose?—Yes.
10,766. Did you keep your watch in your hand all the time?—Yes.
10,767. Did you ever travel at a rate of 10,768. Is your answer, that you took from five to ten times?—Yes, I thought it was kept.
10,769. And when you had been travelling at a rate of 10,770. What did you take the time with?—My watch.
10,771. You were not advised of any signal by the driver?—Yes.
10,772. When the Tay Bridge was opened did you see any sparks flying out of your wheels?—No, except when I applied the brake.
10,773. If the brake was applied you had sparks, but not without?—No, not without.
10,774. (The Commissioner.) Did you see those sparks at night when the engine-driver applied the brake?—Yes.
10,775. From the van you saw them coming from the engine?—Yes.

The witness withdrew.

ALEXANDER RAMSEY sworn.

Examined by Mr. Balfour.

10,780. You are a railway guard I believe?—Yes.
10,781. And you have been so for 27 years?—Yes.
10,782. And for 22 years of that time you have been on the Leuchars and St. Andrews line?—Yes.
10,783. When the Tay Bridge was opened did you begin to run from St. Andrews to Dundee?—Yes.
10,784. And when the Newport branch was opened did you begin to run between those places by way of Newport?—Yes.
10,785. Did you take you turn in bringing the first two trains from St. Andrews to Dundee in the morning?—Yes.
10,786. Those being the ones that leave Newport at 7 o'clock and at 8.35 in the morning?—Yes.
10,787. And you took your turn with the other trains in the same way, I suppose?—Yes.
10,788. How many times a day did you pass the Tay Bridge?—The greatest number of times was four, two each way.
10,789. What drivers did you go with?—Brand and Anderson; generally Anderson.
10,790. Did anything strike you about the speed at which they passed the bridge?—Nothing unusual.
10,791. Were you aware of the rule that it should not exceed 25 miles an hour?—Yes.
10,792. Did it appear to you that that speed was exceeded or not?—Not in the least.
10,793. If it had appeared to you that it was exceeded would you have done anything?—I would have applied the brake to keep them back.
10,794. Or called attention to it, or spoken about it?—Yes.
10,795. Having been a guard for so long a time I suppose you have some idea what a 40 mile an hour speed is?—Yes.
10,796. Have you ever run along any part of the bridge at 40 miles an hour?—No.
10,797. Or anything the least like it?—Nothing like it.
10,798. Did you ever time your run from cabin to cabin?—No, I never did.
10,799. Have you any idea as to what the time would be between cabin and cabin?—With regard to that I could not say.
10,800. But you know what a 25 mile an hour speed is, and you do not think it was exceeded?—No.
10,801. If it was exceeded at all, must it have been only slightly?—Yes, only slightly.
10,802. At what part of the run along the bridge was the speed highest?—Well, I should think it was after they left the summit of the centre of the bridge.
10,803. The summit of the centre?—Yes.
10,804. Could you define that place by the girders; where about was it in the high girders?—It was from the centre of the high girders that I looked at the speed of the train.
10,805. What do you call the summit?—It is just as you enter the rise of the centre of the bridge.
(The Commissioner.) By the centre of the bridge does he mean the high girders?
10,806. (Mr. Balfour.) Do you know the number of span that there were on the high girders?—Yes.
10,807. At what part of the high girders do you count the summit to be; how many from the south end or the north end?—About four or five spans from the north end.
10,808. (The Commissioner.) Do you know it positively?—I never saw it any further than when I was passing over in the train.
10,809. Can you tell us at what part of the bridge the driver shut off his steam usually?—At the highest part of the bridge.
10,810. And where was that?—Just as he entered over the highest part of the bridge.
10,811. Within the high girders?—Within the high girders.
10,812. How many girders from the south end of the high girders do you think?—About eight.
10,813. (The Commissioner.) About eight from south and about four from the north; is that what you say?—Yes.
10,814. (Mr. Balfour.) When the driver shut off his steam what did he do next; did he put on a brake?—I expect so.
10,815. You put on a brake I believe, did you not, afterwards?—Yes.
10,816. At what point?—Just as we were coming out of the high girders.
(The Commissioner.) Is that where the distant post is?
(Mr. Balfour.) No, I think it is further north.
(To the Witness.) Where was the distant signal?—It was about from 400 to 600 yards outside the high girders.
10,817. You put it on just as you were coming out of the high girders?—Yes.
10,818. Was there ever anything in your experience of the bridge that suggested to you any doubt of its safety or stability?—Nothing.
10,819. You knew the rule which required that you should slow down at the cabins at each end to take and receive the bonus?—Yes.
10,820. Was that rule observed?—Yes.
10,821. Carefully?—Carefully.
10,822. To what speed did you slow down?—Down to two miles an hour.
Mr. Trayer stated that he had no questions to put to this witness.

The witness withdrew.

(Mr. Balfour.) I do not know whether this is a kind of evidence which it will be useful to tender any more of. These men have been official on the Newport trains, with reference to which the chief complaint was made. I do not know that they would add very much to the knowledge that we already possess.

(The Commissioner.) I do not think you could add very much to the knowledge by calling more witnesses of the same class, assuming that they would speak pretty nearly in the same way.

(Mr. Balfour.) The other witnesses would be through drivers against whom there has been no suggestion of overspeed. I think that is probably all the evidence which at this stage bears upon the evidence which the Board of Trade have tendered. Of course, as I explained the other day, Mr. Grothe, and Mr. Delpratt, and Mr. Reeves are abroad, and we have had no access to them.

(The Commissioner.) And not only that, but their evidence would chiefly go to the stability of the bridge.

(Mr. Balfour.) Of course if there be any other branches of the inquiry opened up by the Board of Trade upon which the Court would desire information, it would be open to us to tender it.

(The Commissioner.) We will give you an opportunity of producing any evidence you think fit. May I ask, Mr. Trayer, if you have any further witnesses?

(Mr. Trayer.) Yes, sir; I propose, in consequence of information I have obtained since I closed my case, to examine one or two other witnesses, but they will be very short.

(The Commissioner.) Colonel Yolland suggests to me that it would be advisable if you, Mr. Balfour, would kindly put in the printed working time-table for the month of December—Could you give us each a copy?

(Mr. Balfour.) Certainly, that shall be done. I am afraid we have not them here to-day, but they shall be supplied.

(Colonel Yolland.) Have the Company any specific knowledge as to whether the engine which is lying in the Tay at the present time has its motion reversed or direct, and whether the regulator is open or shut?

(Mr. Balfour.) I will inquire into that certainly, and that information shall be obtained.

(Colonel Yolland.) I have seen the statements on the subject, and that makes no ask the question.

(Mr. Balfour.) Perhaps the best way will be for Mr. Drummond to go into the box, and explain what he knows about it?

(Mr. Drummond.) We have got no information in our hands about it. I sent the diver down and he found the inside of the cab that is next the front of the boiler entirely blocked up with coal, so that he could give us no information upon that point; but that we will ascertain.
Alexander Milne sworn.

Examined by Mr. Trayner.

10,854. And after you put in the Beaumont egg you did rub it with a stone, I suppose, to make it look like metal?—Yes.

10,855. Did you see any columns of that kind that passed from you filled up in that way after they came out of the turner’s shop?—I never paid any attention to that. I put them into the lathe and took them out, but I never looked to see where they went.

10,856. But did some of the columns that you filled up in that way go on to the lathe and come out of the turner’s shop to be laid down?—Yes.

10,857. And they were not checked by the turner? They were not checked by the turner.

10,858. After they left the turner’s shop what was done with them, do you know?—Nothing. I have seen them go into the lathe quite whole apparently and honeycombed after they were taken out.

10,859. What was done with those?—The honeycombed holes were generally filled up with that same combustible, Beaumont egg.

10,860. After the turners had had them?—Yes.

10,861. And laid down with the others to go to the bridge?—Yes.

10,862. Were they painted before they went away?—There was white lead and green melted and put on them to keep them from rusting.

10,863. But was there any paint along the columns?—Yes, they were all painted when they left the turners.

10,864. And before they went to the bridge?—Yes.

10,865. What was this Beaumont egg made of?—It is composed of beeswax, fiddler’s rosin, and the finest iron borings melted up, and a little lamp black.

10,866. Is it when used a kind of paste, or is it fluid?—It is quite hard, and it will break like metal.

10,867. How do you put it in?—You take a rod, bar and melt it in.

10,868. And then it hardens like metal?—It sets again like metal.

10,869. Where did you get this Beaumont egg?—From the foreman moulder.

10,870. Who was he?—Fergus Ferguson.

10,871. Did he give you the stuff?—Yes, when I asked for it.

10,872. Did he know for what it was to be used?—Certainly.

10,873. Did you see any holes filled with cement?—No, not in the columns.

10,874. In the lugs?—No.

10,875. Were the holes that you have told me about that were filled up with Beaumont egg both in the columns and in the lugs?—Yes, both in the body of the columns and in the lugs.

(\textit{The Commissioner.}) By cement you meant Portland cement, I suppose?

10,876. (\textit{Mr. Trayner.}) No, sir, it was Roman cement, but he did not know anything about it. (\textit{To the witness}) Where was the Beaumont egg kept?—In a little office that Ferguson had, the foreman’s office.

10,877. Did you apply to him when you wanted it?—Yes.

10,878. Did he ever give it to you?—Yes.

10,879. More than once?—Two or three times; more so at the finish up of the foundry; there was a great number of burns and one thing or another put up that way. There were a great many columns that were damaged on the outside with lugs knocked off, and they got lugs burned on, and where there was any part of the burn that did not melt together we just gave it a fill up with that.

10,880. At what part of the burning did you most generally find the defect that you had to fill up with Beaumont egg?—Near the body of the column at the tail of the lug.

10,881. Was there any crack observable?—It was always cracked on the solid metal, not the burn; below the burning generally, out round the flange.
10,864. Cracks of that kind were filled up with Beaumont egg?—Yes, they were filled up with Beaumont egg and pinned together with the hammer for they were not visible.

10,885. So as to prevent the crack being seen?—Yes.

10,886. After some of the lugs were burnt on near the end of the work at the foundry, had you anything to do with the chipping of them?—I chipped them all.

10,887. Was that for?—Because when it is burnt there is always an inch and a half left more than is required on the burn and that has to be chipped off or cut off to the shape of the lug.

10,888. Did you chip a good many of these burns near the end of the work?—Six of them, I think, in the inside of two days.

10,889. What kind of hammer did you use for that?—A chipping hammer.

10,890. Had you to do that carefully?—Very carefully.

10,891. Why, were you afraid of anything?—Driving it away.

10,892. Knocking off the burn?—Yes.

10,893. Was that work done within the knowledge of Mr. Ferguson?—Yes.

Cross-examined by Mr. BALFOUR.

10,894. You say that you were two years and a half working at the Worrant Foundry?—Yes.

10,895. Can you give us about the year you began and the year you ended, or the month?—I went to the Tay bridge in Strachan's time, but when he was dismissed from the bridge the men were all paid away from the foundry, and I was put to the jetty to work in the smithy.

10,896. Why were you paid away from the foundry?—Because when that man went away seven or eight were put away with him for bonus.

10,897. Were you not told why you were not to wait?—That there was no work for me till they got a new foreman.

10,898. Did you go back to the foundry?—Yes, when Ferguson started with the men there again.

10,899. How long had you worked under Strachan altogether, a week?—Yes, about.

10,900. Except the week, the rest of the time was under Ferguson?—Yes.

10,901. Was Mr. Beattie the engineer there during the whole or part of your time?—All my time. No man was there there, I suppose, for about seven or eight months before I left.

10,902. For nearly two years Mr. Beattie was in charge?—Yes.

10,903. And Mr. Campbaxis for the rest of the time?—Yes.

10,904. Did Mr. Beattie take the chief charge of the foundry for the last part of the time and Mr. Campbaxis after?—Yes.

10,905. Was Mr. Beattie often coming about the foundry?—Yes, he came generally twice or three times a day.

10,906. Did he usually come at the time you were making the castings?—Very often he did if there was anything uncommon: break or anything of that kind being done.

10,907. Did you ever see him looking over the work that you turned out?—Yes.

10,908. Did the always do that?—Generally, I was working on one column that did not please him, and he told the foreman to send me back to it.

10,909. Did Mr. Beattie make a practice of looking over every column that was turned out by the moulders?—I did not see that.

10,910. Did you not see him looking over every one?—No.

10,911. But you saw him looking over some?—Yes.

10,912. Where were the columns turned out of the moulding shop; where were they put?—About five yards from the wall; they were all dressed outside.

10,913. Were you most of the time working as a moulder or dresser?—I was a dresser.

10,914. You were never a moulder at all?—No.

10,915. Did Mr. Beattie often look at the work that was going on when you were dressing?—Yes.

10,916. Did you see him looking over the columns?—Yes.

10,917. Was he particular to see whether they were all right?—I suppose he was more particular about that.

10,918. Was he particular in his examination?—Yes.

10,919. They were taken next to the turning shop?—Yes.

10,920. Where was that?—Just in the moulding shop.

10,921. Have you seen Mr. Beattie looking at them in the turning shop?—Not except there was some flaw.

10,922. I think you said that in the turning sometimes a honeycomb which had not been seen before was made apparent?—Yes.

10,923. Was that when it was all turned out?—May be one cut or two cuts off it, it was seen.

10,924. Who was the head turner then?—George Fender.

10,925. You said, I think, that you had seen some honeycomb turned and made to appear?—Yes.

10,926. Had you anything to do with the columns after they left the turning shop?—No; only before Mr. Ferguson told us to fill up those honeycomb holes.

10,927. Unless you were told to do so you had nothing whatever to do with them?—No.

10,928. Did you ever see any columns broken up?—A great deal.

10,929. How many?—I believe upwards of 40.

10,930. What were they broken up for?—Being past mending I thought.

10,931. For defects?—Yes.

10,932. Who gave the orders to break them up?—Mr. Ferguson.

10,933. Did Mr. Beattie ever give any orders to break them up?—Not that I know of.

10,934. You did not hear that?—No.

10,935. You do not know, I suppose, whether any were broken up after they had gone away from the turning?—There were never any broken up after.

10,936. Were all those that you know of broken up before going to the turners?—Yes, they never went to the turners.

10,937. If they were very bad, they were never sent to the turning shop at all?—No.

10,938. Whether any were broken up after they had passed through the hands of the turners you cannot tell?—No.

10,939. Were the ones that you know of as being broken up, broken up before going to the dressers?—After they were dressed, not for the turners, they were broken up.

10,940. And those are the only ones that you know of?—Yes.

10,941. You told us about the stuff called Beaumont egg?—Yes.

10,942. You say Mr. Ferguson gave you the Beaumont egg?—Yes.

10,943. Was it kept regularly for use?—As far as I know, I think that all the men were in the habit of making it regularly.

10,944. Who were they?—A man named Tasker and a man of the name of Tuttle that was called here before you.
10,945. Peter Tuite; who else?—Those are the only two that I know of who ever made it.
10,946. Did they make it themselves or did anybody give it to them?—Tasker got money from Mr. Ferguson to go to Westport to buy the materials.
10,947. Was all the Beaumont egg that was used in your time made under the direction of Mr. Ferguson?—I do not say, it was generally used by his directions.
10,948. He knew about it?—Yes.
10,949. Who else knew it?—I do not know of any one else.
10,950. Did Mr. Beattie know about it?—I cannot say, I never saw him look at it.
10,951. Did you intend him to know it?—I never kept it in any secret way from him.
10,952. Was it intended that it should be known or hidden?—It was more like hidden. We were ordered to throw a cloth over the bad part at such time as they would go by.
10,953. Who told you to do that?—Mr. Ferguson.
10,954. You put a cloth over the bad part to hide it from whom?—I suppose Mr. Beattie or some of the head engineers, Mr. Beattie or Mr. Ramsay.
10,955. It was intended to be done secretly from them?—Apparently to me it was.
10,956. Did Mr. Beattie ever find out at any time when you were there that Beaumont egg had been used?—I never noticed that, I never seen it.
10,957. Were any of the men dismissed for having found it when you were there?—Yes.
10,958. Did you think it was right to use it?—I did not think it was right.
10,959. Did you think it was wrong?—Quite wrong.
10,960. Why did you think so?—Because I had occasion to do it, I was paid for doing what my overseer told me to do; I had nothing to do with it; I could not interfere with it.
10,961. If you thought that it was wrong, why did you do it?—It was wrong this far, if they were paying for a sound article and were not getting it.
10,962. Was not it very wrong to give what you thought was not a sound article if a sound one was being paid for?—I had no business with that. If I could have been here, I should have had to leave the ground.
10,963. Why?—Because I should have been dismissed, I suppose.
10,964. Would Mr. Beattie have dismissed you for refusing to use "beaumontag"?—I do not know that.
10,965. Do you not think it was very wrong to do that now, looking back?—All the pieces of beaumontag that were put into the small holes were neither here nor there.
10,966. You did not think that any of the holes that you filled up could have endangered the columns?—No, not much.
10,967. Would it have endangered them anything?—Not much.
10,968. If you had thought that it might bring down the bridge, would you have done it?—No.
10,969. You did not think it would endanger the bridge?—I did not think it would fetch it down.
10,970. Or endanger the lives of any one passing over it?—No.
10,971. Do you think now that any of the holes that you filled in endangered the bridge?—It was just a little hole or little flaw; there were no big holes.
10,972. There was nothing that you thought important?—No.
10,973. If you had thought that it was important would you have done it?—Possibly I might.
10,974. Endangering people's lives and turning out dishonest work?—I was not looking at that. There were men far above me who had to look at that.
10,975. Who were they?—The great engineers, Mr. Beattie and others.
10,976. Did you hide it from them?—No; I had no business to hide it.
10,977. Did you intend them to know it?—No.
10,978. Then did you intend that they should not know it?—I never hid it from any one.
10,979. What do you say about the cloth that was thrown over?—I generally saw it; whoever was working at that column did that.
10,980. But who threw the cloth over?—The man who was there working at that flaw, or anything else.
10,981. Did you ever do it?—I do not think I did; I was not so long at the dressing.
10,982. Would you not have done such a thing?—If I had thought it was any matter I might have done it.
10,983. But not if it was not important?—No; when we saw any flaw we always went for Mr. Ferguson to see it.
10,984. Did the others do the same?—Yes.
10,985. What was the name of any man who hid it with a cloth or a brush?—I cannot mention the name. There were many people there at the time I was there; I believe Peter Tuite; I should call him to see it.
10,986. Did you think he was doing a right thing in hiding it?—I could not say that.
10,987. If it was wrong why did you not tell your superiors about it?—Who?
10,988. Mr. Beattie or whoever was in charge?—I never spoke to Mr. Beattie.
10,989. Or Mr. Ferguson; did you never speak to him?—I often spoke to him.
10,990. Did he know that things were hidden in that way?—None were hidden from him.
10,991. Did he know that they were hidden from others?—I suppose he would if he saw a very bad flaw in a column pointed out by the man that dressed it.
10,992. Was it the bad flaws or the little flaws that were hidden?—None were hidden from him.
10,993. Was it the bad flaws or the little flaws that you saw the cloth thrown over?—Any of them that were there; blown snugs.
10,994. Only little ones?—No.
10,995. If it was a big one it was cooled and broken off?—Certainly.
10,996. Without being filled up with the Beaumont egg at all?—Yes, without being filled up with the Beaumont egg at all.
10,997. Was the biggest flaw that you have seen filled up as you describe about half an inch in size?—Yes.
10,998. Just one question about this Beaumont egg; you say that it is composed of iron borings?—Borings dust.
10,999. Dust from the metal of the shops, which is very hard?—It is quite hard and brittle after being made up.
11,000. Would it melt in the sun?—No.
11,001. There is resin in it, is there not?—Yes.
11,002. But there is so much metal dust that it would not melt in the sun?—No.
11,003. Is there any way in which it could be found out; could you find it out by pricking it with a knife?—Yes.
11,004. It could be found out with a knife?—If the casting was cleared of the paint, I believe it could be pricked out.
11,005. If you looked carefully along it, could you see it before it was painted?—Yes.
11,006. Could anyone, looking at it carefully, see it?—Yes, anyone that knew the nature of it.
11,007. Did the turners know of it?—Yes, they saw it often done.
11,008. The turners might have seen it?—Yes, I think so.
11,009. George Fender, for instance?—Yes.
11,010. Were there any others?—There was William Stewart on the next shift.
11,011. George Fender and William Stewart, the turners, would see it as well as Ferguson?—Yes.
11,012. Did they ever make any remark about it? —Yes.

11,013. What remark did they make? —I have heard them say that it was not right in any column to put Beaumont egg into it. Did you believe them when they said it was not right? —I had no occasion to dispute them. 11,015. Did they forbid you to do it? —No.

11,016. Did you continue to do it after Fender and Stewart said that it was not right? —I never did it unless I was told to do it.

11,017. By Ferguson or anybody else? —Yes.

11,018. Did you do it after Fender and Stewart said it was not right? —I was there on the night shift, and that was the time he spoke about it.

11,019. Did you ever put in Beaumont egg after Fender and Stewart said that it was not right? —No. I do not think anything of that kind was doing then, because the melting shop was about finished then.

11,020. Did Fender and Stewart only find it out when the shop was shutting up? —I cannot say.

11,021. When did you first hear them speak of it? —I think a bit fell out. I think it had been chipped and fell out. I was there then, and I told them what the stuff was.

11,022. They did not know of it until you told them? —No, I do not think they did.

11,023. Was it new to them? —I do not know.

11,024. Does it come to this, then, that Fender and Stewart only found it out when the foundry was going to be shut up? —I cannot say; they might have known what Beaumont egg was before.

11,025. Did they not know sooner that you had been putting it into the holes? —Not to my knowledge.

11,026. Did they speak of it as a thing that you could find out very simply? —It seemed to me that they did.

11,027. You had an opportunity of seeing it before they did; when the columns went to be turned you had been doing it long before they found it out, had you not? —I cannot say. I had to see that my column was right, if there was anything wrong with it, it was different.

11,028. How long had you been using Beaumont egg before Fender and Stewart found it out? —I cannot say.

11,029. Had you, say, six months? —Yes, six months. Beaumont egg was used six months to my knowledge.

11,030. More than that? —Yes.

11,031. Would you say a year? —No, I cannot say a year.

11,032. Was the only Beaumont egg that you knew about used within the last year? —Yes, within the last year that I was there.

11,033. None was used sooner? —Not that I know of.

11,034. Had you been there 18 months before any Beaumont egg was used, had you not? —Yes, to my knowledge.

11,035. Had none of the castings of the parts that you turned out in the first 18 months of your time had it put into them? —I have never seen it or heard of it.

11,036. Who made it at that particular time? —I cannot say. There was one who had a sort of charge of us, John Tashler, and it was him that used to make it.

11,037. Was it his idea? —I do not know.

11,038. But you had never heard of it before that? —I was not in the foundry before that to know what it was.

11,039. You had been working there 18 months before it was used to your knowledge? —Yes.

11,040. For how long had you been using it before George Fender spoke about it, or Stewart? —I suppose it was about six or seven months, as near as I can say.

11,041. Did you use it after they had spoken about it? —I never had any business to do it.

11,042. Then all the using of it that you knew about was in the last six or seven months that you were at the foundry? —Yes.

11,043. If it had been used before, would you have known it? —Possibly I might have seen it.

11,044. Would you not have seen it when going over the columns as a dresser? —There was no Beaumont egg put into the columns before you dressed them; it was always afterwards.

11,045. You would have known if it had been done, would you not? —Yes; if I had seen it, I should have known it.

11,046. You said something about a chaplet-hole, I think, that had been filled up with Beaumont egg, and out of which it fell? —It appeared as if it was a chaplet-hole.

11,047. Were they using chaplets in the castings at that time? —No.

11,048. Then how could it be a chaplet-hole, if they were not using chaplets? —I cannot say when the column was cast.

11,049. Were they ever using chaplets in the last two years at all? —I have never seen them used, but I have seen them there when they were not used. They have used them; I saw that.

11,050. Had they used any chaplets in moulding during the time that you were there? —No.

11,051. Did you think it was a chaplet-hole? —It appeared to me to be so.

11,052. What was the size of it? —It was about a half-inch hole.

11,053. Each way? —Yes.

11,054. Where had that column come from? —I cannot say.

11,055. Whether it had been cast before they had been using chaplets, you do not know?

Re-examined by Mr. Trayner.

11,056. You have given us the size of the hole that you filled up; will you tell me, if you can, what was the extent of the crack that you filled up with Beaumont egg between the lug and the flange? —It would be nothing but a sixteenth part into the thickest part leading away to nothing.

11,057. (The Commissioner.) I believe you painted the columns after they had been in the hands of the turners? —Yes, generally I did.

11,058. Did you ever paint any in which you had put Beaumont egg? —I believe I have, but I had not paid attention to that. I painted them all latterly at the finish.

11,059. After they were painted, could this Beaumont egg have been detected at all or seen? —If the column got a sudden shake it would fall out; without that it would not be seen, or not very easily seen, by any one looking over it.

The witness withdrew.

Peter Tutle sworn.

Examined by Mr. Trayner.

11,060. Were you at Wormit Foundry? —Yes.

11,061. How long were you there? —Between three and four years.

11,062. Were you there in Strachan's time, when he was foreman? —Yes.

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11,063. And afterwards when Ferguson was foreman? —Yes.

11,064. Were you there down to the end of the work? —Yes.

11,065. What was your business? —I was dressing for about two years and a half. I was at the furnace casting metal till they finished.

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11,065. Melting at the cupola?—Yes.
11,067. Was it during the last 18 months of your employment that you were at the cupola?—Yes.
11,068. When you were a dresser did you see any columns, or did you dress any columns or lugs that had holes in them?—Some.
11,069. Many?—Not very many.
11,070. How many do you think?—I suppose several hundred of columns. There was generally a kind of blown hole in the columns. I have been 16 years about furnaces, and I have seen them generally sometimes.
11,071. At Wormit it was just an odd column or lug that had a hole in it?—It was very seldom that I saw anything of the kind.
11,072. What was the size of the biggest?—You could get the shank of a pipe into some of them, and some were a little larger than that.
11,073. At that end of the lug (pointing to a specimen)?—Just at the top of it.
11,074. Between the lug and the column?—In the top of the pocket itself.
11,075. Was that the biggest you ever saw to let in the shank of a pipe?—Yes, in the pockets. If they were thicker than that, they were taken round and broken off.
11,076. What was done with those holes in the pockets or lugs?—If they were not blown mucn, they were chipped off; the burning put upon it had shifted in the hole.
11,077. In the case of those in which a hole that would admit of a pipe shank, were any of those filled up?—Yes, there might be a bit of putty stuck in, if it was not deep enough—if it was not deep enough, we filled it up.
11,078. What depth of hole did you fill with putty?—Very nearly a quarter of an inch.
11,079. Did you ever see any cracks between the burnt on bit and the lug after the new but was burnt on?—Yes, I did a little.
11,080. Of what size?—It may have been half an inch or the like of that sunk down.
11,081. Did you see a crack between the flange and the burnt on bit at any time?—In the one that was broken.
11,082. Were the cracks which you saw, and which were not broken, filled up?—They would admit of nothing to fill them in; they were narrow.
11,083. When you talk of a crack being half an inch, you mean half an inch in length?—Yes.
11,084. But in breadth what was it?—You could not get any split or anything.
11,085. But you said that it was a crack?—Yes.
11,086. Did you see any holes in any of the columns themselves that you dressed?—Yes, in the bodies of some of them.
11,087. What was the biggest hole that you ever saw in the body of a column?—In some places there would be a shank, and you would chip it, it would rise over, and it would leave a hole in other places, and if it was big we would chip it, and bring it round to the rest of the body.
11,088. Take the blown holes on the skin of a column?—I have seen a hole of the length of an inch inside.
11,089. Small at the top, but a hole of the length of an inch inside?—Yes.
11,090. Of what depth?—A quarter of an inch or a little more.
11,091. Were any holes of that size filled up?—I cannot say that I have ever filled any—every dresser felt certain of his own column.
11,092. Did you not fill up any?—I generally showed them to the foreman, and he ordered them round to the cupola, and the furnace man broke them up.
11,093. Any pipes then that went to the furnace having a hole of that size were broken and not filled up?—No, anything that was important was shown to Mr. Campbell and Mr. Ferguson.
11,094. Did you ever fill up any hole at all in the body of a column?—I did. I put in Beamont egg sometimes.
11,095. Of what size was it?—As small as a quarter deep; may be the size of the point of my finger.
11,096. And half an inch long?—No, a quarter deep, that my finger would go in.
11,097. How much in diameter was it?—I cannot say; may be a quarter of an inch or half an inch, but that would have no effect upon the strength; it would not make the column anything the worse.
11,098. Holes a quarter of an inch in depth and a quarter of an inch in diameter would have no effect upon the strength of the column?—No.
11,099. How many holes like that did you fill up?—A good many. I had been there a long time.
11,100. What did you fill them up with?—Sometimes with blue putty and sometimes with Beamont egg.
11,101. Where did you get the Beamont egg from?—In a wee box that lay between the turning shop and the moulding shop on the brick wall.
11,102. Was it always lying there?—Yes.
11,103. Anybody going about the shop, I suppose, could see it?—Yes.
11,104. Do you know if the engineers knew about it?—I cannot say, but they could not but see it when they were passing and coming by at the time.
11,105. They could see the Beamont egg as they passed through the shop, could they?—No, I do not think they could.
11,106. Did Ferguson see it?—I believe he did.
11,107. Did he ever know of your using Beamont egg in the holes that you have mentioned?—I believe he did.
11,108. Did you ever buy the stuff to make this Beamont egg?—No.

Cross-examined by Mr. R. BALLOU.
11,109. I think you said you had been at the foundry for 26 years?—Yes.
11,110. Were the blown holes and the other defects you have described just such as you meet with in foundries?—Yes.
11,111. In other foundries?—Yes.
11,112. The ordinary defects that come out sometimes in foundries?—Yes.
11,113. And if the defects appeared to be important were the columns broken up?—Yes.
11,114. Was it only a few that appeared to be unimportant which were filled up as you have described?—Yes.
11,115. Did you ever send out through your time any one that you thought would endanger the bridge at all?—No.
11,116. If you had thought that the holes would be of any importance what would you have done?—Showed them to my foreman.
11,117. What was his name?—Ferguson, Hector Strachan, and the first.
11,118. Then did they break them up?—Yes.
11,119. Did they break up some with their own hands, and show others to Mr. Beattie?—Yes, but he did not like to let Mr. Beattie see it if it was a very bad cast, and he broke it up himself in the morning.
11,120. He broke it up himself if it was very bad, and if it was doubtful he showed it to Mr. Beattie?—Yes.
11,121. In the foundries that you have been in is Beamont egg commonly used to fill up little holes?—Yes, for certain jobs.
11,122. I mean in what I may call structural castings?—Yes.
11,123. For building, or such work as that?—Yes.
11,124. Was it commonly used for filling up important holes in other castings?—Wee holes and the like of them.
11,125. Just as you used it in this foundry?—Yes.
11,126. (The Commissioner.) Then it must have been known to Mr. Ferguson; he must have known
of them, I suppose, being there.—Yes, I suppose he did.

11,127. It was not in his shop, was it; he was foreman of the shop.—Yes.

11,128. It was in his box in his cabin, was it?—Yes, I believe it was sometimes.

11,129. So that I suppose he would know about it, of course.—Yes.

11,130. Then who was it that bought this stuff?—I think it was a man called Tasker.

11,131. Out of his own money?—I do not know.

11,132. Is it likely that he spent his own money?—No, I do not say that; I do not think he did.

11,133. Then he must have got the money from the foreman, or from somebody else?—Or from the firm.

The witness withdrew.

John Gibb sworn.

Examined by Mr. Trathen.

11,134. Were you engaged at Wormit Foundry?—Yes.

11,135. How long were you there?—About two years and a half.

11,136. Were you there till the close?—No, I was not.

11,137. What were you; a dresser?—Yes.

11,138. Who was your foreman?—Mr. Strachan and Mr. Ferguson.

11,139. You were there for a while under Mr. Strachan, and then under Mr. Ferguson?—Yes.

11,140. Did you dress any columns that had holes in them?—Yes.

11,141. Many? —I dressed a few.

11,142. With holes in them blown?—Yes.

11,143. Of what size were those holes? What was the biggest and the smallest that you saw?—About a quarter of an inch to an inch or so.

11,144. From a quarter of an inch up to an inch in diameter?—Yes.

11,145. In depth what were they?—About a quarter or three-eighths of an inch or so.

11,146. They would vary in size and depth?—Yes.

11,147. Did you fill up any holes in the columns?—Yes.

11,148. What was the biggest hole that you ever filled up in a column that was passed and not broken up?—About three inches.

11,149. A hole of three inches?—Yes.

11,150. You said a little while ago that the biggest was an inch?—That was in a snug, I was talking of columns alone.

11,151. What was the biggest hole you ever filled up in a column?—About a quarter of an inch.

11,152. In diameter?—Yes.

11,153. And in depth what was it?—About three-eighths of an inch.

11,154. What did you fill it up with?—With Beaumont egg.

11,155. Did you fill up many holes like that with the Beaumont egg?—Yes.

11,156. Where did you get the Beaumont egg?—I do not know where it was got.

11,157. Where did you get it?—From the gaffer.

11,158. What was his name?—Tasker. I got it from the dressers.

11,159. Where was it kept?—In the gaffer’s huckie. That is the place where he adds up his books.

11,160. Who had that huckie; whose place was it?—Mr. Ferguson’s.

11,161. You knew that Tasker got it there, and gave it to you to fill up any holes?—Yes.

11,162. Did you ever fill up any blown holes in a lug?—Yes.

11,163. What was the biggest you filled up in a lug?—About three inches.

11,164. In diameter?—In depth.

11,165. And the holes between the burnings, how were they?—Right down into the flange.

11,166. At the side into the flange?—Yes.

11,167. Near the column, or off from it?—At side of the column.

11,168. What did you fill it up with?—With lead.

11,169. Molten lead that you poured in?—Yes.

11,170. Did you fill up any holes in snugir with Beaumont egg?—Yes.

11,171. What was the biggest hole that you filled up in a snug with Beaumont egg?—About half an inch or three-quarters of an inch.

11,172. Do you mean in length?—Yes.

11,173. Did it extend the whole breadth of the snug?—No.

11,174. What breadth was it?—About half an inch or three-quarters of an inch.

11,175. And running down to how much?—Half an inch.

11,176. And you filled that up with Beaumont egg?—Yes.

11,177. Did you ever see any cracks between the snug and the flange?—Yes.

11,178. Where there had been hits burnt on?—Yes.

11,179. Was anything done to cure the crack by chipping or otherwise?—Yes, they put pokes over them to hide them.

11,180. Do you mean cloths or sacks?—Yes.

11,181. Whom were you hiding them from?—The company, I expect.

11,182. Were those filled up afterwards, or hidden in any way in the painting?—They were just chipped, and then painted.

11,183. Do you mean chipped with the hammer?—Yes.

11,184. What was the biggest crack that you ever saw between the flange and the snug that was chipped in that way?—About three or four inches was the biggest I ever saw.

11,185. In length?—Yes.

11,186. Did that go through the whole way?—No.

11,187. Were any of them filled up with Beaumont egg?—None of them.

11,188. Did anybody give you orders to chip these flanges?—Yes.

11,189. Who?—The gaffer.

11,190. What gaffer?—Ferguson Ferguson.

11,191. He knew that you were using Beaumont egg for other holes?—Yes.

11,192. And lead?—Yes.

Cross-examined by Mr. Balfour.

11,193. Did you ever see any columns broken up when you were there?—Yes.

11,194. Why were they broken up?—They were broken up with a big hammer.

11,195. But why were they broken up?—When they were bad.

11,196. Who ordered them to be broken up?—The gaffer.

11,197. Ferguson Ferguson?—Yes.

11,198. What was bad about those that were broken up?—Twisted, some of them, and some of them had big blown holes.

11,199. If the blown holes were big they were broken up by Mr. Ferguson?—Yes, if they were big.

11,200. And the holes were filled up with Beaumont egg?—Yes.

11,201. If the holes were thought to be important, were they filled up or were the columns broken?—Some of them were filled up and others broken.

11,202. Had you anything to do with showing
the columns to Mr. Beattie?—No, I do not mean that.

11,203. You had merely to work under Mr. Ferguson?—Yes.

11,204. You told us that pokes were thrown over some of the columns to hide them from the company?—The contractors: I mean ourselves.

11,205. To hide them from the contractors or their engineers?—Yes.

11,206. Will you give us the names of the persons that it was intended to hide them from?—From Mr. Grödhe, or Mr. Gilkes, or Mr. Beattie.

11,207. You spoke, I think, about lead; just let me understand that; was that where there was a hole running down into the lug?—Yes.

11,208. What sized hole have you seen filled with lead?—About three-eighths.

11,209. Do you mean about three-eighths deep?—Yes.

11,210. What sized hole was it; how much across?—About half an inch or three-quarters.

11,211. Was it a round hole?—I cannot say it was round.

11,212. A kind of sound, or nearly so?—Yes.

11,213. How often have you seen it done?—I have seen it done two or three times all the time I was there.

11,214. Who did it?—I have done it.

11,215. Who else saw it done; name some of them?—Tasker, Bell, Gibb, and Peter Tuite. I do not know whether the whole of them saw it or not.

11,216. But you know that some of them saw it?—Yes.

11,217. You had only to do with the moulding and dressing, I understand?—Yes.

11,218. You had nothing to do with the turning?—We put them out into the lathe at the turners.

11,219. But you had not to turn them yourself?—No.

11,220. You do not know what became of the columns, I suppose, after they were put out of your hands?—No.

Re-examined by Mr. Traillier.

11,221. Did you paint them after they got out of the turners' hands?—Yes.

11,222. Did you paint any columns after they had been through the turners' hands and had been filled up either with lead or Beaumont egg?—No; we put putty into them.

11,223. Some of them before they went to the turners had been filled with lead and with Beaumont egg?—Yes.

11,224. Did you paint any of those columns after they came away from the turners?—Yes.

11,225. Those columns that you painted after they came from the turners, and which you had previously filled up with Beaumont egg and lead, what because of them?—I put them away out into the barges.

11,226. Did they go to the bridge?—Yes.

11,227. They were not broken up?—No, they were not broken up.

The witness withdrew.

John Tasker sworn.

Examined by Mr. Traillier.

11,228. Were you engaged at Wormit Foundry for some time?—Yes.

11,229. For how long?—About 20 months.

11,230. Who was your foreman?—Mr. Strachan and Mr. Ferguson.

11,231. What were you?—I was a hand there—a dresser.

11,232. You dressed the columns after they came out of the mould?—Yes.

11,233. Did you find any of the columns that you were dressing with blown holes in them?—Yes.

11,234. Many of them?—Yes, many of them.

11,235. What was the largest hole you saw in the columns that came from the turners?—I have seen them through and through the one together.

11,236. When they were through and through what was done with these columns?—Sent out to the bridge.

11,237. Did you do something to them before you sent them out?—Yes, I plugged them up.

11,238. What with?—With different things to fill them up with.

11,239. What did you fill them up with?—With putty, cement, and one thing and another, and anything like that to hide them.

11,240. Did you fill up any holes with Beaumont egg?—Yes.

11,241. What was the biggest hole you filled up with Beaumont egg?—I cannot say.

11,242. Tell us as nearly as you can recollect, what was the diameter—an inch?—I cannot say that.

11,243. Give me your idea—tell me?—We filled up many a hole with Beaumont egg.

11,244. Were did you get it?—I made it.

11,245. It was made, I believe, of resin, beeswax, lampblack, and iron borings?—Yes, just like that.

11,246. Where did you get the money to buy these things—who gave it to you?—Mr. Ferguson gave me the money to buy these things.

11,247. And where was it kept after the Beaumont egg was made?—When you were not using it?—Under Mr. Ferguson's office.

11,248. Did you see any holes in the lugs that were cast?—Hundreds.

11,249. Lugs that had been partly burnt on?—Yes.

11,250. Of what size were they?—They were all just blown holes; they were cracked after we tried to put them on.

11,251. The blown holes would come out in the original casting, I suppose?—Yes.

11,252. Did you fill up any of the holes in the lugs with anything?—Yes.

11,253. What with?—With putty and Beaumont egg.

11,254. And lead?—Beaumont egg.

11,255. Did you ever see lead? and pour it in?—Very little—we could not get enough of it.

11,256. Did you ever see in any lugs where there had been a bit burnt on, a crack between the bit that was burnt on and the flange?—No.

11,257. Did you ever see any crack on any column where a bit had been burnt on?—No.

11,258. After these holes were filled up did you do anything—did you take them to the turners?—Yes, they were sent to the turners.

11,259. And after they came back from the turners were they painted?—Yes, they were all painted.

11,260. Did you see any of the columns that had been filled up with putty or Beaumont egg come out of the turners' hands into your hands for painting?—They all went through my hands.

11,261. You filled up any holes in the columns before they went into the turners' hands?—Yes, they were all filled up before they went to the turners at all.

11,262. Was every column that was partly filled up in that way received at the turners' shop, and on coming out of the turners' shop painted?—The turners had nothing to do with them at all.

11,263. Those that came out as you filled them up from the turners were painted, were they?—The turners had nothing to do with them at all.

11,264. Those that came out as you filled them up from the turners were painted, were they?—The turners had nothing to do with them at all.

11,265. But some columns that you had filled up holes in and that came away from the turners were painted, were they not?—Yes, they were all painted after the turners had turned them.
11,266. Do you know that the columns that you had filled up before they went into the turners' hands and came back from the turners were painted, and then went to the bridge? — They were all piled up, sorted, and painted after they left the turners.

Cross-examined by Mr. BALFOUR.

11,267. Did you ever see any columns broken up? — Yes.
11,268. When you were there? — Yes.
11,269. How many did you see broken up? — I cannot say, but I have seen a great many broken up.
11,270. Would you say 100 or 200? — I could not say.
11,271. As many or more? — I could not say.
11,272. But a great many? — A great many I have seen broken up that were not fit to put out to the bridge.
11,273. What was the reason that they were broken up? — They were just not fit for the work to put out to the bridge.
11,274. Did you break up all those that were not fit to put out on to the bridge? — I thought they did.
11,275. You told us about some that had holes in them? — Yes.
11,276. And I think you said that you had seen holes through and through the columns? — Yes.
11,277. How big a hole have you ever seen? — Only the size of your finger.
11,278. You saw daylight through it? — Yes.
11,279. Did anybody else in the foundry see a hole like that? — Yes, of course I let the foreman see it.
11,280. Mr. Ferguson saw it? — Yes.
11,281. Did anybody else see it? — I was not to let any other body see it.
11,282. Why not? — Because there was no other body that had any business with it.
11,283. Had not the contractors any business with it? — The contractors never looked at the castings at all.
11,284. Had Mr. Beattie no business with it? — Mr. Beattie never looked at them.
11,285. Did Mr. Camphuis look at them? — Mr. Camphuis know'd nothing about the castings at all.
11,286. He never looked at them? — Not in my time.
11,287. Even if a man did not know much about the castings, he would know if he saw a hole as big as your thumb with daylight through it? — Yes, but he did not see it. If I was ordered to plug it up, I did it before Mr. Camphuis saw it.
11,288. Was it from fear of Mr. Camphuis that you wanted to hide the holes? — In my time it was Mr. Beattie.
11,289. Only Mr. Beattie? — Yes.
11,290. Why did you want to hide them from Mr. Beattie? — Because I got orders to plug them up.
11,291. From Mr. Ferguson? — Yes.
11,292. Did he want to hide them from Mr. Beattie? — Yes.
11,293. Did Mr. Ferguson ever show Mr. Beattie any columns with holes in them? — I do not know.
11,294. Of course he did not if he wanted to hide them from him? — I do not know.
11,295. You would not expect that he would ever point out any holes to Mr. Beattie from what you saw? — No.
11,296. Did you ever hear him ask Mr. Beattie whether the columns should be broken up owing to the holes? — I never saw Mr. Beattie asking about them.
11,297. Did you ever see him looking at the castings that came out? — Yes, I had seen him.
11,298. Was he often about the foundry? — Yes, very often.
11,299. Every day? — Yes, every day.
11,300. How often in the day? — Just once a day.
11,301. At what time? — He used to come by and look in.
11,302. Was he sometimes there when you were moulding? — I was never moulding.
11,303. But the other men were moulding? — Yes.
11,304. Was he there when they were moulding? — Yes.
11,305. Have you ever seen Mr. Beattie looking at the columns that you were dressing? — Yes.
11,306. What was he looking at them for? — Just to see how we were getting on, I suppose.
11,307. It was to see if they were right, I suppose? — I suppose it was.
11,308. Did he ask any questions of you about them? — No.
11,309. Did you ever point out to him anything that was wrong with them? — I did not.
11,310. Why not? — Did you think that he did not want to know? — I do not know as to that.
11,311. Did you not think it was your duty to point out any defects in the columns to him? — No, I had a foreman over me, it was the foreman's duty.
11,312. Did you think it was right to fill up the holes that you filled up? — I do not know.
11,313. Did you think it was wrong? — I do not know. I did what my master told me.
11,314. Did you think at the time that it was right or that it was wrong? — I do not know for that.
11,315. What do you think about it now, do you think now that it was right or that it was wrong? — I do not know what I think about it.
11,316. Here you no opinion? — No opinion at all.
11,317. Did you think that those holes would endanger anybody's life? — I did not think it.
11,318. You would not let columns go out, I suppose, that you thought would make the bridge dangerous? — I had nothing to do with that.
11,319. Did you think that those columns would make the bridge unsafe or not? — No, I had no idea about it.
11,320. You would not pass an opinion upon that? — No.
11,321. Were you dismissed by Mr. Ferguson? — Yes.
11,323. Did he give you no reason? — He said I stopped too long off.
11,324. What were you doing stopping too long off? — I was off my work.
11,325. For how long? — For a fortnight.
11,326. What had you been doing? — I was off my work.
11,327. What were you doing off your work, were you drinking? — Yes.
11,328. You have been off just now, have you not? — No.
11,329. Have you been drinking today? — Yes, somewhat.
11,330. When were you working last? — Yesterday.

Re-examined by Mr. TRAYNER.

11,331. I suppose it was no business of yours to consider whether a hole was a dangerous hole or not a dangerous hole? — No.
11,332. When you saw a column with a hole, big or little, did you refer it to Mr. Ferguson? — Yes, I told him of it.
11,333. And you took his orders as to whether it should be filled up or what should be done with it? — Yes.
11,334. Do you say that Mr. Ferguson told you to fill up a hole that was through and through the metal? — Yes.
11,335. More than one? — Two or three.
11,336. Were those columns with holes through and through, columns that you think would have been sent to the bridge if the contractors had known about it? — I cannot say.
11,337. Do you think that the contractors would have taken those columns out of the moulder's hands if they had known that they had a hole in them? — I cannot say.
11,338. (The Commissioner.) You say you do not know whether it was right or wrong to fill up those holes, and that you did so because you were told to do so? — Yes.
11,339. You did not care one way or the other, did you? — No, I did not care; I did what I was bidden.

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J. TUCKER.
3 March 1880.
Mr. Trayner stated that this was all the evidence he
proposed to tender.

(The Commissioner to Mr. Balfour.) As Mr. Trayner
says he has no further witnesses to produce, I
presume you have produced all the evidence that
you can offer.

(Mr. Balfour.) I may say, sir, that there has been
put into my hands a statement with reference to this
matter of the Beaumont egg from a person who is
said to have been at the foundry, and I will just for a
moment consider this.

(The Commissioner.) There seems to be no doubt
about it, I think. The question is what it was used
for.

Mr. Balfour stated that he wished to call one more
witness before the inquiry closed.

William Winter sworn.

Examined by Mr. Balfour.

11,340. You are an apprentice boiler maker?—Yes.
11,341. Were you working at the Wormit Foundry,
on the south side of the Tay Bridge?—Yes.
11,342. For how long?—About six months.
11,343. Before it stopped?—Yes.
11,344. What were you doing there?—Painting the
columns.
11,345. After they came out of the hands of the
turners?—Yes.
11,346. Did you ever see any columns with the
stuff called Beaumont egg put into the holes, or putty?
—Yes.
11,347. A blush putty?—Yes.
11,348. To you, as a painter, was it quite visible?
—Yes.
11,349. Do you know where it was put in, and by
whom?—By the dressers.
11,350. Will you give us the size of any hole which
you saw into which it was put?—The largest hole
I ever saw was scarcely a quarter of an inch.
11,351. Had you any instructions from Mr. Ferguson
about any holes or defects that you saw?—Yes.
11,352. What instructions had you?—To come and
tell him.
11,353. What were you to do?—To let him see them.
11,354. Did you tell him whether you had found
any cases of holes with that stuff in them?—Yes.
11,355. What did he do?—If a column was fit for
use the hole was putted up.

(The Commissioner.) I think that for the present
will close the inquiry. Mr. Trayner has produced all
his witnesses. (To Mr. Trayner and Mr. Balfour.) We
will adjourn now until we meet again wherever it may,
be decided to proceed farther with the inquiry. We
shall communicate with you in good-time.

AT WESTMINSTER.

TENTH DAY.

Monday, 19th April 1880.

Mr. Trayner appeared for the Board of Trade.
Mr. Balfour appeared for the North British
Railway Company.
Mr. Webster, Q.C., and Mr. Macnorty appeared
for the contractors, Messrs. Hopkins, Gilkes, and Co.
(Limited), instructed by John T. Balk and Farrington
of Middlesborough.
Mr. Bidder appeared for Sir Thomas Bouch,
instructed by Messrs. A. and J. Dickson, W.S., Edin-
burgh, and Mr. William Robertson, London.
Mr. Payk stated that in the absence of Mr. Bidder
he would take a note of the evidence for him.

(The Commissioner.) I ought to say before we
commence, that we think it would be desirable that
we should have some evidence in regard to wind
pressure, and there are four gentlemen whom it has
occurred to us might be desirable should be called,
and any others whom you, Mr. Trayner, or you, Mr.
Balfour, or any of the other parties might think proper
to call; but we think the Astronomer Royal might be
called, and we think that Professor Stokes, who has
devoted a good deal of attention to the subject of
wind pressure, should also be called, and perhaps
Mr. Secord from the Meteorological Office, and also
perhaps Sir Ralph Abercrombie, and any others who
might be suggested by the learned counsel. It is
desirable in an inquiry of this kind that we should
ascertain whether or not due allowance has been
made for wind pressure. With respect to the testing,
also, we are very sorry that there has been any delay, and that the different portions of the bridge which have been sent up have not been tested before we recommended the inquiry, because we had intimated to Mr. Kirkaldy that no further delay should take place. I am in hopes that arrangements will be made this evening to do what is required, so that you will in the course of a day or two hear what the result is.

Mr. Henry Abel

Examined by Mr. Trimmee.

11,368. What is your occupation at present?—Inspector of the Tay Bridge.

11,369. You are in the employ of the North British Railway Company, are you not?—Yes.

11,370. How long have you been in their employment?—Since the bridge was opened.

11,371. And that was when?—In 1878, about May 1878.

11,372. In May 1878?—Yes.

11,373. Was it not opened earlier than May 1878 for some kind of traffic?—Yes, it was open for ballast, taking ballast over the bridge to fill up the embankment of Dundee.

11,374. Did you run ballast trucks over it before it was opened for passenger traffic?—Yes, I should suppose for three or four months.

11,375. You have had charge of the railway since it was opened for ballast traffic?—Just so. No, that is wrong. I took charge of that since May 1878.

11,376. I think you were inspector of the permanent way on the bridge?—No, I was not.

11,377. What were you?—I was inspector of the foundations, looking at the foundations and the bed of the river, in order to prevent subsidence of the piers, in order to form an engine might not be a man qualified to judge of the stability of a bridge?—Yes, that is right.

11,378. And prior to that you had seven men?—Yes.

11,379. Were those men, except the one whom you specially mentioned a little while ago, all men in the position of labourers?—No, one of those men was employed upon the railway company, the particular duty which you were to perform for the railway company. That particular duty was to take soundings in the bed of the river in relation to the piers, in order to see whether there was any scour taking place, and if such scour did take place to supply it by using rubble stones placed round the piers. That was the chief duty.

11,379. To protect the piers from either subsidence of the foundations or from anything happening in the scour that affected their stability?—It would not have affected the piers from subsidence of the foundations, but it was to protect them from subsidence through the scour.

11,380. Besides looking after the foundations of the pier in that way, had you any other duty to perform under the instructions of the company?—No, I cannot say that I had. I received positive orders from the company to overhaul the columns, but I think that I took it upon myself to set those men to work when they were not engaged, which could only be done at high water, so as to occupy their time in overhauling those columns.

(The Commissioner.)—Did you say that you did not receive any instruction, but that you employed men to look at that work?

(A Mr. Trimmee.)—He means without doing anything else within his proper employment, he asked those men to look to see if anything was wanting doing to them.

(The Witness.)—Yes.

11,381. Were they skilled workmen or labourers?—One of them had been foreman under the contractor.

11,382. What was his name?—McKenna.


11,384. Foreman of what?—In erecting the columns.

11,385. Are you sure of that?—Quite certain.

11,386. And from being foreman in the erection of the bridge he came to be your workman?—Yes, he had had an accident, and he was taken on by the North British Railway Company.

11,388. How many men had you under you for the performance of those duties?—From the month of May, when I took over the duties from Sir Thomas Bouch for the railway company, I had seven men until the following December.

11,389. After December how many had you?—From December I had three men employed: four men with McKenna. From September 1878 till December 1879 I had three men employed.

11,390. After December 1879, and until the bridge fell, how many men had you employed?—The same number, three men.

11,391. From December 1878 to December 1879 you had three men employed under you?—Yes, three.

11,392. And from September 1879 to December 1879 you had the same number, had you?—No, it was December 1878; from January 1879 to December 1879, it is just a month difference.

11,393. From the 31st of December 1878 till December 1879, when the bridge fell, you had three men under your employ; is that right?—Yes, that is right.

11,394. And prior to that you had seven men?—Yes.

11,395. Were those men, except the one whom you specially mentioned a little while ago, all men in the position of labourers?—No, one of those men was capable of taking care of an engine, and we pay him as an engineer or fireman on board.

11,396. What is his name?—William Nash.

11,397. But a man accustomed or able to take care of an engine might not be a man qualified to judge of the stability of a bridge?—No, that of course is a matter of opinion; but I considered him quite competent to do what I required of him.

11,398. Had you any other skilled labour, or were the rest labourers?—I think I can classify the rest as labourers.

11,399. So that the result of your examination shows that there was no scouring taking place threatening any danger to the stability of the piers?—There was a slight alteration in comparing the soundings for the last arch with the previous soundings, but very slight; it was made up by rubble, but nothing to cause any serious doubt.

11,400. In the case of how many piers did that happen?—I can tell you if I have my books.

11,401. Give me roughly?—I think it was something like twelve piers where there had been a slight alteration.

11,402. You easily supplied the place of a scour with rubble stones?—Just so.

11,403. There was no scour to suggest any danger to the stability of the piers?—Not the slightest.

11,404. Leaving the foundations, let us go up a little bit. Did you discover whether any of the ironwork of the bridge was getting unstable or loose?—In taking those soundings that I have spoken of, I noticed or heard a clattering of the bars.

11,405. You heard them moving or shaking?—Yes.

11,406. Was it in the lowest tier of bars nearest the stonework of the piers that you found the bars clattering?—Generally, as far as my remembrance goes, it was something like the third or fourth tier down. I cannot positively say; such a thing might have taken place in the second tier from the top to the bottom.

11,407. Speaking from the best of your recollection, can you say whereabouts in any of those piers or columns, not the supports, you first observed that any...
of those bars were loose?—I cannot speak from
recollection.
11,408. Were those loose bars within the high
girders or without the high girders, or both?—They
were both.
11,409. Did you examine the bars in order to see
what was the matter with them, or whether they
needed any repairs?—Yes.
11,410. Tell me what it was you found to be wrong
with the bars on your examination of them?—I do
not know whether I can explain it to you. I found
that the cotters in coming together had got a little
loose—there was not a sufficient width to get a good
grip, and they had got a little loose.
11,411. Was the fault of the cotters or the slot-
holes which you cannot answer? I am not sufficiently
up with that to tell whether it was the slot-hole or the
cotter. I took it for the cotter.
11,412. Could you not see whether the slot-hole
had worked at all, or whether the cotter had been
working, and had lost its grip?—You could not see
anything of the slot-hole underneath the nut, the bolt,
or the washer, the nut at one side and the bolt at the
other.
11,413. Could you see the cotters?—Most de-
cidedly.
11,414. Were there two cotters, I believe, in each
slot-hole?—Yes.
11,415. Were they, in the places you examined, so
loose that they could have been removed by the hand?
—No, in no case.
11,416. How loose were they?—Had they been
loose of course they would have been found at sight.
We had to go and find out where this chattering
motion took place, and then through the cotters to see
which was loose, which showed us the extent of it,
which in your opinion was not sufficient. I found
that the cotters had been just about as tight as this.
In sounding them with a hammer we found that they were not
tightened up sufficiently. In driving them home we
found out that they were scarcely wide enough to get
a tight grip.
11,417. Should not those two cotters, if they had
been properly fitted, have filled up the slot-hole
entirely, and have gripped each other absolutely?
—Certainly.
11,418. Did you suppose that those cotters had
originally fitted the slot-hole perfectly, and had got
loose from some cause or other, or that they originally
had been defective?—The impression it made upon
my mind was this—that they had not been driven up
tight in the first place, because I had no ground for
believing that they were loose by any other means.
11,419. Did you find that you could drive them
home tightly with the hammer?—I found out that
I could drive them home tight with the hammer on
account that they were not wide enough in those places
when I found them.
11,420. Then the cotters were too small for the
slot-hole, you think?—Yes, in those places.
11,421. No amount of driving would have made
them quite tight in the slot-hole so as to make the
tightness right?—Not properly.
11,422. Would any amount of driving have made
them tight, in the slot-hole in the first instance?
—Not those cotters.
11,423. Then it comes to this—that from the outset
those cotters were too small for these particular slots?
—That is my opinion.
11,424. It was not careful work you think?—I
should not think so.
11,425. Did you report what you found to anybody?
—No.
11,426. Why?—Because I thought I could remedy
it.
11,427. Did it not occur to you that it was a thing
that it would have been right to have laid before
the engineer of the company?—No; I did not think of
sufficient importance.
11,428. If you had thought that the stability of the
bridge depended upon those cotters to any extent,
should you have regarded that of sufficient importance
to have reported the matter to the company's engineer?
—Most undoubtedly, I should.
11,429. But do you not think it did?—No.
11,430. Do you think so now?—I do not.
11,431. What was the use of those cotters?—To
tighten up the bracings.
11,432. What was the purpose of having the brac-
ings tight?—To make the bridge stable.
11,433. If the cotters came away and the bracings
would not have got loose, that would affect the stability of the bridge, would it not? Most decidedly, if there were a
sufficient number of them loose.
11,434. It was not the character of the defect, but
the extent of it, which in your opinion made it not
worth while reporting it to the engineer?—Just so.
11,435. If you had not thought it a sufficient
number of places to have alarmed you for the
stability of the bridge, you would have felt it your
duty to have reported it, would you not?—I should
have done so.
11,436. Had you any instructions to interfere
with the ironwork of the bridge either by way of repair
or otherwise?—No.
11,437. Why did you take it upon yourself to do
this repairing of the ironwork without instructions?—
Simply because I should have imagined that ironwork
which had been so recently constructed would not have
required any particular amount of supervision being
given to it by the company.
11,438. But you thought it a sufficiently important
thing to induce you at once to repair it?—Where I
heard a noise from the jingling of the bars I tried to
remedy it.
11,439. It was a matter of importance to you to
remedy it, and you did remedy it at once?—Yes.
11,440. Why did you do it?—I think I must put a
different construction upon the matter from what you
would have made me put upon it. If you will give me
patience I will try to explain it to you. If I heard a
jingling of a bracing bar to-day, very likely the next
day, if I had an opportunity, I should put in a slip to
secure it, that is to say to tighten up with a slip
between the cotters, and I should then leave it and
not interfere with it again. I might go again, in three
or four days to any part of the bridge and hear
another jingling somewhere else, and repair it till I
had thought it necessary; but I had men to overhaul
the whole of the columns and just see whether there was
anything likely to take place in the shape of a loose
column, and then if it was so we did what was
necessary.
11,441. The result of your examination was to show
that there were a good many cotters in the same
position, is that so?—Yes, just so; it must have been
so, above a hundred.
11,442. Can you give me an idea of the number of
cotters that you found loose?—I should say 100 would
cover it.
11,443. Were they distributed throughout the
bridge, or were they to be found more at one particular
part than another?—I cannot tell you that, but there
were plenty of them to be seen in the standing portion
of the bridge.
11,444. And some of them were in other parts?—
Yes; I cannot give you the number.
11,445. You repaired them I think you said?—No.
11,446. You did repair them, did you not?—We
wet the iron for them.
11,447. Where did you get the iron from?—From
Nicholls, in Ward Row, in Dundee.
11,448. When did you get the first iron to mend
those cotters with?—I think it was in December
1878.
11,449. No; look at your book; it was much earlier.
I find that you got a bar of the first iron on the 21st
October?—That is right; that I took from the book of
the man who supplied it.
11,450. You having got a bar of the first iron,
weighing 5 lbs., on the 21st October 1878, it was
used to tighten up those gibes?—Yes.
11,451. Give me an idea out of the 5 lbs. how many
packing pieces it would make?—They are in 12 feet length, that is 144 inches.

11,452. There are about 10 to a lb., are there not?—I do not know, I am sure, how many there are to the lb. I have got a piece here which I will hand in (handing it to the learned counsel).

11,453. This one of the pieces which were taken off?—Yes.

11,454. That is another, is it not (handing the same to the witness)?—Yes, I think that is another.

11,455. Can you not give me any idea how many of the lbs.—I cannot.

11,456. Those two are fair specimens of the packing pieces that you made of the iron which you so obtained?—They are very fair specimens.

11,457. That exaggerated the iron which you got on the 21st of October. On the 11th of November you got three pieces weighing 7 lbs., and on the 2nd of December you got two weighing 10 lbs.?—Yes.

11,458. Is that all you got to repair the bridge?—That is all.

11,459. Is that all the iron you got to repair the bridge with?—Yes.

11,460. What is the total price of that 22 lbs. of iron pieces?—

11,461. Did you use the first 5 lbs. before you ordered the second supply on the 11th of November?—I do not know; I am sure; I cannot tell you.

11,462. Try and recollect; you did not buy any iron to keep it by you, I suppose?—I do not know; we kept it by us, and we can produce it now.

11,463. That is part of the 10 lbs. that you did not use?—Yes.

11,464. I want to know this: I find that you had kept up the first 5 lbs. before you went and bought the second lot of 7 lbs.?—No doubt about it; in my mind it was so.

11,465. There was no necessity for keeping iron to keep lying about you; you bought what was necessary at the time?—I believe that is true.

11,466. Do you think that your survey of the bridge was such as to enable you to say that there were none of the cotsers loose except those that you tightened up with packing pieces?—I could pronounce with my own mind that there was not anything wrong of loose up to the time of the calamity; that is my firm belief.

11,467. Did you make any examination of the ironwork of the bridge except in those places where the movement of the bars and the noise made by that movement attracted your attention?—Yes.

11,468. Did you examine it from end to end?—Yes.

11,469. When did you make this examination?—Examinations have taken place in the bridge during these last 12 months on several occasions at intervals.

11,470. I mean before the catastrophe. What examination did you make with a view to find out whether the cotsers were sound and tight apart from those places which you had repaired with packing pieces?—I made up my mind to go all through the columns, I think, in the month of October last, the latter end of the month and the beginning of November, and through the whole of the work, and we found then, I think, a cotter or two loose. I think they had been all made good previous to that.

11,471. All but those that you made good?—Yes.

11,472. Will you give me an idea of what you mean by saying that you found one or two of the cotsers were loose in October immediately before the catastrophe?—In examining the columns of the bridge we tried the bracings with a hammer, and we found, I think, only two loose during the month of October.

11,473. Did you put them right?—Yes.

11,474. Were those in the upper tier?—No, I think it was on the standing portion of the bridge towards the north side; it was not in the large column at all.

11,475. In the examinations you made, do you mean that you went over the columns from the bottom to the top or from the top to the bottom?—From the top to the bottom.

11,476. You went down the whole column till you came to the pier it stands on?—Yes.

11,477. The result of your examination was that in October last all these cotsers were perfectly tight, with the exception, perhaps, of the two you discovered, and which you repaired?—Yes, as far as my knowledge goes.

11,478. Will you tell me in the course of those examinations who accompanied you, if any one?—Two men, Nash and Bell.

11,479. Were those two men labourers?—One of them was the man I described as sufficiently able to take charge of an engine, and the other was a labourer.

11,480. Did you make any examination of the columns themselves?—Yes.

11,481. Did you find them complete?—I found them all complete, with the exception of the two or three columns on the northern side of the bridge which are standing now.

11,482. And those two or three columns were defective in what respect?—It appeared to us—and not only did it appear to us, but it was so—that there was a slit in one of the columns.

11,483. Was that column near the foot or near the top?—You must take this part of the model out of the way; I am not alluding to the large column now. We call this north-west (pointing to the model); it was a slit in the bottom column there, north-west.

11,484. That column was slit; what was the extent of it?—Something like five feet in length.

11,485. Was it at the top of the column or at the bottom of it?—If you follow me (pointing to the model) it was something like two feet I think as high as I can judge from the bottom of the flange, and extended up about five feet.

11,486. It was not at either end of the column, but between the flanges?—Yes.

11,487. About two feet up from the bottom of the flange?—Yes, as high as my judgment will carry me.

11,488. That is one column; but were there other columns that were defective?—Yes; I have got two bands round the columns underneath those columns.

11,489. What were the defects in the columns?—The defect in the other columns is something after the same style that I have described, only less in extent.

11,490. How many columns altogether did you discover that were defective in that way?—Three on the northern side of the bridge, and five on the other side.

11,491. Were there any others throughout the whole structure?—Not one. That was on No. 38 pier, under the large girders.

11,492. (The Commissioner.) Counting from the south?—Yes.

11,493. (Mr. Trayner.) Was the defect on the column on No. 38 pier of the same character as the other two?—It was just of the same character that I have described with this bottom column here (pointing to the model).

11,494. What was the extent of it?—It was, I dare say, six or seven feet in length.

11,495. It was a most serious defect in the bridge, was it not?—Yes; it was six feet in length, I believe.

11,496. In which of the columns?—I mean in what part of the columns of the pier, so to speak, was that one situated?; was it near the bottom or near the top?—This is the column in this case (pointing to the model), against the bottom of the north-west column of No. 38 pier.

11,497. (Colonel Yolland.) 18 inch or 15 inch?—15 inch.

11,498. (Mr. Trayner.) With reference to each of those four columns, what did you do in order to remedy the defects?—I will take one girder first, and describe what I did with it.—No. 38—I placed four bands round that column.

11,499. Iron bands, do you mean?—Four iron bands.
11,500. What was the width of the bands?—3½ inches.

11,501. Each band?—Yes, each band.

11,502. And the thickness?—Five-eighths.

11,503. Did you do that on your own hand, or on special instruction from any one?—I did it on my own hand, but I wrote about it to Sir Thomas Bouch, and described to him what I had done.

11,504. Did you write to him after you had done it, or before?—After I had done it.

11,505.—You had made no report to him or to anybody else before you did it?—No.

11,506.—Where did you get those bands made?—They were made at Mr. Luckie's, the engineer, of Dundee.

11,507. How did you get them on; you must have had some appliances at the bridge to enable you to put them on?—No, they were made at the engineer's forge; they were made in half rounds, bolted at each side.

11,508. Was there a plate, a protruding plate, on each half?—No.

11,509. Into which you sent the bolt?—No.

11,510. Were they bolted to the columns?—Yes.

11,511. The two halves were made exactly to fit the column, and they were bolted to the column by bolts at each end of each half?—That was so.

11,512. Did they not overlap?—They had to be tightened up.

11,513. How were they tightened up?—By screwing up the bolt.

11,514. (The Commissioner.) The bands were in two halves?—Yes.

11,515. (Mr. Trauger.) Were there in each of those halves bolt holes cast or made?—The bolt holes were made by the smith—punched, I suppose.

11,516. In the half band?—Yes.

11,517. I am under no misapprehension when I say, having applied a half band to a column, you drove the bolt in, in order to keep it secure in, through the column, and fastened it, as you say?—Yes.

11,518. (The Commissioner.) Did you drill holes in the column?—No, they were apart from the column; they were banded round, outside of the column.

11,519. (Mr. Trauger.) There was a circular column which you wanted to band?—Yes.

11,520. Had that a band round it?—Yes.

11,521. And that band was made originally in two halves?—Yes.

11,522. I asked you whether any part of each half proved so as to screw it up tight with a bolt in it, and you said no?—I should have said yes; I misunderstood you.

11,523. Then bolts were screwed in through the two halves, but no part of those bolts went into the column itself?—No.

11,524. Was it like the eccentric band of a steam engine?—Just the same.

11,525. How had the bolt holes been made?—They were drilled in.

11,526. How did you fasten up the bolts?—By screwing them on with a spanner.

11,527. (Colonel Yolland.) With a nut on the end?—Yes.

11,528. (Mr. Trauger.) What was the size of the bolt?—It was an inch in that case.

11,529. With of course a nut at each end which you screwed up?—Yes.

11,530. There would be a nut on each side—at each end?—A head, and then a nut.

11,531. With regard to the other columns, did you fasten them up in the same way?—Yes; but I must tell you that there is a circumstance connected with that; there was not so much care taken with those bands as there was with this one (pointing to the model), and for this reason I wrote to Sir Thomas Bouch, and told him about this column going on the north side, and he came down and saw it, but I had banded it up first. He came to the determination of having extra bracings upon the whole of the columns at the northern side round the columns of the bridge, and we have now one set of those bracings all ready made and lying by ready for use when the calamity happened under the high girders.

11,532. (Colonel Yolland.) You say he was going to have extra bracings put into the columns?—He was going to have the columns according to the plan banded, and extra bracings put into those columns that we are speaking of now.

11,533. Do you mean extra bracings put in under the high girders?—No; where they are now standing.

11,534. Did Sir Thomas Bouch at any time visit the bridge along with you to look at that part of the bridge, or defective column under the high girders?—Yes; he visited the bridge, I think, on the Tuesday or the Monday before the calamity took place, and he saw that the thing was perfect.

11,535. There was no suggestion as to an extra bracing there?—It was not considered to be required.

11,536. I did not ask you that. There was, no suggestion?—There was no suggestion.

11,537. With the exception of those four columns, and the tightening up of the bracing, did you do anything else to the ironwork of the bridge?—No, that is all that was done, or what was in immediate notice in connection with the ironwork of the columns.

11,538. You were constantly at the bridge, were you?—Always.

11,539. And you will be able to tell me this: no one else did anything in the way of repairing the ironwork of the bridge except you, or what was done under your superintendence?—Not after me, when the inspector of the ironwork left.

11,540. That would be in May 1878?—Yes.

11,541. Who was the inspector prior to May 1878 that had charge of the ironwork?—Mr. Macbeath.

11,542. Who was the last of the inspectors at the bridge who represented the contractors?—Mr. Cumpus, I think, was the last gentleman who was there under the contractors; I am pretty well sure of that.

11,543. Who was the last person there superintending the bridge prior to May 1878 on behalf of Sir Thomas Bouch?—Mr. Macbeath.

11,544. Are you quite certain that you did not report any of those defects that you have mentioned, either to Sir Thomas Bouch or to any one else representing the company, prior to the time when you commenced making the repairs?—I never did.

11,545. Had you not instructions to report to your superiors in the railway company any defects, if any defects were discovered?—No, because they were not so well that I should do it; so that it was not required. I expect—they never asked me any particular thing.

11,546. Will you just answer this question: you never received instructions from them to report any defects that you should discover in the structure of the bridge?—No, I never had any such instructions.

11,547. Had you general instructions to repair any thing you might find defective without going to your superiors in the company's service?—I never had any instructions at all.

11,548. No instructions to repair, and no instructions to report?—No.

11,549. What were your instructions when you went there?—My instructions were, as I said before, to look after the foundations in the bed of the river in relation to the pier.

11,550. So far as you know, there was no one there charged at all with the duty of looking after the ironwork of the bridge?—Not under my platform, but above there was.

11,551. No one was there to look after the ironwork of the bridge so far as it stood between the top of the pier and the bottom of the platform?—Except myself.

11,552. You had no instructions?—I had no instructions.

11,553. How did you get paid for the outlay of the money upon the iron?—Very simply; bills came in and I sent them to the North British Railway.
11,576. Did you tell Sir Thomas Bouch at any
time that you had heard this chattering of the bars,
and what you had done?—No, I never told him.
11,577. Did you suppose it would not come to his
knowledge unless you told him?—It would not.
11,578. When you told Sir Thomas Bouch about
the repairs executed on the columns below the high
girders, did he then inspect any other column than
the one you had repaired?—I do not know. He
asked me whether anything had taken place upon
the other columns, and I told him no, at the
time.
11,379. Then I suppose he relied upon your state-
ment, and did not make any examination?—Just so, I
expect so.
11,680. You did not think it worth while to tell
him that those bracing bars had got loose?—No, I
did not think it of sufficient moment. I may have
been wrong, but I freely admit that I did not.
11,581. You did not do it?—I did not.
11,582. Was there any person other than Sir
Thomas Bouch himself that you had been in the habit
of communicating with about the bridge?—No.
11,683. Neither before May nor after May 1878?—
Only by sending in the accounts that I required to
the head office.
11,584. At the bridge itself you were not in the
habit of talking to anybody about the condition of
the bridge except Sir Thomas Bouch, and only to him
on the occasions you have mentioned?—I do not
remember any other person, is that certain.
11,585. What were you bred to?—I was apprenticed
to a bricklayer, and I worked myself out,
and was taken by the Board of Works for nine years;
the Metropolitan Board made me an inspector, and I
am an inspector now of brickwork.
11,586. (The Commissioner.) Do you mean here in
London?—Yes, in London; I was appointed by
the Metropolitan Board.
11,587. (Mr. Trayner.) But you have no engineer-
ing skill?—No.
11,588. (The Commissioner.) Have counsel arranged
among themselves in what order they would like to cross-
examine the witnesses?
11,589. (Mr. Webster.) I have very little to ask the witness,
Sir.
11,590. (Mr. Pyke.) I must ask the Court to delay the
cross-examination for Mr. Bidder's attendance. I
will take a note for him in his absence.
11,591. (Mr. Webster.) I know Mr. Bidder is coming.
11,592. (The Commissioner.) You have no objection to go
on?
11,593. (Mr. Webster.)—No. (To the witness): Those cots
and gibbs were in the one end, of what has been
called the tie bar, were they not?—Yes.
11,594. Just touch one of them; one of the
diagonal ones?—This one (pointing to the same).
11,595. Yes. They were always in the bottom
or in the top. Do you remember?—In the bottom.
11,596. At the top there was a screw bolt, was
there not?—No; I cannot answer that. I have no
means of answering that question, because I cannot
tell you. They were all covered up when I saw them.
I do not know.
11,597. So far as you know it was not cotter and
gib at the top?—As far as I know the bracing bar has
not a cotter and a gib.
11,598. The cots and gibs were of were always at
the bottom?—Yes.
11,599. Now you have spoken of that, or Mr. Tray-
ergy has put it to you as one gib or cotter; there were
gibbs and cots in each slot, were they not?—One
gib and two cots.
11,600. Will you look at that picture (showing a
sketch to the witness). The pieces with the ends over
are called gibbs, are they not?—I have never seen two
gibs myself.

Mr. H. A. Noble.

19 April 1880.
TAY BRIDGE DISASTER.

Mr. Barlow. Will you have the goodness to hand up that sketch. (It was handed up to the Court.)

11,597. (Mr. Webster.) They are shown in the Board of Trade drawing. (To the witness.) You have just anticipated the question I was going to put to you. You never saw a gib or a cotter off?—No.

11,598. That is to say off of the tie or brace?—No.

11,599. You never knocked off a cotter; what you did was, in certain instances when I will ask you about, to put a little bit of iron in by the side of the cotter?—Yes.

11,600. Did you ever try to knock off a cotter on this bridge?—No, I do not think I should have troubled myself to do that, if it was tight.

11,601. Could you tell the Court how many gibbs and how many cotters there are in the whole bridge?—I have not the slightest idea.

11,602. I believe that is a matter to be verified. I believe there are 4,192 cotters and 8,334 gibbs, but I will have them checked by counting. You say that to the best of your recollection a hundred would cover the number of pieces that you put in?—I think a hundred would do it.

11,603. You had to put a piece to every loose cotter; that you had, I think?—Of course, if it was loose.

11,604. You say that you bought seven shilling-worth of iron, but you did not use it all, and you have some of it left?—Yes.

11,605. How much of it is there left—is there a quarter of it, or half of it left?—We had 17 feet, and then we had a portion used and turned up for a poker, and that was added to it we measured 17 feet, and there were 2 feet, a portion that we found they had used for a drag to draw up a cable in the harbour at the time—about 20 or 21 feet was the whole.

11,606. The 17 feet were not used, and the poker and the drag, making 21 feet altogether, were not used?—Yes.

11,607. I think one of those bits has been fractured; would that represent the length of the thing as you put it?—They both represent the length.

11,608. The longer or the shorter one might have been the length that you put in?—Yes.

11,609. Can you tell the Court the largest number that you found in any one pier or column?—I do not recollect.

11,610. I want to understand you clearly. Your attention was first attracted, as I understand you, when you were at the base of the piers, by hearing the chattering?—No, I stated that my attention was called to it when I was taking soundings in the bed of the river round the piers.

11,611. Being about the bottom of the piers you heard that rattling or chattering?—Yes.

11,612. (Mr. Webster.) May it have been from the passage of a train?—Never.

11,613. Did you ever, in any instance, find one of the little pieces come out after you had put it in?—Never.

11,614. Am I correct in saying that after you had put a little piece in, whatever you call it, a packing piece of iron, you never noticed that bar chatter again?—No, it became rigid.

11,615. I gather that the time you were there was from May 1878 until the accident?—Just so.

11,616. I think Mr. Trayler elicited from you that you bought the first piece of iron in October 1878?—Yes.

11,617. (The Commissioner.) And the next in November, and the next in December?—That is right, Sir.

11,618. (Mr. Webster.) Up to what time before the accident happened, or was the last time that you put in the pieces, or had you bought a piece in October 1878?—Do you remember putting in a piece in 1878?—I think at the latter end of October or November 1879 I found two pieces, on the northern side.

11,619. I gather now that in October 1879 you made a thorough examination of the columns of the bridge?—Yes, in October and November 1879. I also must state in December too.

11,620. Take one thing at a time. You had found everything tight except at two places?—Yes, except at two places.

11,621. Do you remember where those two places were?—I believe it was towards the northern end of the bridge, at all events I know it was not under the large girders; I am positive of that, but towards the north.

11,622. Is this correct, that at that inspection there was as far as you could ascertain no loose cotter, to use that expression, or looseness of any part, under the great girders in October 1878?—And I do not know whether I made a mistake; I think I said it was in December I went over the columns the last time.

11,623. I took it as being in October?—It was in December that I put in those two pieces.

11,624. The inspection when you put in the last two pieces was in December 1879?—Yes.

11,625. The inspection, as I understand, was in December 1879?—Yes, and that is when I put in those two pieces.

11,626. Do you remember with regard to the earlier time about when you put in, or ceased to put in, the chief part of the other pieces that were used, when you got a piece of iron in October 1878, or the beginning of 1879; when did you put in most of the pieces?—You see we just took the bracings to make good as we heard, but that was at such different times that I cannot positively state.

11,627. You took the bracings to make good when you heard a sound, and they occupied such intervals that you cannot say when one was done or another was done?—Just so.

11,628. May I say that you cannot tell us whether this occurred at the end of 1878 and the early part of 1879, or in the middle?—According to my system of work, I think it was in the month of October 1878.

11,629. Up to when?—I believe that in October 1878 the majority of those pieces must have been put, because I invariably took my soundings in September and March; I see that I bought iron in October, and I believe the majority, that is to say all that iron, must have been used up before I ordered another piece in the following November.

11,630. All the iron that was used?—Not all the iron.

11,631. It amounts to this, does it not, that you think that substantially the bulk of those pieces were put in after the September soundings in 1878, or in October 1878?—If you call the first order the bulk, you must see what the second order is to find out what the quantity is; I think it is rather bulkier.

11,632. Did you hear any chattering in the March sounding of 1879?—No; I could not have heard any. My last soundings were taken in September, and the preceding ones in March.

11,633. In September 1879 you heard some chattering and you bought some iron in the November and December following?—Yes.

11,634. Do you recollect, when you sounded again in the early part of 1879, whether your attention was directed to any chattering then?—I cannot remember.

11,635. I think you took down the dates, Sir, of those parcels of iron?—Yes.

11,636. (Mr. Webster.) I will read the accounts (reading the same). (To the Witness): You have stated fairly that you could not say what was the most you found in one of the piers—No.

11,637. Can you tell the Court at all whether, as far as you recollect, the 100, or any number under
100 that you put in, was spread fairly and equally over the bridge, or more on the north, or more upon the south, or in the centre? - I really cannot answer that; it was a question where it took place at the time.

11,658. Had you had to do with cotters and gibas before? - No.

11,659. Do you know whether it is an unusual thing where you have length of iron subject to expansion and contraction from heat and other causes, and where there are a large number of cotters, that some of them do work loose at times? - I do not know.

11,660. You, finding this, and seeing what had happened, thought it was a thing you could put right, and you did put it right? - Yes, I did.

11,661. You have said that the impression upon your mind was that the cotters had not been driven home. Will you tell the Court what was the thing you saw which led you to the impression that the cotters had not been driven home? - The impression was that, in bending the bars we found out that there was a jingling in driving the cotters home with a hammer; it passed through.

11,662. Further through? - Yes.

11,663. I understand that in no instance did you ever take a cotter right off? - No.

11,664. I understand you to say that you could drive it further? - Yes.

11,665. What led you to the impression that they had not been driven home; was it what you saw of them when you found that they would go further in? - They did.

11,666. That is what you meant by saying that the impression on your mind was that they had not been driven home? - Just so.

11,667. Was there anything else that led you to the impression that they had not been driven fairly home in the first instance, except that when you tapped them you found they would go further in in some cases? - My impression was that they did go further in, and there was any slip, that the cotter was too small.

11,668. Was there anything else which you saw that led to the impression that you have? - That is all I found.

11,669. You know nothing about the dimensions of the cotters or of what size they were intended to be? - No.

11,670. Now, about the cracks; I think you have already answered Mr. Trayner's question, and I ask you distinctly: it was no part of your duty, and you did not in fact communicate anything that you saw in regard to the ironwork to anyone on behalf of the contractors, Messrs. Hopkins, Gilkee, and Company? - I had no means of doing so.

11,671. You did not do it, and you had no instructions to do it? - No.

11,672. Could you fix the date when you found the crack in the north-west corner of pillar No. 38? - Yes, I can tell you when I banded it up.

11,673. When did you first find it? - The painters drew my attention to that column.

11,674. When was that? - In September.


11,676. That is the one under the north-west column, under the high girder, No. 38? - Yes.

11,677. Do you remember the painter who called your attention to that column? - No.

11,678. You, yourself, had not seen it before? - No, I had not.


11,680. (The Commissioner.) It is what we call the northernmost section.

11,681. (Mr. Webster.) It is at the north side.

11,682. (The Commissioner.) Not very far from the northern end of the high girder?

11,683. (The Witness.) No.

11,684. (Mr. Webster.) It is a north-west column, a 15-inch column. (To the witness): You said No. 38? - Yes.

11,685. You went and saw it? - Yes.

11,686. You described the crack to Mr. Trayner, which I think you said was some six or seven feet long? - Yes.

11,687. And in this position, starting from about two feet from the flange, and running upwards? - Yes, just so.

11,688. Did you see that crack on more than one occasion afterwards? - On three other occasions.

11,689. Did it appear to you then to be in the same condition as when you first saw it? - Just in the same condition as I left it when I first banded it up.

11,690. Will you be good enough to tell us when you banded it up? - The 27th day of September.

11,691. And, as far as you saw, it was in the same condition from the time when your attention was first called to it to the day of the accident? - Till the Tuesday previous to the accident.

11,692. Did you happen to take the dimensions of the crack at the time? - If you will allow me, I will just explain it in a few words. I gave orders to the painters that in the course of their work any little defect they might see they would call my attention to it, in case it slipped my supervision, and the result of it was that my attention was called to this crack in this column after they had painted it, and I immediately banded it, and after I had banded it I sent a telegram to Sir Thomas Bouch to say what I had done, stating the date that it was done, and he came down and saw it.

11,693. What I want to know is this—did you ever take the measurement of the crack yourself at any time? - Yes, I have.

11,694. Did you take it down? - Yes, I took it down, and the crack at the time was something like two feet from the bottom, and six feet six inches long.

11,695. Did you ever indicate the width of the crack if there was a perceptible width to it? - Yes, when I found it out I took a leaf from my pocket book and held it over the crack and waited till the impression was about to come over, and I held the leaf across the crack and wetted the paper with my tongue when the train came by to see if there was any sensible motion as regards the opening of the crack, and I found out that it did not tear the paper, which I considered was about the most sensitive way I could try anything of that kind, and then I immediately banded it up independently of that. Since then I have visited the columns.

11,696. It comes to this, does it not, that you were not able to detect any motion whatever at the edge of the crack? - Just so, there was none.

11,697. Can you tell me in any way what the extreme width of the crack was; was there any perceptible width to it? - Yes.

11,698. What was the extreme width? - It must have been very near about the 32ndth of an inch. I should think it was less than yth.

11,699. You think it was about the 32ndth of an inch—was it tapering at all? - No, it was vertical, correctly vertical, strictly vertical.

11,700. Was it tapering at all—I do not mean the line of the crack, but did the 32ndth of an inch taper down to a point or did it break out at once into the 32ndth? - I tried to find the depth of the column.

11,701. You have not quite followed me. Assume that it was like that (showing a sketch to the witness); did it suddenly break out to what you think was the 32ndth of an inch, or did it run up to a point top and bottom? - I will describe it in this way. I will draw the column (drawing on a piece of paper). The crack was about two feet from the flange here (pointing to the drawing); the crack commenced and went correctly vertical to within about six feet six inches in length—the widest part was here (pointing to the drawing); and it died out to nothing at each end.

11,702. The widest part was about the middle? - Yes.

11,703. And it died out to nothing at the top? - Yes.
11,680. And it died out to nothing at the bottom as well?—Yes, just where the bands are below.

11,681. How many bands were there?—Four. I placed one band here, and another here, and one below the crack here (pointing to the sketch), above the crack, and one above the crack.

11,682. Now you have said that that was on the north-west of the 15-inch column, whereabouts was it on the column as it stood on the pier, which side of the pier was it?—It was here (pointing to the model).

11,683. Roughly it would be about on the inside of it? (pointing here) (pointing to the model) in the centre of that column (pointing to the same), just up to the pier.

11,684. Do you mean the diagonal centre?—No, I mean, the centre of the circle, the south side of the column; that is the very spot where it was (pointing to the model).

11,685. Yes, I said that you tried to find the depth of it—you tell the Court how deep it went, or were you able to find the depth of it at any point of the crack?

—No, I could not; I tried a fine piece of wire, and after cutting the mouth of the crack I could not get it in any further, and I died the end of it, and still I had a loss, and the next day I got a fine wire out of a ginger-beer bottle or a soda-water bottle, and I tried it again by that: that I could never get the wire through what I considered to be the thickness of the iron to get to the concrete inside.

11,686. You could never get it down to the cement?

11,687. How far did it go in?—About three-quarters of an inch.

11,688. And at what part of the crack was that?—In the widest part of it.

11,689. Were you able to form any judgment as to what caused that crack?—Not the slightest.

11,690. Then I understand you to say that to the best of your belief the crack came some time before September, when it was called to your attention?—It must have been. It may have missed the inspection of our iron man, Mr. Macbeth.

11,691. Have you any opinion as to what time that crack occurred; how long it was before that crack took place?—I have not the slightest idea about that; it might have been a twelvemonth.

11,692. (Colonel Yolland.) Did you say it might have been there when Mr. Macbeth left?—Yes; I said it may have escaped the notice of Mr. Macbeth. It is evident that it had escaped mine, because I had been over the pier before.

11,693. (Mr. Webster.) Did you form a judgment as to whether the crack had been originally there and escaped your notice, or whether it had come there after the pier had been erected?—I believe myself that it was there; my impression is that it must have been there some time, previous to that, that is my impression, and I repeat that in the painting and scraping they found it out.

11,694. Tell us, if you please, what was the contrivance which was going to be put, not upon this pier or upon this column, but upon the one at the northern end which you referred to, some bracing which you put up, and if you had ready upon the ground, just show it there on this model. You first said that the crack was in about the same position as the north-west column on one of the piers, but you have not given us the number?—It is No. 76.

11,695. (Baron.) I understood that the column was much higher up.

11,696. (Mr. Webster.) Wheresoever was it?—At the same place in No. 76 pier.

11,697. NORTH-WEST?—Yes.

11,698. Wheresoever was the crack?—That was on the north-west.

11,699. Outside?—Yes, the north side of the column.

11,700. (Colonel Yolland) Which pier are you speaking of?—No. 76, nearly at the bottom of the incline at the curve towards Dundee, the outside column.

11,701. What was the extreme depth of that crack; did you try it?—Four feet, I think I said.

11,702. Thickness and depth I want, or width and depth?—We bored a hole in those to take the quality of the metal, and having found the metal good, the crack went right through; we proved that the crack went right through in that case.

11,703. You bored the hole there to see whether there was anything wrong with the iron where the crack was?—Yes, and the thickness.

11,704. And you found that the metal was perfectly good?—Yes; but you will understand me; we found the metal perfectly good. That was the opinion expressed by other parties that knew more about metal than I did.

11,705. You found it an inch thick, did you not?—Yes, the full thickness there.

11,706. Will you tell us if you can, the extreme width of that crack, and the extreme depth of it, if you know it?—It was an eighth of an inch in width, and of course it went through.

11,707. For what portion of its length out of the four feet?—It was four feet six. There is no doubt that it went through the whole length of the crack.

11,708. Were you able to form any opinion as to how that crack had been caused?—No.

11,709. Or whether it had been there for a long time or for a short time before it was called to your attention?—I have no hesitation in saying that that crack was not there in the month of October or November 1879.

11,710. Tell me, if you please, when that crack was first noticed—Saw it myself.

11,711. When did you see it?—In either the latter part of October or November in going over my inspection of the columns at that time.

11,712. Will you tell me how long before October inspection. Are you satisfied it was not there?—I have no hesitation in saying that that crack was not there in the month of October or November 1879.

11,713. Tell me, if you please, when that crack was first noticed?—Saw it myself.

11,714. Yes?—It is a pity I have not the plan here, but Sir Thomas Bouch had a plan for putting six-inch bands around with bracing bars, diagonal bracing bars.

11,715. To the south-west?—From north-west to south-east, and the same thing in this direction (pointing to the model). The bars were to be six inches in thickness, and the bands to be six inches in thickness. We had one set of these bracings ready made for fixing as the calamity took place in December.

11,716. On that pier where the crack was, it was proposed to put some bands and bracings from the north-west column to the south-west column, and also from the north-east on to the south-west?—Yes, I may say on all those double columns on the curve.

11,717. Whatever the reason of it may have been, that was what you understood the intention of the design to be?—Yes.

11,718. It may be important that you should just tell me where the other two cracks were. You told Mr. Tynan that you found those on the north side, and one under the high arches. We have dealt with two—where were the other two cracks on the north side?—I cannot describe it very well (pointing to the model).

11,719. First of all, which pier was it on?—On No. 78 pier.

11,720. Both of them?—Yes, both of them; that is a single column pier, and one of those cracks is on the west and the other on the east side.

11,721. (Colonel Yolland) In the same pier—
MINUTES OF EVIDENCE.

Yes, but I may state that the one already there has a hand round it; one of these cracks, although it can scarcely be called a crack; whether it was some defect in the skin of the iron or not I do not know, but to be certain I put a band round, or else no one could scarcely see anything.

11,722. (Mr. Webster.) One, you say, was scarcely perceptible, but you have not told us whereabouts it was?—It was underneath the girders.

11,723. How high up was it?—It was underneath the girders; the top column.

11,724. Which column?—The east column.

11,725. (The Commissioner.) And west too?—Yes, and second one.

11,726. (Mr. Webster.) When did you perceive those cracks?—The same time as I did the other.

11,727. The northern one?—Yes.

11,728. Can you say whether those cracks had been there two months before?—We never saw them.

11,729. Can you go further than that?—No, we never saw them.

11,730. You cannot go further than saying that you never saw them until October or November 1879?—No. This column (pointing to the model) brought about a close inspection.

11,731. The northern one brought about a close inspection?—Yes.

11,732. All the northern columns are still standing?—Yes, they are all standing.

11,733. And can be seen?—Yes, and they stood the traffic where those bands are.

11,734. (The Commissioner.) They are all standing except the high-girders?—Yes.

Examined by Mr. Balfour.

11,735. You told us, I think, that you entered the employment of the railway company in May 1878, did you not?—Yes.

11,736. Had you been engaged upon their bridge before May 1878?—Yes.

11,737. In whose employment, and for what time?—Sir Thomas Bouch's employment from 1871.

11,738. You had been in the employment of Sir Thomas Bouch and were paid by him from 1871 down to May 1878?—Yes, just so.

11,739. And I believe, been recommended to Sir Thomas Bouch by Sir Joseph Bazalgette, of the Metropolitan Board of Works in London?—Yes.

11,740. And after May 1878, did Sir Thomas Bouch remain the engineer in charge of the bridge?—I cannot answer that question, but I can tell you that as far as I am concerned, as regards the foundations, there was an understanding that I was to communicate to Sir Thomas Bouch, which I did.

11,741. Was he the person to whom you made any communications there with respect to the bridge?—Relative to anything being the matter that I considered necessary, it was to Sir Thomas Bouch that I communicated it.

11,742. Are you not aware whether Sir Thomas Bouch was still in charge of the bridge?—No, I am not.

11,743. But at all events you acted upon that assumption by communicating with him on the subject?—Most decidedly, I know that the North British Company paid me.

11,744. But it was with Sir Thomas Bouch that you communicated on the subject?—Everything in connection with the bridge which I thought was of serious import.

Re-examined by Mr. Travers.

11,745. That, there may be no misunderstanding about a matter of fact, do you know cotters when you see them?—Yes, I have one here.

11,746. The gib is the U-shaped piece of iron that holds the plates together?—Yes.

11,747. And the cotters are the two wedges put in to keep it all tight?—Yes.

11,748. (Mr. Webster.) I am informed that the piece that goes in the middle is called a cotter, and the two U-shaped pieces are called gibs.

11,749. Did you notice, those cotters that were loose whether they had been faced, or merely forged?—I do not think after the thing had been pointed out to me I could tell the difference. I did not notice the feature; I did not take particular notice.

11,750. Were these cotters and was the whole ironwork of the bridge painted once or twice in your time?—I am speaking of the iron structure generally;—I should suppose it would have had three or four coats on it in the time.

11,751. When you saw those loose cotters, could you tell from the state of the paint whether they had worked a little loose out of the position in which they had been when painted?—That means that you want to know whether there was any exhibition of rust.

11,752. Whether there was any exhibition of rust upon which there was no paint?—No, I cannot call that to mind. I never saw any loose, but only just hand tight.

11,753. In those places where you put in the packing pieces you cannot recollect whether there was any exhibition of rust that was not painted?—No, I never studied that.

11,754. You had got 5 lbs. of iron on the 21st of October 1878; you used up the whole of that for those packing pieces?—No doubt.

11,755. And you so used it before the 11th of November when you got the next supply of iron?—I expect so.

11,756. You have no doubt about it, have you?—I have no doubt about it.

11,757. Your supply of the 11th of November was entirely used up, I suppose, in like manner before you got the third supply on the 2nd of December?—The men said they had used the slips they had got on the 11th of November, so I said “You had better get another supply of iron.”

11,758. You had no reason to doubt their statement?—No.

11,759. So you had used up in packing pieces 12 lbs. of iron before the 2nd of December?—Very likely.

11,760. Can you tell me what proportion of the 10 lbs. got on the 2nd of December was used for packing pieces?—I cannot tell you.

11,761. Can you tell me approximately?—No.

11,762. Some part of it no doubt was.—It would not have been ordered unless I was in want of iron for that purpose.

11,763. You would not order iron to make pokers, or anything else?—Certainly not, though they were made into pokers afterwards.

Examined by the Commissioner.

11,764. I think you said that you had been for seven years in the employment of the Metropolitan Board—?—I was for eight or nine years under the Metropolitan Board.

11,765. At what time was that?—That was previous to 1871.

11,766. Up to that time?—Yes.

11,767. What were you employed by the Metropolitan Board as?—Inspector of brickwork.

11,768. Had you anything to do with ironwork?—No further than looking to the metal of the girders or pen stocks.

11,769. When you were employed from 1871 by Sir Thomas Bouch, what were you employed as?—Inspector of brickwork.

11,770. Not of ironwork?—Not of ironwork.

11,771. Then when you were taken on by the
company, I understand that your duties were to see 
whether or not there was any scouring at the bottom 
of the piers?—Yes.

11,772. Those were your special duties?—Those 
were my special duties.

11,773. They were, in fact, your only duties?— 
Those were the only duties I had really to perform.

11,774. You said that you generally made your 
inspections in September and March?—My sound-

11,775. What did you do at other times?—I would 
never make the columns of the bridge.

11,776. You were not appointed for that?—No, 
Sir.

11,777. You do this voluntary work of going over 
the columns?—Supposing you had not taken this work 
upon you, what other work would you have had to do, 
your own work?—There would have been nothing 
close to do.

11,778. Than you had seven men; what did they 
do for?—Those seven men were required.

11,779. What for?—In working the steam-boat 
at the time, and in assisting in taking the soundings, 
because you required to have three men in the boat.

31,780. They were only required in March and 
September?—Yes, just so; but I made use of the 
men, and kept them without authority from the North 
British Company, to fill up their time in overhauling 
the piers. I must admit that I took that upon myself 
entirely.

11,781. Yon had no knowledge yourself of iron-
work?—No; but I had a knowledge to this extent: 
I considered that if there was a bar began to chatter, 
and it required stiffening so as to make it rigid, a slip 
put in between the croters would hold it right, because 
Sir Thomas had men there within five months of the 
time after it had been out of the hands of the contrac-
tors. Sir Thomas had an inspector over these very 
things, with a gang of men tightening up bolts or 
removing any defect that might have happened, 
and when he left it he left it with the understanding 
that everything was secure, and I never thought at 
that time that there would not have been anything requi-
sitive till such time as I heard the bars chatter, and 
then I went to inspect them.

11,782. Just look at that drawing (handing it to 
the witness). You observe there that there is a coter 
between two gibs?—Yes.

11,783. You said, in answer to a question that was 
put to you by Mr. Webster, that there was only one 
gib?—Only one.

11,784. And there was only one?—I never saw 
two.

11,785. There was not one on each side?—I never 
saw two.

11,786. There was one gib and two cotters?—Yes.

11,787. Not like that drawing?—Not like that.

11,788. Your impression was that the clattering 
and stiffness of the braces was due to the croters not 
being driven home?—Just so.

11,789. Is that your impression now?—I am of the 
same opinion now.

11,790. Then why did not you drive them home, 
when you saw you require these pieces to be in put in for?— 
Because the croters were driven as far as they would 
go, but I found upon sounding them that they were 
like hand-tight, and I drew the croters out a bit, and 
finding that if I had driven it home there would not 
have been sufficient grip, I drove this thing into the 
ends of the croters.

11,791. But not because it was not driven home; 
but not because it did not fit?—It was home as far 
as the croters would go, but it would not have suffi-
cient grip.

11,792. You said that your attention was first called 
to the crack in pier No. 39 by the painters?—Yes.

11,793. The painters had no particular knowledge 
of ironwork, had they?—Not that I am aware of, but 
they could see a crack if there was one.

11,794. They would not know whether or not there 
was anything wrong in the ironwork as regards the 
fitting?—No, I do not suppose they would.

11,795. If there was anything at all wrong in 
the way of the braces being loose, or anything of that 
kind, they would not know that?—Yes, they would 
be bound to know it; they would be bound in such a 
way if there was a bracing loose, because they had to climb 
up and down these columns to paint them. I thought 
by their going minutely over the thing with the brush 
they would be able to discover anything wrong that 
might have passed my knowledge, which may have 
been the case with that column. I do not think it, 
but it might have passed my knowledge.

11,796. At any rate this had passed your know-
ledge?—Yes.

11,797. In sounding this crack why did not you 
sound it with a piece of paper; with a piece of paper, 
you could have seen at once whether it would have 
gone through, without putting a wire through?—The 
idea of putting a bit of paper into the crack never 
struck me.

11,798. If you had put a piece of paper into it, 
you would have sounded the crack at once, would not 
you?—I do not know whether I could have got a bit of paper 
in a sufficient depth. I should have thought a piece 
of fine wire would have been best—it is an old Metropoli-
tan Board system; we generally stop the place with a piece of paper before we open the cutting, and 
then put in a wire, and I adopted the same thing here.

11,799. (Colonel Yolland.) Referring to the time 
when the crack was discovered in No. 38, pier, had 
you or had there not to your knowledge been any 
particularly cold weather before that?—No, because 
it was in September.

11,800. When you put the piece of wire from a 
soda-water bottle through, you said it went through 
about three-quarters of an inch?—Yes.

11,801. Do you think it was stopped by the metal 
of the column or by the concrete that was inside?— 
The metal of the column, because if it had been the 
concrete I could have found it out directly.

11,802. (Mr. Barlow.) Do you have any occasion to 
tighten the same tie bar more than once?—I never 
tightened a bar after the time I had done it; after I 
had left the bar tightened up.

11,803. (Colonel Yolland.) Did you observe in-
any of the columns of the portion that has fallen 
whether the tie bars were bent the same as you see them in-
that model?—The fact of this column cracking, or 
being split, caused a thoroughly close inspection of 
the bridge to be made at that time, as I told you, at 
the latter end of October, when I found the column at 
the north side split. The cold weather was then coming 
on, and Sir Thomas was in a great state of anxiety 
about this, and I went over every column with my 
men right through the whole of the bridge, there being 
trains passing at the same time, and I found every-
thing in a pretty good rigid state; and I never found 
any of those pieces out of place that I had stuck in, or 
rather driven in. That is as far as my knowledge 
truthfully goes of my supervision during December. 
I went over the whole.

11,804. With reference to the long bars themselves, 
were they all stretched, or, were any of them 
buckled at that time?—All that I ever found was their 
being so close together here in the centre. I never 
saw any buckled away from the bar.

11,805. (Mr. Barlow.) Was there any district 
engineer superintending your part of the line?—The 
surface, but he had nothing to do with this business 
it we have been talking about.

11,806. That would be only the permanent way 
supersintendent?—Only the permanent way superinten-
dent.

11,807. Practically there was no engineer?—No. 
11,808. Did that apply also to the part of the line 
north and south of the bridge; was there no district 
engineer to that?—There was a district engineer who 
had command of all the surface, and who had men 
under him.
Mr. James Francis Hadland sworn.

Examined by Mr. Trayner.

11,813. You reside at Middlebrough, in Yorkshire?—I do.

11,814. I believe you were head clerk to the Cleveland-Bolt and Nut Company?—I was in 1873.

11,815. In what year you went there in 1873?—Yes, I went there in 1873.

11,816. And remained there till when?—I was there something like five years.

11,817. Did the works close then?—Shortly after I left they closed.

11,818. You left in 1878, and shortly after that they closed?—Yes.

11,819. You were there till shortly before the works closed?—Yes.

11,820. You had previously been, I believe, employed in a nut and bolt company in Birmingham?—Yes.

11,821. How long were you in that service?—I was there three years.

11,822. I suppose in both these situations you acquired a considerable knowledge of the nut and bolt trade, and the mode of carrying it on?—Yes.

11,823. Who was the manager of the Cleveland Company while you were there?—Joseph Preston.

11,824. Is he now dead, I believe?—Yes.

11,825. Did you act under his supervision and orders?—I did.

11,826. Will you tell me what was the course followed when you received orders for bolts and nuts and washers, and such other things as your company supplied?—Every morning when the manager came with the letters I went into his office and we went through the letters together. The orders and all correspondence relating to orders were handed to me and I superintended the entering of them by the order clerk; into the various work books, and I afterwards had charge of all the orders until they were completed to a certain extent. I had the supervision under the manager’s direction.

11,827. You had a mode of acknowledging the receipt of an order with the view of seeing whether you had accurately read the order?—Yes, that was a lithographed form, and at the foot of it we set out the order as we understood it.

11,828. A lithographed form to this effect: “We are favoured with your orders as below.”—Yes.

11,829. You then repeated the order which you understood it, so that if there was any misunderstanding the customer could correct you before the order was commenced to be executed?—Exactly.

11,830. Did you get a good many orders in the course of your service with this company from Messrs. Hopkins, Gilkes, and Company?—Yes.

11,831. And did you, in acknowledging their orders, use the lithographed form which you have mentioned?—Yes, as a rule.

11,832. Was there any case in which you did not?—The order clerk may have made an omission. I could not speak to that. It was his duty to acknowledge the order in that form.

11,833. Did you ever receive any letter from Messrs. Hopkins, Gilkes, and Company saying that you had misunderstood a previous order, or complaining about its non-execution at all?—No, I think not.

11,834. I suppose you have no doubt that Messrs. Hopkins, Gilkes, and Company’s orders were received, acknowledged, and executed in the ordinary course of business and in the right way?—Yes, I believe that every original order bears my initials.

11,835. You have searched for Messrs. Hopkins, Gilkes, and Company’s orders, I believe?—Yes.

11,836. And so far as they are in existence you have them?—I have them all.

11,837. You have supplied them to the Board of Trade, and they are in print?—I have supplied copies.

(Mr. Trayner.) We will put them in print.

(The Witness.) I have the originals here.

11,838. (Mr. Trayner.) I will furnish copies to the learned counsel on the other side. (To the witness)
11,839. And when you had not the goods in stock, I suppose you gave instructions to the proper workmen to execute the order to get them made?—Yes.

11,840. And did you this upon an order slip?—Yes, upon an order slip.

11,841. The workman getting the order slip would go to the stores, I suppose, to get the necessary materials?—Yes, to get the necessary iron to make the goods.

11,842. Where had you the iron necessary for the order, which you were to give to the workmen?—Yes.

11,843. When had you not it would be ordered in?—Yes.

11,844. What were the orders, generally speaking, for which Messrs. Hopkins, Gilkes, and Company sent?—For every class of work comprised in the nut and bolt business—bolts, nuts, rivets, washers, set pins, and everything.

11,845. Did you fulfil their orders with iron procured from any particular person, or were the orders executed out of iron obtained from various makers?—The iron, in some cases, was ordered from Messrs. Jaques and Company, of Stockton, and in some cases from Messrs. Jackson, Gill, and Company, of Heaton, near Middlesbrough.

11,846. Do Messrs. Hopkins, Gilkes, and Company's orders show that many of the bolts and other things ordered by them were for the Tay Bridge?—Yes.

11,847. And they gave instructions to have them so labelled?—Yes.

11,848. You have copies of the orders which Messrs. Hopkins, Gilkes, and Company sent to the firm in whose employment you were?—Yes; I have the originals.

11,849. You have also made excerpts from your books, you have, not show the order, the description of goods, the price, the date of delivery, and the weight?—Yes; I have the order books containing all these details.

11,850. And they have been made up from your books?—Yes.

11,851. You have supplied true copies of them?—Yes, they were supplied by me.

11,852. You have also made up copies of the letters by your company to Messrs. Hopkins, Gilkes, and Company giving quotations of prices?—As far as we have them.

11,853. And the acknowledgments on the part of the Cleveland Company to Messrs. Hopkins, Gilkes, and Company of their orders?—Press copies of them are.

11,854. And letters from the Cleveland Company to Messrs. Hopkins, Gilkes, and Company, referring to the quality of the iron ordered?—Of some iron sent.

(Mr. Trampler.) We will let you have copies of all these (Handing one).

11,855. First, there are copies of dates, and acknowledgments, then copies of letters from the Cleveland Nut and Bolt Company, then copies of Messrs. Hopkins and Gilkes' orders to the Cleveland Nut and Bolt Company, and copies of the quotations of price.

(Mr. Trampler.) Yes. (To the witness): Can you tell me from those orders, of what quality of iron the bolts were to be made that were ordered by Hopkins and Gilkes?—They were made of ordinary Cleveland iron.

11,856. If the order did not specify a particular quality, or character of iron, you always made them of ordinary Cleveland iron?—Always made them of ordinary Cleveland iron.

11,857. You are quite familiar with those orders; do you any of Messrs. Hopkins and Gilkes' orders relative to bolts for the Tay Bridge specify any quality of iron?—They do not, except the order may say that they are of good quality, which only means that they are to be of good ordinary quality, or good 'best' quality, or good 'best best,' as the case may be.

11,857. You have technical names for the qualities of iron which distinguish the particular iron?—Yes.

11,858. Since you have mentioned them, let us have what the names mean; what does 'best' mean?—It means a step beyond ordinary.

11,859. And 'best best'?—A step beyond "best."—Yes.

11,860. And "best best best"?—That is a step beyond.

11,861. "Best" iron means not the best iron; there is something a great deal better than the best. —Yes; there is something better than "best best," and there is something better than "best best best." You get then into Low Moor qualities.

11,862. None of the iron of which those bolts were made was "best"?—No.

11,863. None of them were up to the quality of "best"?—No.

11,864. There was no such thing as Low Moor iron used in Hopkins and Gilkes' bolts?—No.

11,865. On the 21st March 1874, you quoted Messrs. Hopkins and Gilkes' for fifty tons and a half of rivets, 1½d. 10s. a ton?—Yes.

11,866. Of what were these qualities? They were ordinary rivets.

11,867. Common quality?—Ordinary rivets.

11,868. That was your price at the time for common rivets?—Yes.

11,869. What were you quoting for better quality at that time?—Several pounds a ton more than that.

11,870. The price shows you that they were ordinary rivets?—Yes.

11,871. And not a superior class of iron?—And not a superior class of iron.

11,872. On the 11th and the 19th of May, and on the 15th of June following, Messrs. Hopkins and Gilkes sent you orders against that quotation?—Yes.

11,873. Then again, I find on the 1st. of August 1874 you quoted Messrs. Hopkins and Gilkes' 13½ tons a ton for rivets?—Yes, iron had gone down.

11,874. Those were still common rivets?—Yes.

11,875. Made of ordinary iron?—Yes.

11,876. And against this quotation you had orders on the 1st and 22nd of August?—Yes, somewhere about those dates.

(Mr. Webster.) I do not see the 1st of August in what you have given us.

(The Witness.) A great many of the quotations were verbal.

11,877. (Mr. Trampler.) On the 11th of August 1874 there is a letter from Messrs. Hopkins and Gilkes in which they ask you the price for 98 cwts., and on the 16th of September 1874 there is a letter from Messrs. Hopkins and Gilkes enclosing an order for 9,800 ½ inch bolts?—Yes.

11,878. And that letter says that they were to be transmitted to the Tay Bridge for the Tay Bridge contract?—Yes.

11,879. What was the price?—21½, a ton.

11,880. What kind of iron was it?—Ordinary iron.

11,881. On the 16th of September they altered the diameter of those bolts from ¾ inch to 1 inch?—Yes.

11,882. I see they say, "please note the order for 9,800 ½ inch diameter should read now 9,800 1 inch," to tracing." Have you searched for that tracing?—Yes, I have searched very carefully for it, and I cannot find the book in which the tracings were kept.

11,883. The tracings would show nothing about the quality of the iron?—I never saw a tracing with the quality of the iron mentioned upon it.

11,884. It would be simply size and form?—Simply size and form.

11,885. The quality, if mentioned at all, would have been mentioned in the order?—Yes.
11,886. Do you know what kind of nuts were supplied with those bolts?—They would be ordinary nuts.

11,887. Did you see them?—I dare say I saw a great many of them.

11,888. Were they of the ordinary thickness?—Yes, I imagine so. I do not know what the tracing was. I have not seen the bolts since they left.

11,889. You cannot say, as a matter of fact, what were the dimensions of the nuts?—I should imagine the nuts were the same thickness as the head of the bolt.

11,890. Never mind what you imagine, but in point of fact you cannot tell us what the thickness of the nuts was?—No.

11,891. I need not take you through all the different orders; but will you tell me this: had you any orders for Low Moor iron: rivets from Messrs. Hopkins and Gilkes, and if there was a small quantity of Low Moor iron sent us from Messrs. Hopkins and Gilkes, and we were instructed to make that into rivets, I do not think there was more than a ton, or something like that of it.

11,892. What was their charge for the iron they sent?—I do not know exactly what the price of Low Moor iron was at the time.

11,893. Do your books show what Messrs. Hopkins and Gilkes charged you for the iron so sent?—I think it was 20l. a ton.

11,894. Do the books show?—Yes.

11,895. Have you your books here?—Yes.

11,896. Will you lock to the 15th of October 1874?—Yes.

11,897. On the 15th of October 1874, Messrs. Hopkins and Gilkes sent an order for 38 cwt. of 1½ lb. iron rivets ½ in. and 2 cwt. of 24 inches, to be made from Low Moor iron to be supplied by them at 22l. a cwt.

11,898. What would be the price of those bolts be per ton if they were rivets.

11,899. What would be the price of the rivets per ton, after you had made them?—Our charge to them was 27½. a ton, after giving them credit for 22l. a ton. We charged them 5a. a cwt. for the making; for the labour, 3s. a ton.

11,900. (Mr. Webster.) The witness just said that he thinks there was about a ton of it: the order is about two tons?—I said 38 cwt.

11,901. (Mr. Webster.) And then there was another 2 cwt. in the same order; it is 2 tons.

11,902. (Mr. Traeymer.) Can you find the order of Messrs. Hopkins, Gilkes, and Company of the 9th of January 1875, for a quantity of nuts for bolts of ½ inch?—On the 9th of January 1875, Hopkins, Gilkes, and Company ordered 104 cwt. of hexagon nuts screwed for ½ inch bolts.

11,903. You did not supply the bolts for those?—No.

11,904. Did you see those nuts?—I do not know that I did; probably so.

11,905. Looking to the order, of what quality of iron would they be made?—Ordinary iron.

11,906. (Mr. Webster.) What is the date of the order?—9th January 1875, No. 1,293.

11,907. (Mr. Traeymer.) On the 4th August 1875 you agreed to supply to Messrs. Hopkins and Gilkes, 482 bolts of ½ inch. On the 9th of January 1875, Hopkins, Gilkes, and Company ordered 104 cwt. of hexagon nuts screwed for ½ inch bolts.

11,908. You did not supply those bolts?—They were supplied at 19½s. a cwt.

11,909. Were they for the Tay Bridge?—Yes.

11,910. When were those supplied?—The works order book shows that on October 14th they were 38 cwt. 5 qr. and 19 lb. sent of the first lot of 26 inches in length.

11,911. Did you want the particular quantity sent, but I wait the dates at which this order was fulfilled?—It was fulfilled on October 14th, 26th, November 2nd, November 11th, November 25th, the 29th of October, the 9th. There were some of another size; there were various sizes, and the deliveries go against the various sizes.

11,911. Were those all deliveries under that order?—Yes, they were delivered in small quantities on various dates. On December 1st the order seems to have been completed.

11,912. You were in the habit, I suppose, of going about the works a good deal?—Yes.

11,913. And you had opportunities of seeing how these bolts were made; were they forged or were they fitted?—Some of them were made by machinery, and some of them were made by hand. The order we are now looking at was made on the machines.

11,914. Were the bolts turned at all?—No.

11,915. Were they faced where the bolt and nut came together?—No, there would be only a little rough edge to be taken off, but they were not what I understand as faced.

11,916. Did you know of any bolts made in your place being faced?—No, unless they were engineers' bolts; that is bolts used for engines, or anything of that sort, then they are often turned bright.

11,917. I suppose you made bolts and nuts for a great many other people besides Hopkins and Gilkes?

11,918. For nearly every railway company in the world I think.

11,919. Were those orders when sent to you for execution, and when in course of execution, inspected by anybody as a rule?—Yes, as a rule, very rigidly.

11,920. I suppose that was for the purpose of seeing, not the quality, but the manufacture?—Exactly; the orders were usually given subject to inspection; then we knew what to expect.

11,921. And I suppose your firm would be an exception from the community generally. You are more careful when you expect somebody to look at your work than when you do not?—Yes.

11,922. Did Messrs. Hopkins and Gilkes inspect any of your work?—I am not aware that they did, whether they did or not I cannot say.

11,923. You were aware that other people were inspecting?—Yes, if any particular inspector was appointed I knew it.

11,924. How did you become aware of that?—Because we were in communication with him.

11,925. Seeing him there?—Seeing him there, and having to do with him, and going with him to see the work.

11,926. Did you ever see anyone from Messrs. Hopkins and Gilkes who came to inspect any order they ever gave you?—I think not; we used to have bills of Messrs. Hopkins and Gilkes' men there, not officially to inspect.

11,927. What were their men doing there when they did come?—They came to see how we were getting on with the orders that were for delivery, and to give instructions as to what deliveries they wanted.

11,928. But inspecting the work, testing its quality, or examining the mode of manufacture, so far as you know, was a thing that Messrs. Hopkins and Gilkes never did?—That was a thing they never did.

11,929. If they had done it, it must have been within your knowledge?—I think so.

11,930. So far as you are aware, did any inspection, take place on behalf of Messrs. Hopkins and Gilkes of the bolts supplied by you specially for the Tay Bridge?—I think not.

11,931. What kind of iron did you use; that is to say, the common iron; was it good common iron?—We ordered it to be good common iron, but in some instances we got inferior iron.

11,932. Did you use the inferior iron?—In some cases we did.

11,933. Did you send much back; did you send more back than you kept, or did you keep more back than you sent back?—We kept more bad iron than we returned.

11,934. Did you return anything to speak of?—Very little; I only remember one lot of any importance.

11,935. When was that?—I do not know the date of it. We had an order for the Indian State Railway
for some important spikes; we ordered the iron from Whitwell, of Stockton, and the quality was found to be bad, and we returned it.


11,936. Was the kind of iron that Messrs. Jaques sent you, as a rule, common iron?—As a rule it was inferior.

11,937. What was the character of the iron supplied by Jackson, Gill, and Company?—As a rule, it was good.

11,938. But the inferior iron from Messrs. Jackson and Company, as a rule, was kept?—As a rule was kept.

11,939. You told us that Mr. Preston was the manager; who was the foreman of the works?—Charles Banks.

11,940. Was it Bankes's duty to have sent the iron back when it was bad?—It was the duty of the iron storekeeper to report the iron to the office; his duty would be to take samples from every truck of iron as received, or to take a sample of each size or quality as received, and submit it to the office; and if the office published it, it was unloosed.

11,941. In point of fact, did Bankes complain to you sometimes about the quality of the iron that Messers. Jaques and Company were supplying?—No, he never complained to me.

(Mr. Webster.) I do not know how far we are to go. As far as the witness is saying who supplied the iron, Messrs. Hopkins and Gilkes it may be legitimate, but I do not know that we can have a complaint made by their own workman to this witness as to the supply of the iron by Messrs. Jaques. (Mr. Trainer.) If it does not affect Messers. Hopkins, Gilkes, and Company, it cannot be evidence against them.

(The Commissioner.) You object that it is hearsay evidence. (Mr. Webster.) Yes.

(Mr. Trainer.) It cannot be hearsay. This man is speaking to what took place. (Mr. Webster.) You asked him if any complaint was made to him by Bankes with regard to the quality of the iron that Messers. Jackson and Company were supplying.

(Mr. Trainer.) Yes, that is not hearsay evidence; that is what the foreman said to his superior. (The Commissioner.) That can be taken for what it is worth; it would be no proof that the iron was bad unless it be simply proof of what took place between Bankes and the witness.

(Mr. Trainer.) A good deal may be said about Bankes hereafter, and I thought it right to put the question to the witness. I do not wish to press it if the Court think I ought not to put it.

(The Commissioner.) No, I do not think you ought to put it.

11,942. (Mr. Trainer, to the witness): Did Bankes ever complain to you about the quality of the iron that had come from Messrs. Jaques and Company?—No; he never complained to me personally.

11,943. Where is Bankes now?—I believe he is in Herefordshire; he is in the Forest of Dean.

(Mr. Webster.) I would ask you to have the witness in attendance again for a further cross-examination, if necessary.

We had no notice of this as being likely to arise.

(The Commissioner.) Certainly.

Cross-examined by Mr. Webster.

11,944. You have talked about nobody coming to inspect from Messrs. Hopkins, Gilkes, and Company. I do not quite understand what your position in the works was?—I was head-clerk there acting under the supervision of the manager. If the manager was away I had charge of the works.

11,945. Do you mean you had the whole supervision?—The whole supervision. Bankes was foreman.

11,946. Did you employ many people?—Then, I suppose, altogether.

11,947. Bankes, you say, was the foreman?—Yes.

11,948. Mr. Preston was the manager?—Yes.

11,949. Who was the foreman at that time?—Mr. Preston was the manager at that time.

11,950. He is not now alive, as I understand?—He is dead.

11,951. Messrs. Hopkins and Gilkes' place is just the other side of the street, isn't it?—Yes, close to.

11,952. Do you represent to the Court that there was no examination of the bolts and rivets that were sent across or delivered to Messrs. Hopkins, Gilkes, and Company?—I do not know what they did with them after they got them. So far as I know there was nobody to inspect them at our works.

11,953. Do you represent that there was no examination of them within your own knowledge?—Your not speaking of the technical word inspection; I am speaking of examination; that is to say, looking into the matter?—Their men may have come and picked up some of the bolts in different stages of manufacture.

11,954. Do you not know that a very considerable quantity of bolts were returned to your premises as being defective, and others ordered?—I do not know that there was any great quantity.

11,955. Is it not the fact that bolts supplied by your firm to Messrs. Hopkins, Gilkes, and Company were returned, and others required in place of them?—I do not know that. As far as the least show there is nothing to show that.

11,956. Do you mean to say that you have no knowledge of that?—I do not know of that. Not of any considerable quantity. Messrs. Hopkins, Gilkes, and Company have sent us various lots of small things back again.

11,957. You say "any considerable quantity." I must here it from you one way or the other. Do you repeat that there was no return of bolts or rivets for defective manufacture, or improper material, or do you represent that it was only a very small quantity that was returned?—There were some sent back. I do not know how many.

11,958. Tell me the dates of the returns?—I cannot. They would not go through my books.

11,959. They would go through some book?—Yes, but a great number of the books of the Cleveland Nut and Bolt Company are not forthcoming.

11,960. You have trouble to take out, for those who have asked you to do so, the orders of Messrs. Hopkins, Gilkes, and Company, and the deliveries in pursuance of those orders. Have you made any effort to take out of the books what were returned by Messrs. Hopkins, Gilkes, and Company?—I have.

11,961. Have you any list of them?—I have not an list of them. The Cleveland Nut and Bolt Company are in liquidation, and they had ever so many books, and what the trustees considered to be unimportant books have been destroyed.

11,962. You said you attempted to take out the returns?—I found out a few returns. I do know where they are. I did not find any large quantity of bolts, but they were chiefly small quantities of rivets.

11,963. If you were taking out a list of the deliveries and a list of the orders, why haven't you brought with you a list of the returns?—Because they were so very few.

11,964. Will you pledge your recollection to any quality that they were as small as I cannot say, I found one or two small quantities. I found some as small as 24 or 25 lbs.

11,965. Have you got the book here from which those returns were taken?—No.

11,966. Why have you not brought it up?—I do not know where the book is now. I got the information from some old books about the place.

11,967. You are put forward as an independent person, and you come and pledge your word to there
being no inspection, and yet you do not bring up a list of bolts returned?—I searched to find Messrs. Hopkins and Gilkes' returns to us, and I could not find that there were any particular matter in question.

11,958. When were you first asked about this?—A month ago.

11,959. Finding, that your own books were not perfect, and that there were some lost, did you apply to Messrs. Hopkins and Gilkes to see whether they could give you a list of the bolts returned?—I was not instructed to do so.

11,960. I asked you whether you applied to Messrs. Hopkins and Gilkes to see whether they could give you such a list?—I did not.

11,961. Did you supply to the Board of Trade the return as far as you had got them?—I do not think I did; they were so small as far as I could find any.

11,972. You say that they were so small you could not pledge yourself to any quantity just now?—(Mr. Trager.) He did particularize some returns. He said somewhere, to the extent of 24 lbs. or 25 lbs.

11,973. (Mr. Webster.) I will put it to you again. Will you pledge your word to the maximum quantity of bolts and rivets returned?—I will not.

11,974. When you informed the Board of Trade that there was no inspection, by which I understand you to mean that there were no formal inspectors appointed, did you inform the Board of Trade also that either bolts or rivets had been returned for defective workmanship?—I do not know that they asked me, or I should have informed them.

11,975. You now say that Jacques' iron was inferior, what have you got by which to identify the bolts or rivets in other than the books in your store?—The order from the Cleveland Nut and Bolt Company to Messrs. Jacques and Company about the same time as we got the order to supply the articles.

11,976. Anything else?—I do not know. The number of the order would be upon the order to Messrs. Jacques.

11,977. How many people did you buy iron from?—We bought iron from Jacques and Company, from Jackson, Gill, and Company, and from Whitwell and Company.

11,978. Anybody else?—And we had at one time some iron from Kirk and Company.

11,979. Kirk and Company, did you have any from Kirk and Company, in Cumberland?—Yes, we bought some from Kirk and Company, in Cumberland.

11,980. Anybody else?—We sometimes bought through merchants.

11,981. Can you tell the Court the quantity you have sold from Messrs. Jacques in any given year that we are dealing with as compared with the quantity from the rest of the people?—Yes, the quantity ordered from Messrs. Jacques and Company corresponded somewhat with the deliveries of bolts.

11,982. That is not my question; what year are you speaking of?—I am speaking of 1874.

11,983. Can you tell the Court how many tons of iron you had from Messrs. Jacques in 1874, and how many you had from the other people?—I think we had 43 tons in 1874.

11,984. You have said that these bolts were made mostly of iron from Messrs. Jacques and Messrs. Jackson and Company; that your reason for supposing you did it from them is because you happen to find a contemporaneous order. Will you be good enough to tell the Court in the year 1874, or six months, or any portion of that year, how much you were having from the five other firms, and how much from Messrs. Jacques and Company?—As far as the books go there is no order of the sort, except from Messrs. Jacques and Company; an inch and an eighth is rather an unusual size.

11,985. Was nothing else at ordered?—Lots of other sizes, but no inch and an eighth from anyone else; so far as the books go, that is to say, so far as I find from the books.

11,986. Do you pledge your word that all the inch and an eighth came from Messrs. Jacques?—I would not go that far.

11,987. What did Messrs. Jackson's supply?—I do not think they supplied any inch and an eighth used for that order.

11,988. I am not speaking of any particular order. You have said, not referring to any particular order, that substantially the bolts and rivets were from Messrs. Hopkins and Gilkes were made from Messrs. Jacques' iron and Messrs. Jackson's iron; do you adhere to that?—I am speaking of bolts particularly; rivets are different altogether. In 1874 the bolts were made, as far as I can learn, from iron supplied by Messrs. Jacques and Company, and in 1875 the inch and an eighth bolts were made from iron supplied by Messrs. Jackson, Gill, and Company.

11,989. Have you anything in your books to show that the 1874 bolts were in fact made from Messrs. Jacques' iron?—No, I have nothing in those books to show that, only that there was no other inch and an eighth ordered of any consequence.

11,990. Now you say of any consequences; have you anything to show that the 1875 bolts were made from Messrs. Jackson's iron?—Yes, the iron was ordered at the time we got the order for them.

11,991. You have said that Messrs. Jacques' iron was inferior; why did you go on using it?—That was a question for the manager to deal with; I had no voice in that.

11,992. You are put forward as the manager in the absence of Mr. Preston. When did Mr. Preston die?—Mr. Preston died about 12 months after the works were closed.

11,993. When was Mr. Preston away from the works?—I went there in 1874, and Mr. Preston was then there.

11,994. You have said that in Mr. Preston's absence you had the whole conduct of the works?—So far as giving directions were concerned.

11,995. Were you responsible for the work being properly turned out, or not?—I was not responsible for all the work being properly turned out.

11,996. Who was?—Bankes and Preston.

11,997. You have nothing to do with it?—I was not responsible; I merely acted in the absence of Mr. Preston; he was not very often absent.

11,998. How is it that you know that Messrs. Jacques' iron was inferior?—Because I have seen it.

11,999. Are you a judge of iron?—Yes, so far as relates to making bolts and nuts.

12,000. Can you explain how it was that Messrs. Jacques' iron went on to be used?—I can give you my own opinion.

12,001. I want to know the fact?—As far as I know, the manager was bribed by Messrs. Jacques, to keep the iron.

12,002. That is what you say?—Yes.

12,003. Did you know it at the time?—No, I did not tell me; I had no idea it was so. I have known money sent.

12,004. I ask you this: did you know it at the time?—It was not within my own knowledge; certainly; he would not be likely to tell me he was going to keep the iron.

12,005. Nobody would suppose that he was going to tell you of it; it came to your knowledge indirectly, or indirectly at the time?—I cannot say if I knew my knowledge indirectly; I know money was sent from Messrs. Jacques to the manager, and we had a lot of iron from Messrs. Jacques, and I wrote and said the iron was bad.

12,006. Do not let us have any reference to a letter unless you produce a copy of the letter; it coming indirectly to your knowledge at the time that Bankes your foreman was being paid to keep bad iron—Not Bankes the foreman, Preston.

12,007. It coming to your knowledge indirectly that Preston was being paid to keep bad iron, did you make any representation to it to your head people?—I was very seldom in communication with the head people at all; the whole thing was left in the manager's
bands; the manager and the foreman had the whole control.

12,009. I ask you this,—Were not the owners of your works in Middlesex every day? —They were, or one of the firm.

12,010. Did you communicate to them, this, the sensation that was going on about the iron? —I did not; I did not communicate to them at one time.

12,011. When? —Shortly before Preston and Banks were discharged.

12,012. When? —I cannot give you the exact date.

12,013. What year? —1877, I think, or 1876; the works were closed, and Preston and Banks were discharged.

12,014. Preston and Banks were discharged from the works being closed? —No, they were discharged, and the works were closed in consequence.

12,015. When? —About 1876 or 1877.

12,016. Which of the two? —I cannot tell you to a few months. —I remember, I had to start the works again; they were closed at Christmas.

12,017. Was it Christmas 1877 or Christmas 1876? —I think it would be 1877.

12,018. When was it the firm failed? —I do not know when they filed their petition; I cannot tell you.

12,019. You have all the books here. Cannot you tell me when the firm failed? —I cannot, because I had left them.

12,020. How long before the works closed did the firm fail? —I do not know; I was not there then.

12,021. When did you first make the discovery to which you have pledged your oath to-day, that the iron sold to Messrs. Hopkins and Gilkes was made of bad iron? —The books show that.

12,022. My question is, when did you first make the discovery? —On searching the books about a month ago.

12,023. Just show me any entry in the books which points to the making of the bolts in 1874, and the supply of the iron in 1874? —Are you talking of the inch and an eighth bolts in 1874 or those in 1875.

12,024. I said 1874; will you give me any entries from your books which enable you to say that these inch and an eighth bolts in 1874 were made of bad iron? —Can you give me the number of the order?

12,025. 15th September 1874; No. 1440? —This is the original order.

12,026. Begin at the beginning of it? —It is 1440; that is Hopkins and Gilkes, No. —"Middlesex, 15th September 1874. Please send goods as under, carriage paid, addressed 'Tea Engine Works, Middlesex,' 9,800 inch and a half (altered to inch and one-eighth) bolts, to our tracing sent August 11th. Bage to be extra strong. Price 2s. per cwt. at our works. To be oiled and packed in bages."

12,027. Do you represent that 211. a cwt, that is to say 211. a ton, is a low price for iron for bolts? —It was about the ordinary price of bolts at the time.

12,028. What would be your prices for various qualities of iron? —I cannot tell you; there are so many different prices and so many details with regard to bolt and making of bolt, that it would be impossible for me to answer accurately.

12,029. If you were to just read the price was to be 211. per cwt, or 211. a ton; of what iron do you pledge your word that those bolts were made on? —I should imagine from that price it would be common iron.

12,030. Can you go any further than that; what were the prices of iron at the time? —There were so many different sizes.

12,031. Listen to me a moment; you say you imagine from that price it would be common iron; the price for these bolts is to be 211. per cwt, or 211. a ton; what prices do you have in your mind when you say that? —You imagine from the price it would be ordinary iron; put the prices down on a bit of paper? —I cannot do that, because I cannot get to know all the details relating to these particular bolts. There is no particular range of prices. The price is given according to the bolt that is supplied.

12,032. You said that 211. a cwt, or 211. a ton was the ordinary price for ordinary iron; will you tell me on what prices you base that judgment, if you do not know the actual prices? —Take iron at 21. a ton.

12,033. In 1874? —I do not know what the price was in 1874.

12,034. Was the price of iron high or low in 1874? —It was tolerably high.

12,035. Tell me how you get at the 211. per cwt, or 211. a ton; take your 21. per ton as the price of iron, what other figures have you in your mind? —There would be something like 2s. a cwt, or probably 5s., for making. I cannot speak positively, because prices have altered so; I have been unable to get any books that would throw any light upon that.

12,036. Is it not the fact that the figure you quoted just now, namely, 5s. a cwt, is about the price for making? —As far as I can recollect, but the price paid for making would be per gross probably, and it is difficult to find what that would work out.

12,037. Then what figures had you in your mind when you said that the price of 211. a ton would be the price for ordinary iron? —I cannot give you the exact details.

12,038. On what do you form your judgment? —I have no doubt there were other orders about the same time.

12,039. You have been put forward as a witness who is coming to suggest that these bolts and nuts were made of inferior ordinary iron. I ask you to tell the Court what figures you had in your mind when you pledged your oath that the 211. a cwt, was paid for ordinary iron? —I am not in a position to go into any detail; it is only my own idea of it; I cannot go into all the details. If I had one of the bolts I could find out exactly what it cost to make.

12,040. Just address to me for a moment: Is a ton the figure you gave just now for the iron, 211. a ton would be the figure that Hopkins and Gilkes paid you for making, that would come to 141.; how do you account for the difference of 71.? —There are various items to be considered, the bolts have to be frayed and washers and nuts would have to be supplied.

12,041. Would that be beyond the 5s.? —Yes.

12,042. Give me the items? —I cannot.

12,043. Can you give me the money of them? —No, and no one could. If I had a bolt complete I could tell you what it cost to make.

12,044. Is it not the fact that the 5s. per cwt. or 5s. per ton covered everything except the iron? —No, it did not.

12,045. Will you swear that it did not? —No, I will not swear it, because, as I say, I have not been able to get hold of one of the bolts.

12,046. Now, you know I press you upon this matter. You have given me 5s. a ton and you have given me 51. a ton, will you pledge your oath side by side with these other facts, that that 211. a cwt, is for ordinary iron, and bad iron as you have said? —But iron has been going down and down continually from the time that order was given.

12,047. But I am speaking of 1874. Can you give me any figure, either in shillings or pence, to make up the difference between the 141. and the 211.? —There would be the fraying to be paid for.

12,048. How much would that be? —I cannot tell, because I cannot get hold of the figures in the books; but the nuts would have to be supplied, and the washers would have to be supplied, and the wear and tear of material, and the coal that would have to be used would be an element.

12,049. Now just listen to me a moment. Will you turn to the order which you say shows that there 8,000 bolts were made of Jacques' iron? I have here a copy of an order to Jacques and Company three days after we got the order.

12,050. Give me the date, please? —September the
12,063. Do you know?—I will not say positively.

12,064. You say that you have not found any orders of the kind you described?—I have not, and I do not recollect positively.

12,065. Then you did not put your book in order before the delivery is required. —Shortly after we get the orders.

12,066. Did you inspect the iron or not?—I did.

12,067. Did you yourself inspect the iron or not?—I did.

12,068. Did you yourself inspect the iron or not?—Yes. I find these 18 tons.

12,069. You say now that you ordered it. —This is iron you ordered, but I do not recollect positively.

12,070. You know if you look through the whole of the books and I cannot find the iron?

12,071. You know from Mr. Webster.

12,072. You said 15 tons when you were examined a few moments ago, and you gave that as a reason for its corresponding with the 12 tons 13 cwt.; now it comes to 18 tons; will you undertake to say that there is no more than 1½-inch iron through the books?—I do not think so, so far as I can find it.

12,073. What is the date of the last 8 lots?—The 29th of September.

12,074. Is it your practice to get the iron shortly before the delivery is required?—Shortly after we get the orders.

12,075. Not shortly before you get the delivery?—It varies.

12,076. Can you tell us how long before these bolts were delivered they were made?—I am not sure whether I can; unfortunately the books which would have given every information have some of them destroyed: there were some 1½-inch bolts made in September, and some in October.

12,077. You know if you look at the delivery book that they are delivered in even numbers of bolts, but in rather peculiar quantities; and it runs from October 1874 to June 1876; how long before they were delivered do you think that these bolts were made?—I cannot tell at all; there is no record at all to go by; this is the only wage book that I can find which bears upon the case. I have searched very diligently through the whole of the books and I cannot find anything else.

12,078. Have you anybody here who inspected either of the five tons or the eight tons of iron which came from Messrs. Jaques in September 1874?—Yes, there is the iron store keeper.

12,079. Who is that?—Lister.

12,080. Is he here?—He is.

12,081. Did you yourself inspect it?—I did not; it was the duty of the iron store keeper to bring samples of all iron into the office.

12,082. Did you inspect that iron or not?—I did not see it in trucks, and I am not sure that I saw samples of it.

12,083. Do you pledge your personal statement to the fact that either of these lots of iron were bad?—There is a letter here which I wrote.

12,084. Do answer the question. Do you pledge your personal statement to the fact that either of these lots of iron were bad?—There is a letter here which I wrote.

12,085. Do you not remember it?—With so many transactions always going on it would be impossible to remember it.

12,086. Now, will you give me what it is that leads you to say that the first lot was bad; turn to the letter?—On October the 5th we wrote to Messrs. Jaques and Company: 'We are sending by rail a sample of 1½-inch iron, which we dare not use, and consequently have not unloaded the truck.'

12,087. Do you know if that iron was taken?—I do not.

12,088. And you do not know which that refers to either?—No, I do not; it applies to the 1½-inch iron from Messrs. Jaques.
12,089. I am quite aware of that. Now, when was the iron which was quite ordered on the three dates the Commission has taken down, I think the 15th, the 26th, and the 30th, actually delivered?—I do not know.

12,090. How long, in the usual course, would the iron be delivered after you had ordered it from Messrs. Jaques?—It might be rolled on the next shift, or it might not be rolled for a month.

12,091. Is that your or Mr. Preston’s writing?—It is in my writing; the initials are G. N., George Nessan.

12,092. Then this was the iron which you complained of and dared not use, but you do not know whether it was used or not?—I do not know whether it was used or not.

12,093. Now, will you tell me what scrap of evidence you have before you upon which you come here and say that the iron from which those bolts were made was bad?—Because there was nothing but common iron, ordered from Messrs. Jaques and Co., 1/- each.

12,094. But you do not know the price?—But there was nothing said upon the orders to stipulate that it should be better iron.

12,095. What price did you pay for the iron?—I think the price was 9/- 10d. a ton for ordinary bars.

12,096. I do not ask the price for ordinary bars, but what price you paid Milas. Jaques?—I do not know that.

12,097. Was it as a common thing in your orders to specify the quality of the iron?—If we wanted “best” iron we should specify it.

12,098. Can you tell me what the price of “best” iron was in September 1874?—Supposing the price of common iron to be 9/-, it would be 30/- above that.

12,099. Therefore about 10/- 10d. was it?—Yes.

12,100. You cannot give me nearer than that?—No.

12,101. Were any samples kept of the iron as delivered to you from which your work was done? You say it is the duty of the store keeper to bring it into the office?—These samples were kept until a heap accumulated, and then a man would be sent for, and he would put it upon the scrap heap.

12,102. You have not now got any of the samples which were supplied in 1874?—We have no means of getting them.

12,103. You have not got them?—No.

12,104. How was the iron sent across to Messrs. Hopkins, Gilkes, and Company; was it sent across by them coming and sending a truck for it, or sending anything for it, or did you send it over to their works?—It may be that we would send souce, and that they would send for some.

12,105. You do not know which?—Not exactly.

12,106. Assuming Mr. Preston was there, and Mr. Bankes there, what were your duties then?—I had the correspondence to see to, and any matters relating to the business which cropped up, which Mr. Preston liked to give me to do.

12,107. It amounted to this, that when Mr. Preston was there your work was office work?—If any people gave me their orders or wrote about their orders I went down to the works and found out how things stood.

12,108. Then, in effect, unless Mr. Preston gave you anything to do, your work was office work or making inquiries and writing letters in reply to letters you received?—Yes.

12,109. And Mr. Bankes was responsible?—Mr. Bankes was responsible mainly.

12,110. Where is he?—I have got his address.

12,111. Where did you get his address from?—I have no recollection.

12,112. I have been told by Mr. May that he was working in the Forest of Dean.

12,113. Counsel applied that in the absence of Mr. Bidder the witness might be recalled in the event of his desiring to examine the witness.

12,114. Mr. Trayner submitted that it would be extremely inconvenient to re-examine until the cross-examination was completed.

12,115. (The Commissioner.) Under those circumstances I think I should not call upon Mr. Trayner to re-examine now. Mr. Trayner would rather examine of course after Mr. Bidder’s examination.

12,116. Mr. Webster stated that he thought it improbable that Mr. Bidder would desire to cross-examine the witness.

Further examined by Mr. Trayner.

12,117. Your duties when Mr. Preston was there were principally office work?—Yes.

12,118. Mr. Preston was a practical bolt and nut maker, I suppose?—Yes; he was a practical bolt and nut maker; he was not a working man; but he had learnt the business.

12,119. But you had acquired a sufficient knowledge of this work and the manufacture of these particular articles to enable you in his absence to go intelligently to the works and inquire after any matter that might be required, and see after things?—Yes, I have learnt the business at a pattern bolt and bolt manufacture. I may say in proof of that, that after Mr. Preston left—

12,120. I am quite satisfied of your experience, and nothing has been said against it. Now you have been asked about the return of bolts; you supplied a great many bolts to Messrs. Hopkins, Gilkes, and Company?

12,121. Yes, a great many.

12,122. And if there had been any large returns you would have been aware of them?—I imagine some of their people would have come to the office, but I do not recollect their doing so.

12,123. And would it not necessarily have appeared in the office some way or other that bolts were returned?—Yes, it would.

12,124. But if only a few were returned, they might not appear?—They should have appeared, but if they were only a few they probably would not.

12,125. You have no interest in this inquiry?—Not the slightest.

12,126. You have given up the books and letters which would assist the Board of Trade?—Yes.

12,127. And you are ready to supply Messrs. Hopkins, Gilkes, and Company with any information the books or your own self can afford?—Yes, I should only be too happy to do so.

12,128. Your books, so far as you can find, do not indicate any returns of bolts by Messrs. Hopkins, Gilkes, and Company as being of bad quality?—So far as I can find they do not.

12,129. Have you any doubt that if there had been any returns of bolts and nuts as being of bad quality to any appreciable extent you would have found it either in the books or elsewhere?—I think so, but it may have been that Messrs. Hopkins and Gilkes would have sent them back with a debit note, without saying what they were returned for; they may have been received too tight, or too big, or not big enough.

12,130. But the fact of their being returned in any quantity would have appeared?—Yes.

12,131. Do you find from the books which are present in your control any evidence whatever of bolts being returned from one cause or another?—No, I do not.

12,132. I cannot find it from the books at all.

12,133. Do you think that it is possible that there could have been any large returns of bolts for any reason without it having appeared in the books which are under your control at this moment?—It should not have been so, and I do not think it would have been so.

12,134. Then I suppose that so far as your knowledge goes, separate from inferences, no bolts were returned; you know of no bolts being returned by Messrs. Hopkins, Gilkes, and Company?—I do not say that exactly; I should rather have thought there were little lots of both returned, but I do not say they
were returned for being bad; they may have been returned to be altered.

Do you know any one in which Messrs. Hopkins, Gilkes, and Company returned any of the bolts ordered by them for the Tay Bridge on the ground of their being of bad quality or inefficient manufacture?—I have not found any such entries.

And so far as you know that never took place. So far as I know.

If it had taken place to any considerable extent you would expect to find it mentioned in the books?—I should.

And from your knowledge of the mode in which the works were conducted, you would have been conscious of it, if it had been the fact?—I should.

And do you not remember, and are not conscious of any such fact?—I am not.

You have referred to a good many orders and letters about Jaques' iron; were you ordering any 14-inch iron at that time from anybody else but Jaques?—According to the books we were not.

And if they had been ordered from anybody else it would have been in the books.

The orders to Jaques and Company for 14-inch iron are all in the books?—Yes.

And regularly entered?—Yes, and regularly entered.

Have you any doubt that if your firm had ordered 14-inch iron from anybody else it would have appeared in the books in the same way as orders to Messrs. Jaques and Company?—It would at that time; in 1874 we were ordering a large quantity of iron from Messrs. Jaques.

But not 14-inch iron from anybody but Jaques?—No.

So far as you know there any iron in the Cleveland Company's store out of which they could have made the 14-inch bolts for the Tay Bridge, except the 14-inch iron supplied by Messrs. Jaques?—I have searched, but cannot find the iron stock book, and cannot therefore find whether at the time there was any 14-inch iron in stock or not.

Have you any orders for 14-inch iron except for Hopkins and Gilkes' bolts?—I think not.

Would you have ordered 14-inch iron if you had been supplied 14-inch iron in your store at that time?—No.

Have you any doubt that that was ordered from Messrs. Jaques and Company to enable you to fulfill Messrs. Hopkins, Gilkes, and Company's order?—That is my belief.

And further than that, you believe it was so, and believe it was so used.

Now you are asked about the price of the iron, being 21s. a cwt., which you said lead you to believe that it was ordinary iron. Can you not tell me from your books at what price you were supplying rivets or bolts at that time of superior iron to anybody else?—The book will give us some idea.

The book will give us some idea.

You can find any orders for bolts at that time, and tell us the price and the quality of the iron, keeping about that size. (The witness referred to the books.)

Before you find that, let me ask you this question.—Is 1½ inch an unusual size?—Yes.

Now, if you can, give me any order about the date of September 1874 for bolts about the same size—say an inch—of better quality iron?—There is an order on. September 24th, 1874, from Messrs. Swan, Coates, and Company, for 2 cwt. of bolts; they are a different class of bolts, inasmuch as they have square heads; they were square heads and square necks; and we charged them 22s. 6d. a cwt.

What I want to get at is the quality of the iron?—That is ordinary iron, but the additional price is for the small quantity, and 1s. 6d. a cwt. extra for the square heads.

We need not go into that; but upon the 18th of September 1874 you got and accepted an order for 9,800 3⁄4-inch bolts at 21s. a cwt., and from that infer that it was common iron that was used?

Yes.

Will you tell me the price you charged about that date for bolts of about an inch, of iron of a superior quality to common iron?—I do not know that I shall find anything.

You never found it?—I will look with pleasure, but I do not think there is anything of that sort here.

In the course of selecting the documents you were requested to find for the Board of Trade, you have looked over Messrs. Hopkins, Gilkes, and Company's orders. Do you find in any of them an order for bolts to be made of iron of a superior kind?—No; they merely say they are to be good, with the exception of the rivets to be made from the Low Moor iron.

And there being no specification of their quality your opinion is that they must all have been made of common iron, that being the practice of the trade when better iron is not specified?—Certainly.

Now just one question more. You told me before that there was no inspection by Messrs. Hopkins and Gilkes so far as you know?—So far as I know.

You know what I mean by the term "inspection"?—It is a common term, is it not, in your trade?—If a man comes to inspect bolts we understand that he tests the quality of them.

And if you accept an order to make bolts subject to the inspection of A. B., that imports to you that A. B. is to test the quality, and to be satisfied with the bolts in every way?—Yes.

And when you have such an order as that it is customary for the persons so named to come to the works and test the work that is to be made subject to his inspection?—Yes, in all its stages.

So far as you are aware, did Messrs. Hopkins and Gilkes ever send and inspect or test the bolts in that manner?—I am not aware that they did.

Do you think it possible that they did?—I am not aware that they did.

They have used without mention of inspection the bolts you have used without mention of inspection?—Yes.

That might be for a different purpose. As bolts of about an inch of iron of a superior quality to common iron?—Yes.

You infer that it was common iron?—Yes.

Now just one question more. You know what I mean by "inspection"?—I will not discuss that.

Are they never inspected at all times, as Messrs. Hopkins and Gilkes are never sent to inspect or test the bolts?—They never.

If you have accepted an order, did Messrs. Hopkins and Gilkes ever send any inspection by them?—They never inspected any.

You know what I mean by "inspection"?—I will not discuss that.

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You know what I mean by "inspection"?—I will not discuss that.
12,170. How much more?—I cannot say, because it would just depend upon the amount of waste in them.

12,171. But upon the average?—There would be something over 5 per cent. of waste.

12,172. But it would be a fair quantity to order for 9,000?—It would be rather in excess of the number, but it may be that we had no 1½-inch iron in stock at the time, and when ordering we would order some six or eight tons more to have some in stock, because if we ordered five tons from the works it would make a shift in the mill.

12,173. At any rate, it would be a fair quantity to order for the 9,800 bolts?—Yes.

12,174. And that is the reason why you think that order from Messrs. Jacques and Company was intended to supply the bolts to complete this order?—Yes.

12,175. When you get an order to make bolts subject to inspection, do you charge more?—It is usually considered that something extra is ordered when they are wanted to be inspected.

12,176. What do you mean by that?—Something of extra quality.

12,177. When then it is only ordinary quality it is not the practice to say "subject to inspection"?—No.

12,178. Then what you mean by "subject to inspection" is, when something superior is ordered, and it is only when something superior is ordered that inspection is stipulated for?—That is the rule.

12,179. You said that you had made bolts for almost every railroad in the world; now you have made them, I suppose, for work of this kind for girders and so on?—Yes, but it was not always stipulated what the bolts were for and we did not inquire what they were for, we were told to make them to stand a certain strain or to be made of a certain quality of iron.

12,180. It is usual in works of this kind from your own knowledge as a pattern bolt maker to make them of the Cleveland iron?—For bolts which have to stand any extra strain it is usual to make them of—

12,181. Low Moor iron?—Not; not of Low Moor iron, but they are frequently ordered to be made of iron equal to best Staffordshire, or of iron equal to Low Moor, or to stand a certain test.

12,182. I see in the specification it states "all bolts to be made of Low Moor iron of or such other iron as shall be specially sanctioned by the engineer." Now you are quite clear that the iron you supplied in this case was not the Low Moor iron?—It was not.

12,183. And you say it is not usual to supply the Low Moor iron?—It is not.

12,184. Was it the same iron which you generally supply for this purpose?—When ordinary.

12,185. You made a great number, you know; will you kindly answer the question; was it the iron of which you made the bolts upon this occasion the ordinary iron which you generally supply for that purpose?—It was.

12,186. And the bolts generally made would be made of the same quality of iron that you were then supplying?—They would.

12,187. You would not then generally make these bolts either of "best," or of "best best," or of "best best best"?—No, we would generally make them of ordinary iron, unless we had distinct orders to the contrary.

12,188. I suppose in every large order you always have some small lots returned to you, do you not?—Yes, very frequently for some cause or other.

12,189. (Colonel Yolland.) With regard to the 18 tons used for making those bolts of 1½-inch iron, did that quantity, which you referred to in your letter of the 3rd of October, as that which you dared not use, form a part of the 18 tons?—That is my impression.

12,190. You are not certain?—I am not certain, but I have not much doubt, because there was no other 1½-inch iron about as far as I can find.

12,191. I think I understand you to say that you cannot say that that was returned?—I do not know.

12,192. You do not know whether it was used for the making of those 9,800 bolts, or whether it was not?—I searched to find whether it had been recharged to Messrs. Jacques, and I could not find that it had.

The witness withdrew.

Mr. George Wingate spoke.

12,204. The fact that it got so easily into the water and ran in that way through the works in the quarry showed to you that it was not good quality iron?—It could not be used.

12,205. If it had been good iron it would edge the heating have still remained in such a condition as the men could have worked it; it would not have run through these quarries?—No, the work could have been made good.

12,206. I suppose you know about bolt making?—Yes.

12,207. Did you see the bolts that were made, generally speaking, by the Cleveland Company?—Yes, some hundreds of tons I have seen made there, of all kinds of bolts and nails.

12,208. Did you see any part of the bolts that were made for the Tay Bridge?—Not to my recollection.

12,209. You know, I suppose, that they were making bolts for the Tay Bridge?—Yes.

12,210. But you never saw anything that you were aware of as being a parcel of bolts going to that special job?—No, I did not.

12,211. Now about this iron that you saw, was it of such a kind that the workmen could not make a good bolt of it?—Sometimes.

12,212. The iron that ran through the quarries was such iron that they could not have made a good bolt of it?—No.

12,213. Just tell me what it was which the workmen did not do to the bolts in consequence of the character of the iron?—In consequence of being over-heated, there would not be sufficient iron when
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12.214. They put in a piece of iron to heat it up to a certain state to make a bolt?—Yes.

12.215. But in consequence of the inferiority, part of the iron escaped through the quarries, and consequently there was not metal enough left to make a good bolt?—No, it was thrown away for scrap.

12.216. What had run away?—Yes.

12.217. But did you see any of these bolts packed up and sent away?—No.

Mr. Macorcy stated that he had no questions to ask the witness.

Examined by the Commissioner.

12.218. Let me understand what you mean. Do you mean to say that all the iron which was used when you were at the Cleveland Company's works was unfit, and of an inferior quality?—No, good and bad; there have been as good bolts made there as any in the world, and there have been inferior at the same time.

12.219. Can you tell me when it was that it was inferior?—During the time of my services there: I could not give you any dates.

12.220. But your services extended from 1868 to 1875?—Yes.

12.221. Was it more generally bad or more generally good?—Generally good.

12.222. What was it that was bad—what sized bolts?—From 3 inch to 4 inch in diameter—that is to say in the thickness of the iron.

12.223. Do you mean to say that these were bad bolts?—Yes.

12.224. And which were the good ones?—There were good and bad too; from any order that came to the works there might be good and bad at the same time, through the over-heating of the iron.

12.225. Was that your fault?—No.

12.226. Then whose fault was it that the iron was over-heated?—The boys who heated the iron at the furnace.

12.227. It was the same quality of iron, but it was dependent on the heating of the furnaces?—Yes.

12.228. Then you regulated the heating of the furnace, did you not?—Yes.

12.229. Then if you regulated the furnaces, you were responsible for the over-heating, were you not?—No, it was the fault of the boys; they were fined for doing so. I had to report it to the manager of the works.

12.230. Did that happen frequently or not?—Constantly; it was an everyday occurrence.

12.231. That it was over-heated?—Yes, it could not be avoided. Sometimes they had to stop in consequence of something happening to the machine, and there would be blank ends, as we call them, in the perforated fire-brick, and they got heated so that the boys could not draw them away.

12.232. But was the iron that you had to use a bad quality of iron?—It was good—and bad. I have had some of the best iron there.

12.233. And you could not say which was good and which was bad?—No.

12.234. (Mr. Barlow.) Nor which was used for the Tay Bridge?—No, I do not recollect anything of that.

The witness withdrew.

Adjourned till to-morrow at half-past 10 o'clock.

ELEVENTH DAY.

Tuesday, 20th April 1880.

(The Commissioner, to Mr. Trayner.) Will you kindly explain to the Court what these documents are that you have given in. I see the first is "Copies of Orders sent by Messrs. Hopkins, Gilkes, and Company to the Cleveland Nut and Bolt Company," limited. Then the next is "Copies of Messrs. Hopkins, Gilkes, and Company's Orders to the Cleveland Nut and Bolt Company." What is the distinction between the two?

(Mr. Trayner.) I think if you will look at the first, Sir, you will find it is "Copies of Orders sent by Messrs. Hopkins, Gilkes, and Company," that is, of letters written by Messrs. Hopkins, Gilkes, and Company, giving the orders. The second document, which is entitled "Copies of Messrs. Hopkins, Gilkes, and Company's Orders," are excerpts from the books of the Cleveland Nut and Bolt Company, showing first what the order is, and then the weight, price, and date of delivery; in short, showing how the order was carried out. It would be incorrect to deal with that second document as copies of Messrs. Hopkins, Gilkes, and Company's orders absolutely. It would be better, I think, to say, "Excerpts from the books of the Cleveland Nut and Bolt Company, showing what those orders were."

(The Commissioner.) In fact, there is a difference in the second part?

(Mr. Trayner.) In this way: That you have in the first document the order itself given with the details, and in the second document you have the details of how the work was carried out by the persons to whom the order was given.

(The Commissioner.) From entries in the books?

(Mr. Trayner.) Yes.

(The Commissioner.) Then there are copies or quotations made in writing by Messrs. Hopkins, Gilkes, and Company, as well as the answers of the Cleveland Nut and Bolt Company to Hopkins, Gilkes, and Company?

(Mr. Trayner.) Yes, Sir.

(The Commissioner.) Then there are other documents acknowledging Messrs. Hopkins, Gilkes, and Company's orders. What is that?

(Mr. Trayner.) Those are acknowledgments by the Cleveland Nut and Bolt Company acknowledging the receipt of the orders in the first document that you have referred to.

(The Commissioner.) Then the last document, except the first page of it, refers entirely to objections to the quality of the iron?

(Mr. Trayner.) That is so.

(Mr. Macorcy.) While we are on the question of these excerpts, I think the Court must see that we have had no opportunity of verifying these statements by the books; and, therefore, I presume, in case it should be necessary for us to examine and verify them, my learned friend, Mr. Trayner, will afford us an opportunity of examining the books.

(Mr. Trayner.) I have no control over these books at all; but any facility that the Board of Trade, through me, can afford, will be afforded.

(Mr. Macorcy.) That is quite sufficient. These documents, Sir, have just been put into our hands, without any notice.
(The Commissioner, to Mr. Bidder.) Do you wish to ask Mr. Noble any questions?

(Mr. Bidder.) I have only just received the minutes of yesterday's evidence, and if you will be kind enough to let it stand over until after lunch, I think I shall not have to ask Mr. Noble many questions; and my friend, Mr. Trayner, says that it will suit his convenience.

(Mr. Trayner.) For to-day. Do you want to cross-examine Mr. Hadland?

(Mr. Bidder.) No.

(Mr. Trayner.) Then he may go.

(The Commissioner, to Mr. Macrory.) Your clients, I presume, will be able to verify these documents by their own books?

(Mr. Macrory.) Yes, one portion of them; but as to such of the orders as appear in the books of the Cleveland Nut and Bolt Company, we shall not be able to do so.

(The Commissioner.) I mean substantially, they will be able to do so?

(Mr. Macrory.) Yes. In making that application Messrs. Hopkins, Gilkes, and Company are as anxious that the truth should come out as anyone else. It is not in any hostile spirit.

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Elijah Coburn sworn.

Examined by Mr. Trayner.

12,233. You reside at Middlesbrough, I believe?—
Not now; I reside at Mashorugh, and am working at Rotherham.

12,234. What is your occupation?—A tap and die maker, for screwing.

12,235. How long have you been so?—About 35 years.

12,236. When did you go to the Cleveland Nut and Bolt Company of Middlesbrough?—I believe it was in 1871.

12,237. How many years did you work there?—About three years, the first time.

12,240. How long were you away?—I was away about 15 months.

12,241. And then did you return?—Yes, in 1875.

12,242. And then how long did you remain the second time?—Till it closed.

12,245. What was your position in the Cleveland Company's works?—I had the screwing shop under my control.

12,244. You and your son, Elijah Coburn, junior?—Yes.

12,245. And made taps and dies for all the screwing and tapping?—Yes.

12,246. Just tell me what is a tap and what is a screw thread?—What we tap the nuts with, through the nuts, to put the threads in.

12,247. And the die is that of which you put the thread on the bolt?—Yes.

12,249. Do you remember a lot of 1\(1/2\)-inch bolts being made for Messrs. Hopkins, Gilkes, and Company?—Yes, there were many of them there?—Yes.

12,250. Did you know what job they were for?—We were told they were for the Tay Bridge; our foreman told us so.

12,253. Mr. Preston was foreman, was he?—He was manager; Mr. Banks was the foreman.

12,254. Were they several lengths, or all of the same length?—Several lengths.

12,255. Can you recollect what the lengths were?—I cannot exactly; from about 4\(1/2\) to 5\(1/4\) I think.

12,256. Is 1\(1/2\)-inch an unusual size?—Yes. There were not such a great many of them; we do not make many of 1\(1/2\)-inch generally.

12,258. What were the bolts made of; what kind of iron?—I believe they were made of Cleveland iron.

12,259. You know the qualities of the iron, I suppose?—Yes.

12,260. So that you can tell us?—Yes, when we are screwing it.

(Mr. Bidder.) Had this witness anything to do with making the bolts? I understood that he made the taps and dies.

(Mr. Trayner.) He must have had the bolts in his hand to do that.

(Mr. Bidder.) That does not follow.

12,264a. (Mr. Trayner, to the witness.) Had you the bolts in your hand at all?—Yes, when we put the bolts in—try the tool.

12,266. Those bolts that you did see, and which you were fitting with nuts, were made of this Cleveland iron, were they?—I believe they were.

12,268. What kind of iron screws is softer than another; is the better quality softer or harder?—Do not ask the better quality of the iron, the better it will screw.

12,269. Is common iron as well rolled as iron of better quality?—Not in a general way, because there is more inside.

12,270. Do you get as good a thread out of common iron as out of a better quality of iron?—Yes, unless the iron should break or peel off when it has not been welded sound.

12,271. Did you ever make any complaint to Mr. Banks about the quality of the iron of which the bolts were made?—Yes; if we had any one break we would show it to him, and he would tell us to put it on one side, and it would be sent to scrap.

12,272. Were the bolts that you saw common forged bolts?—Most of them were made on the machine.

12,273. Were they faced at the place where the nut goes on with the lathe?—Do you mean, painted?—12,274. No; faced. Was the under side of the nut faced?—No, only brazed—none of them—they were brazed in the lathe.

12,275. I mean faced, the bearing made quite clean and straight with the machine?—Not in our works; they were not.

12,276. Were the bolts turned?—No.

12,277. Did anyone from Messrs. Hopkins, Gilkes, and Company ever come, so far as you know, to inspect those bolts or nuts?—No, I never saw them.

12,278. Have you seen inspectors from other companies and other works coming over to inspect the same kind of work?—Yes, we had inspectors for all kinds of work, the Indian State Railway, or anything like that.

12,279. In some work that was going on they had inspectors?—Yes.

12,280. But so far as you know, no such inspection took place on behalf of Messrs. Hopkins, Gilkes, and Company?—Not that I am aware of.

Examined by Mr. Macrory.

12,281. You say that no one came from Messrs. Hopkins, Gilkes, and Company that you saw?—Not that I saw.

12,282. Were they never inside the works?—Yes.

12,283. You say that no one came from Messrs. Hopkins, Gilkes, and Company to inspect the works at the Cleveland Nut and Bolt Company for that quality of iron; you know; no such inspection took place on behalf of Messrs. Hopkins, Gilkes, and Company?—Yes.

12,284. In making such a large order for the buildings of the Indian State Railway, or anything like that, you would have seen them?—Yes.

12,285. Where about were the Messrs. Hopkins, Gilkes, and Company's works?—The opposite corner from ours.

12,286. You say that you had inspectors for other works—the Indian State Railway, for instance, you say?—Different railways.

12,287. Was that to inspect the bolts and nuts?—Yes.

12,288. You say that they came to inspect different work—other work?—The nuts and bolts that we had. We did not make many more things but those.

12,289. In all those cases where inspectors came, they were from persons who had not works in Middlesbrough; for instance, they were from a distance?—Yes.
MINUTES OF EVIDENCE.

12,279. From looking at a bolt casually, would you be able to say whether it was good iron or not?—Not without I saw it tested.

Further examined by Mr. Traynor.

12,280. Was it a very good way to test the quality of the iron by putting a thread on it?—That would not test the iron at all.

12,281. Not its quality?—No; it would be so if it spread or broke or peeled off, but screwing it will not tell you.

12,282. Did many of the bolts that came to you peel off or break?—Very few; there might be a few.

12,283. You said that one man came from Messrs. Hopkins, Gilkes, and Company?—Yes; that was for the rivets, but I had nothing to do with that.

12,284. No one came from Messrs. Hopkins, Gilkes, and Company about the bolts?—Not to me, they did not.

The witness withdrew.

ELLIAS COBURN, jun., sworn.

Examinied by Mr. Traynor.

12,285. You are the son of the last witness?—Yes.

12,286. A tap and die maker?—Yes.

12,287. How long have you been at the work?—As near as I can tell nearly 16 years; since I was a little boy.

12,288. You served your time to a Patent Nut and Bolt Company in Birmingham, and your father was then also, was he not?—Yes.

12,289. How long did you work there?—At different times. I think, I was there about six or seven years.

12,290. And you afterwards worked for the Cleveland Nut and Bolt Company?—Yes.

12,291. For how long?—For about five years, as near as I can recollect.

12,292. You were there when it closed?—Yes.

12,293. Assisting your father in making taps and dies, and managing the screwing shop?—Yes.

12,294. Do you remember a lot of 1/2-inch bolts, for which you made the screws and the taps and the dies?—Yes.

12,295. For Messrs. Hopkins, Gilkes, and Company?—Yes.

12,296. Did you know where they were going?—It was an understood thing that they were for the Tyre Bridge.

12,297. It was generally understood at the works?—Yes.

(The Commissioner.) It is not denied, is it? (Mr. Macready.) No.

12,298-9. (Mr. Traynor.) How were the bolts made, were they machine-made or hand-made?—I believe most of them were made by machine.

12,300. Where the nuts faced?—No, not what you would call faced; they were frayed.

12,301. They were not faced with the lathe?—No.

12,302. You say they were frayed—when you have made a thread in a nut, that leaves a certain protuberance on the face of the nut; does it not?—No.

12,303. When you have made the thread in the nut, does not it leave a slight protuberance on the face of the nut—originally a Burr?—Well, it would be very slight, and we should not take much notice of it.

12,304. What do you mean by saying that the nuts were frayed?—When the nuts are cut by machine it leaves—what we call a rough fraze on the face of the nut; then that is put upon the table and roughly taken off with a cutter.

12,305. That was what was done with those nuts, but they were not faced with the lathe?—Not to leave a surface on them.

12,306. You saw some of the bolts, I suppose?—Yes.

12,307. What kind of iron were they made of, could you tell?—I could not tell; only the ordinary iron; the same as we generally use.

12,308. Did it present all the appearances of the ordinary iron used for bolts?—Yes.

12,309. Was it all of one size?—There would be a slight difference in the size of the bars, but not to any great extent.

12,310. Did that make any difference in the case, with which you got a good thread in the nut or in the bolt?—Yes, it made a slight difference; sometimes the iron was better and eased it off.

12,311. What was the effect upon your work of having the iron a little larger than usual?—We could not screw them so easily. When the iron was large we had to alter the tools to fetch it up, to force the thread, and not to take any more than we could help.

12,312. You did not get as good a thread as if the iron was of smaller size, is it?—If we had a bolt of iron come in and it was large, it would destroy our tools sooner than if it was of the regular size; then we made the tools larger to suit.

12,313. My question did not point to that, but it-pointed to the effect it had upon the thread that you produced on the iron itself. Now did you get the best thread on iron of the ordinary size, or on iron that was larger than that?—We would make them all with a good thread.

12,314. If the iron was smaller than usual would you get as good a thread?—Yes.

12,315. What is the difference between machine-made bolts and hand-made bolts?—There are some sorts of bolts not so good made by machine as by hand.

12,316. Were those 1/2-inch bolts as well made by machine as by hand?—No.

12,317. Why, in your opinion, would they have been better if they had been made by hand?—If they had been made by hand when the head was put on, the man that made it would take care to make it straight. On the machine they cannot make a square or a hexagon head so straight as by hand, as it has to be squared up, and the head has to be knocked on one side till it comes straight as near as they can get it, and that causes a fracture under the head.

12,318. Under a strain, that head would fly off?—Yes, it would fly off sooner than if it was left to stand as it was made.

12,319. Did anybody come from Messrs. Hopkins and Gilkes' office, as far as you know, on their behalf to inspect the bolts?—Not as far as I know.

12,320. Did any of their people come to your works while you were there at any time?—Not that I know of.

12,321. Do you know that other people, who were getting work done of the same kind, were sending to have it tested and the bolts inspected?—I never remember anything of the same description being there.

12,322. The same 1/2-inch?—No.

12,323. You were making plenty of bolts for different people; were those bolts inspected by the other people for whom they were being made—did you ever see inspectors looking at them?—Yes, several—not looking at the 1/2-inch bolts, but for other companies.

12,324. Those people for other companies were inspecting the bolts that the other companies had ordered?—Yes, for themselves.

12,325. But Messrs. Hopkins, Gilkes, and Company, so far as you know, never sent anyone to inspect the bolts that they had ordered?—No.

Examined by Mr. Macready.

12,326. With regard to the inspections at your works, how long were the inspectors from the other
companies usually at your works?—Do you mean through the day?

12,327. Yes, how long were they there—from day to day, the time that you were making the bolts?—It was just according to how long the order lasted.

12,328. While the order was lasting?—Yes.

12,329. What was the longest time you had had an order on hand for, say, the Indian State Railway?—As near as I can tell, I think we had one on hand for the two or three years.

12,330. During those two years, how long were the inspectors from the Indian State Railway inspecting the bolts that were there?—Sometimes they would be there for a week; they would come every day, and then perhaps for a few days they would not come.

12,331. Did they come from time to time at two or three days during the two years the order was on hand?—Yes.

12,332. What were they inspecting while they were there?—They were there to test the iron for their own company.

12,333. What was the iron for; what was it to be used for?—Bolts and spikes for railways.

12,334. You say that during the whole of those two years while this order was on hand, as intervals of two or three days, the inspectors were there?—Yes.

12,335. Did you see them?—Yes, I did.

12,336. You said that bolts made by machine are not as well made as when they are made by hand. Did you know that the Cleveland Nut and Bolt Company made many bolts by hand?—Yes, a great number of bolts were made by hand.

12,337. A great number were made by hand there?—Yes.

12,338. Where were there a great many more made by machine than by hand?—Yes, there were more made by machine than by hand.

12,339. What proportion?—I cannot say.

12,340. How many machines had you at work there—bolt machines?—Sometimes I think about four; four men making bolts, as a rule.

12,341. With one machine?—Yes.

12,342. Can you give the Court any idea of how many bolts in a day these machines would turn out?—It depends upon what sort of bolts they were making.

12,343. Take the ordinary run of bolts?—I have seen the men make 20 gross of bolts in a day, and sometimes not more than four or five gross, with the machine.

12,344. Would the machine make a small bolt or a large bolt most rapidly?—A small bolt.

12,345. Of small bolts they might turn out something like 20 gross a day, and of the large ones somewhere about four or five gross?—Yes, just according to the look of it in the machine.

12,346. With regard to hand-made bolts, how many hand-made bolts would a man turn out in the course of a day?—I cannot say that some of them would not do so, it would depend upon the size of them; perhaps a man would do a good many some days by hand, sometimes half a gross, and at other times five or six gross, in the course of a day.

12,347. Five or six gross in a day?—Yes, small work.

12,348. Do you mean to tell the Court that the same machines that you now have was better-made bolts?—No; some bolts are better made by hand than they are when they are made on the machine.

12,349. Did those machines not turn out good bolts in the Cleveland Company's works?—Yes, they turned out as good bolts as any other machines.

12,350. And such a bolt as you mentioned—a bolt needing to be straightened after it had been made—would that be a fracture that would be easily seen by looking at the bolt?—I do not know how it would be seen till it was stopped by some way.

12,351. Suppose it was screwed on to this place, would not a very partial screwing show the flaw at once?—Not always, it may fly off, but you might get some of them that would stand when the head flew off; you could see where the crack had been.

12,352. How many of the bolts do you think would require this straightening?—There was a man paid for straightening every one; if the machine made them, they had to go through his hands, and he would just square them up; some would want more than others, and some would not want much doing to.

12,353. Every bolt passed through his hands?—Yes, every bolt with square or hexagon heads did.

12,354. With regard to pricing the bolts, is it usual to turn a bolt made by machine—to turn it in the lathe?—No, unless it is the heat engine work, for locomotives.

12,355. That is for bright work?—Yes, finished bright fish bolts.

12,356. I mean the bolts that were used?—Fish bolts for girders were never turned or faced.

12,357. (The Commissioner.) That is so, is it?—Yes.

12,358. (Mr. Atchery.) They are faced, are they not?—Yes, they are faced.

12,359. Then it is a usual thing to face bolts of that sort?—Yes.

12,360. Does the facing injure the bolt in any way?—No, I think not.

12,361. Do you know the "Oliver" machine for bolt making?—I know the "Oliver"; it is a machine.

12,362. Would you call a bolt made by the "Oliver" machine a made bolt or a hand-made bolt?—A hand-made bolt.

12,363. (Mr. Trayner.) If the nut is faced it will have a more direct bearing upon the bolt than otherwise?—It would have a straight pull.

12,364. (The Commissioner.) Am I to understand you to say that these nuts and bolts were what you generally turn out for girdar work and fish-plate work?—Yes, they were made in that way; we had only one order of that description, the 14-inch, and it was an unusual order.

12,365. Supposing you had an order for 14-inch bolts for girdar work, would they be made in the same way as you made the others?—Yes.

12,366. Apart from the size?—Yes; they all go through the same process.

12,367. It was the same process, that you applied to them?—Yes.

12,368. It was iron of the same quality that you would have put into other bolts?—As far as I know, it was of the same quality.

12,369. You have said that sometimes the iron was rather larger?—Yes.

12,370. And you have said that you adjusted the tools to cut it?—Yes.

12,371. Otherwise it would wear them away?—Yes.

12,372. In other words, you made the diameter of the screw rather larger, did you?—Yes.

12,373. It would not fit; you knew that very well?—The nuts are made to suit the bolts.

12,374. Then you made the nuts to suit the bolts?—Yes.

12,375. Therefore, the iron being less, there was no great disadvantage?—No.

12,376. You made the nuts a little larger to fit them?—Yes.

12,377. There was nothing in these nuts or bolts different from what you would have made for other work?—No.

12,378. Either in the iron or the workmanship or anything else?—No.
Examined by Mr. PACHEY.

12,379. You reside at Middlesbrough?—Yes.
12,380. What is your business?—I am at the Cleveland Dockyard, I am a stock-taker there at present.
12,381. What is your own profession?—I am a boltmaker.
12,382. You worked at the Cleveland Bolt Company's works, I believe, for many years before they closed?—Yes.
12,383. How many years?—About six, as near as I can recollect.
12,384. Do you remember making some 1½-inch bolts for Messrs. Hopkins, Gilkes, and Co.?—Yes.
12,385. Was that an unusual size of bolt?—Very unusual.
12,386. What kind of iron were they made of?—I believe the ordinary sort of iron.
12,387. How many did you make, or how long were you engaged making those bolts?—I think about a fortnight.
12,388. How many do you think you made?—I cannot exactly say the number.
12,389. You can give me an idea, can you not?—Some days I should make more, and other days I should make less.
12,390. Did you make hundreds?—I have made thousands of all sorts.
12,391. Of these 1½-inch bolts?—No.
12,392. How many did you make of them?—Perhaps I made 700 of them. *
12,393. Did you know where they were going to?—I was told that they were for the Tay Bridge.
12,394. And the bolts were made of ordinary iron, were they?—Yes, I believe that to have been the case.
12,395. Were they inspected at any time by Messrs. Hopkins, Gilkes, and Company, as far as you know, during the time they were being made?—Not to my knowledge.
12,396. Was it customary for people who had bolts being made at the works to send an inspector to see how they were made, and to test their quality?—In some cases.
12,397. Was it general?—No, it was not general. (Mr. Macenery.) I think that is hardly fair. The witness says "in some cases," and then you ask, "Was it general?" (Mr. Truog.) Why not? (Mr. Macenery.) It is rather a leading question.
12,398. (Mr. Truog.) He says it was not general. (To the witness.) Tell me, if you can, any persons who have sent inspectors to look at the work?—The Indian State Railway Company.
12,399. Did you make some of the bolts for that company?—I made thousands of them.
12,400. Suppose you met the inspectors frequently, and saw them there when you were engaged?—Very nearly every day.
12,401. If Messrs. Hopkins, Gilkes, and Company had been inspecting the manufacture of those bolts, I suppose you would have known it?—I presume he would have come to the machine where I made them, and I should have seen him.
12,402. In point of fact, did such a person come?—Not to my knowledge.
12,403. Not while you were there?—No.
12,404. Just let me know, if you please, how did the inspector for the Indian Railway test the bolts?—How did he inspect them? What did he do?—He took them to the blacksmith's shop and put them on the anvil, and hammered them with a hammer.
12,405. You said that you made bolts; did you make any nuts?—No, I did not.

12,406. Did you see any of the nuts for the bolts that you were making?—I did.
12,407. I suppose you would put the thread on the bolt?—No, I did not.
12,408. Did you see any nuts fitted to the bolts after the thread had been put on each of them?—Yes.
12,409. Did you observe whether the face of the nut had been smoothed in the lathe?—It had not.
12,410. Nor any of the bolts turned?—Not to my knowledge. I never saw any of them.

Examined by Mr. MACHORY.

12,411. You say that you never saw any of them turned; were they frayed?—Yes.
12,412. Is that usually done with bolts of this sort?—Very nearly in all cases; the bolts are all frayed.
12,413. With regard to the inspection of those bolts and nuts for the Indian State Railway, was every bolt taken to the blacksmith's shop and inspected in this way?—No, or else they would not have got any; they would all have been broken.
12,414. Was that the only species of inspection that was made of those bolts and nuts?—Yes.
12,415. They were taken to the blacksmith's shop?—Yes.
12,416. Had you been making any bolts and nuts, while you were there for people in Middlesbrough or the neighbourhood?—Yes, many people.
12,417. Those Indian State bolts were to go abroad, were they not?—Yes, they were.
12,418. (The Commissioner.) You say that you made bolts and nuts for many people in Middlesbrough; used they to have inspectors generally or not?—Not in general.
12,419. Not the Middlesbrough people at all?—No.
12,420. Was it only people at a distance who had inspectors?—Yes, I believe only for Government orders; I have seen them.
12,421. Was there anything different in those bolts which you made from the bolts that were ordinarily made for other people?—No difference whatever.
12,422. There was no difference of any kind, except in the size?—No.
12,423. The size of 1½ was unusual, you say?—It was an unusual thing—I never made any except those.
12,424. As far as regards the manufacture and the quality of the iron, they were just the same?—Yes; it was the ordinary iron, I believe.
12,425. (Mr. Barlow.) I should like to ask you whether the quality of the bolts that were supplied to the Indian State Railway was the same or better than the quality of those supplied to the Tay Bridge?—They were decidedly of a better quality.
12,426. In what respect?—The iron came from a different place altogether.
12,427. The iron was better?—Yes, it came from a different place altogether.
12,428. (The Commissioner.) Were they exceptionally good for the Indian State Railway?—They were very good indeed.
12,429. I mean exceptionally good?—Yes; that is what I mean.
12,430. (Mr. Macenery.) Where did the iron for the Indian State Railway bolts come from?—From Jackson and Gill's; they were branded from them, I used to see the brand when I was working the iron on it.
12,431. Where did the other come from?—I am not prepared to say where it came from.

The witness withdrew.
TAY BRIDGE DISASTER.

THOMAS MASON sworn.

12,442. Should you say hundreds?—Yes, thousands.
12,443. I cannot say exactly the number.
12,444. Did anyone come from Messrs. Hopkins, Gilkes, and Company to test and inspect the bolts during their making?—I think not.
12,445. Did you see anyone?—No.
12,446. You came to where you were working?—No.
12,447. Or tested any of the bolts that you made, so far as you know?—No.

Mr. Macoroy stated that he had no question to ask this witness.

12,448. (The Commissioner.) Those 1¼-inch bolts were made of ordinary iron, were they?—Yes.
12,449. And they were made in the same way in which you made bolts for girders?—Yes.
12,450. There was no difference at all?—No.
12,451. But you sometimes made them of superior iron?—Yes, when ordered.
12,452. When ordered they were made of superior iron?—Yes.
12,453. Was that often?—No, not very often.

The witness withdrew.

GEORGE HINSEY sworn.

12,453.—Did you put the thread on them?—No.
12,454. It was put on after they left your hands,—Yes.
12,455. How were they made; by hand, or by machine?—By machine.
12,456. Did anyone from Messrs. Hopkins, Gilkes, and Company ever come to test those nuts that you know of?—Not to my knowledge.
12,457. Would you have known it if they had sent anyone to test them?—If they had come to test them, they would have had to come to me.
12,458. Other people had inspectors testing the nuts that you were making, had they not?—Yes.
12,459. You saw those inspectors?—Yes.
12,460. Had you ever to complain of the metal that was given you for making the nuts being unusually brittle?—Yes.
12,461. To whom did you complain?—To Mr. Banks.
12,462. What was your objection to the iron?—It was bad—it was short and brittle, and it would not stand the heat; it cracked the nuts, and when they were made of it they would be cracked.
12,463. Muts made of that iron would not stand the heat; they would be apt to crack?—Yes.
12,464. And if cracked, of course they would go with very little strain?—Yes.

Mr. Macoroy stated that he had no question to ask the witness.

12,465. (The Commissioner.) Do you mean that you had to complain of any of the iron of which you made those 1¼-inch bolts?—No, I do not mean so.
12,466. Then what do you mean?—Other work that I have had to make.
12,467. With regard to the 1¼-inch work, had you ever any reason to complain of that iron?—No.
12,468. Never?—No.
12,469. Was it good iron?—As far as I know, it was. I never had any reason to complain of that iron.
12,470. For being brittle or liable to crack?—No.

The witness withdrew.
MINUTES OF EVIDENCE.

HENRY WILLIAMS sworn.

12,491. Were you a clerk in the office of the Cleveland Bolt and Nut Company?—Yes; weigh clerk.
12,492. How long were you there?—About five years.
12,493. Were you there till the works closed, or when did you leave?—In September 1876.
12,494. As a weigh clerk, what was your duty?—To weigh everything that came in.
12,495. And I suppose everything that went out?—No.
12,496. You did not weigh what went out?—No.
12,497. Then you weighed the iron that came in from the different manufacturers or ironworks?—Yes.
12,498. If any of the manufactured iron that had been sent out of your works was returned to the works, was it your duty to weigh it and take a note of it?—Yes.
12,499. You had a good many orders from Messrs. Hopkins, Gilkes, and Company, had you not?—Did you know that your firm executed orders for that company while you were there?—Yes.

The witness withdrew.

EXAMINED BY MR. TRAYNER.

12,500. Did you know that your firm were making bolts said to be for the Tay Bridge?—Yes.
12,501. Did any of those bolts which you sent to Messrs. Hopkins, Gilkes, and Company come back to the works?—Not that I can remember.
12,502. Were there some rivets sent back?—Yes.
12,503. But no bolts that you remember?—No bolts that I remember.
12,504. What number of rivets were returned?—Do you remember?—There were various lots; sometimes two bags—at least 2 cwt., and 3 cwt., and 4 cwt.—and I think I remember examining as many as 16 cwt. that came back, but I cannot say for a certainty. I know we had 24 cwt. and 3 cwt.
12,505. Those were rivets?—Yes.
12,506. To the best of your knowledge, no bolts came back, did they?—No.
12,507. What was done with the rivets that they returned?—They were weighed and entered into the return book, and sent into the works. I do not know what was done with them.

Mr. Macrorry stated that he had no question to ask this witness.

MR. HENRY LAW sworn.

Examined by Mr. Trayner.

12,508. You are a member of the Institution of Civil Engineers?—I am.
12,509. You were instructed by the Court to proceed to the Tay Bridge to obtain information on the spot with the view of giving evidence before the Court with reference to the casualty and its probable cause?—Yes, I was.
12,510. By a letter dated the 22nd of January 1890?—Yes.
12,511. And that letter had appended to it certain general instructions for your guidance?—That is so.
12,512. When did you go to Dundee in consequence of those instructions?—I have paid the usual visits to Dundee. I went to Dundee first on the 26th of January, and remained there until the 6th of February, or the 12th, I think it was.

(Mr. Bidder). Have we all these instructions?

(Mr. Trayner). Yes, and the Court's letter to Mr. Law you can have.

(The Commissioner). Have you had a copy of it?

(Mr. Bidder). Would it be convenient that it should appear upon the proceedings?

(The Commissioner). Certainly.

(Mr. Trayner). Do you want it at this moment?

(The Witness). I can read it if I have it.

(Mr. Trayner). I will put in the letter and the instructions.

(Mr. Bidder). That will be the best way.

12,513. Mr. Trayner, to the witness.) Will you put in the letter containing your instructions?—I have only the original here. I will put it in.

(The following letter and general instructions were handed in.)

"TAY-BRIDGE CASUALTY.

"SIR,

"22nd January 1890.

"We have been requested by Her Majesty's Government to select an engineer in whose knowledge and character we have full confidence to obtain for us, on the spot, information on certain matters connected with the recent accident to the Tay Bridge. Mr. (The Commissioner) to enable us to form an opinion as to the cause of the casualty. We have accordingly selected you, and are very glad to hear that you are willing to accept the appointment, and are prepared to leave for Dundee on Friday next, the 23rd instant, for the purpose of at once entering upon the duties.

"Accompanied are instructions showing the objects to which we wish you especially to direct your attention; any other matter, however, which may seem to have a bearing upon the subject of our inquiry, even though not specially referred to in your instructions, should be noted, and a report thereof made to us.

"We should be glad to receive, from time to time, reports of your proceedings; and should any matter come under your notice to which you think that our attention should be at once called, or on which you require instructions, we should be obliged by your immediately communicating with us on the subject.

"We enclose two letters of the Provost of Dundee, and the other to the Chairman of the North British Railway Company, requesting them to afford you every assistance in their power in carrying out your instructions.

"We propose to recommend that you be paid for your services at the rate of five guineas a day during the time you are employed, such sum to include your hotel charges, but exclusive of your travelling expenses and any other costs that may be necessarily and properly incurred in carrying out the operations at the scene of the casualty. Your accounts should be sent to the Assistant-Secretary to the Board of Trade Railway Department for payment.

"Trusting that these arrangements will be satisfactory to you, and that you will be able to leave, as you propose, for Dundee, on Friday next,

"We are, &c.,

"(Signed) H. C. ROVENRY, Commissioners for W. YOLLAND, the Tay Bridge W. H. BARLOW, Casualty.

GENERAL INSTRUCTIONS FOR MR. HENRY LAW'S GUIDANCE.

1. Whether any, and, if so, what, settlements have been made or been in contemplation between the parties?
2. Whether any, and, if so, what amount of scour has arisen on the river bed in consequence of the erection of the pier? For this purpose, a cross section of the river will be required along the centre line of the viaduct, and two others, at a short distance east and west of the pier, and not exceeding 30 feet from the centre line. Such sections to be plotted so as to compare them with the original section of the river bed as sent to the Board of Trade.
3. The exact dimensions of the diagonal ties and the mode in which they are fastened to the cast iron columns; the amount of play, if any, resulting from the relative dimensions of the bolts and bolt-holes to be especially noted.
4. The nature of the fractures which have occurred in the cast-iron legs of the columns to which the deals (running east and west) have been fastened.

5. The dimensions of the bolts which fasten the bases of the columns to the cast-iron bed plates.

6. The dimensions in length and sectional area of the holding-down bolts by which the bed plates have been fastened to the masonry or brickwork, and the mode of fastening; also how the masonry is dowelled and any other device that was supposed to take place in the masonry and brickwork, and the manner in which the stonework has stepped where such has been the case.

7. The fractures, if any, which have occurred in these holding-down bolts.

8. The dimensions of the bolts which fasten the top of one column to the base of the one above it.

9. Description of the state and condition of each of the masts, from Mr. Meek's inclusive, showing accurately by drawings the movements which have taken place in the masonry and brickwork, and the manner in which the stonework has lifted where such has been the case.

10. The fractured ends of the cast-iron columns, to ascertain whether the core has been cast central, and if not, the degree of eccentricity.

11. The condition of the concrete, or other material, with which the columns have been filled.

12. The manner in which the base of one column has been let into the top of the column below it, and the degree of accuracy in the fitting.

13. To report generally on the apparent quality of the iron as shown by its fracture, with a view to selecting samples for testing.

14. To note, as far as possible, the positions of the fallen girders with reference to the piers.

15. Carefully to examine the condition of the cast-iron framework of the bridge piers, to ascertain if there is any appearance of cracks in them arising from frost action.

16. To report generally on any matters bearing on the subject of the inquiry which may come to my notice.

Dated 22nd day of January 1880.

(Signed) H. C. R. W. Y. W. H. B. Commissioners for the Tay Bridge and Bridge Casualty.

12,514. You left for Dundee on the 26th of January and remained there until the 12th of February, did you not?—That is so, and I went again on the 24th of February, and remained there until the 6th of March.

12,515. Again, I believe you returned to Dundee?—I went to Dundee again on the 24th of March, and remained there until the 27th inclusive.

12,516. And on each of those occasions did you make a thorough examination of the structure of the bridge and how it was?—I did.

12,516. Tell me if I correctly represent the documents that were put into your hands before you went or, during the time of your inspection. You had the shorthand-writer's notes of the proceedings at Dundee, so far as they had been taken prior to you going?—That is so, for the first three days of the inquiry.

12,517. When you were present and heard the evidence given on the subsequent six days in Dundee, were you present?—Yes.

12,518. Had you also given to you a tracing by Mr. Drummond, the locomotive superintendent of the railway company, showing the arrangement of the train and the positions of the locomotives, etc.?—Yes, showing the arrangement and stating the weights and the areas of the carriages.

12,519. You also got, I believe, from Mr. Noble, a book in which he had recorded the result of the tests that were made, from time to time, of the strength of the cement that was used in the construction of the bridge?—Yes, that is so.

12,620. And a transverse section of the river at the site of the bridge showing the soundings taken by Mr. Noble?—Yes, also soundings of the section of the river as it was at the time when the bridge was surveyed by the Board of Trade with the soundings that Mr. Noble had taken in September 1879.

12,521. You had also two contracts, one entered into by the company for the Tay Bridge, and the contract between the railway company and Messrs. Hopkins, Gilkes, and Company?—Yes, these two contracts, and the specifications which were referred to them.

12,522. Had you the drawings of the bridge which have been produced in Court by Sir Thomas Bouch and his assistants?—Yes, I had, and if the Court please, I have the original drawings and also reduced lithographs which were provided for use in this case.

12,523. Also a copy of a report by Mr. Peale and Mr. Stewart to Sir Thomas Bouch, dated the 25th February, with reply to some questions directed by the Court to the railway company?—Yes.

12,524. And you also had the use of some photographs which were made by the examination of the Court of different parts of the bridge which were directed to be photographed?—Yes, I had, of course, having the bridge itself was better—I have seen those and I have examined the structure itself.

12,525. In addition to those documents, I understand you had put at your disposal a steamboat by the company?—Yes, the company provided a steamboat; and Sir Thomas Bouch placed one of his assistants, Mr. Peddie, and also Mr. Noble, who was examined yesterday, at my disposal, to give me all the information and assistance in their power.

12,526. Both Mr. Peddie and Mr. Noble did render assistance?—Yes.

12,527. And the company had instructed their station-master at Dundee also to afford you any facilities that were necessary?—Yes; I may say that I received every possible assistance from the authorities.

12,528. All these documents that you had, if I suppose, you considered very carefully?—Yes, I did; I examined the documents and the structure with the greatest care.

12,529. Then you made a report to the Court. In consequence of those investigations?—Yes; and I have the report, dated the 5th of April.

12,530. (Mr. Bidder.) That is, I suppose, the printed report of which we have a copy?—Yes.

12,530. (Mr. Trayner.) Yes, it is. (To the witness.) Although it is in the report, it might be convenient if you could give us somewhat briefly a description of the bridge, just to appear upon the notes?—I need only remark with reference to the standing part of the structure there were altogether 85 spans, of which 26 remain northern side and 44 on the southern side, or, rather, there are 28 on the southern and 44 on the northern side. I do not know that I need refer to those spans any more which carried the portion of the structure which has fallen.

12,531. That is the northernmost and the southernmost parts of the bridge on which the high girders were originally placed.

12,532. (Mr. Bidder.) Will you identify them by numbers—are they numbered from the south side?—I refer to them always by the same numbers that were put upon them in the lithograph drawings; that, I think, will be found to be convenient. The last span which is standing on the southern portion is marked there span No. 28, and it is borne by piers 27 and 28, the 26th pier being the last pier standing on the southern portion of the bridge.

12,533. On which originally the southernmost end of the high girders was placed?—Not quite so, the high girders which has fallen rested upon a girder which still remains—an existing girder intervened between the two. I will just describe that, on that span of the girder (pointing to the model) which is
now standing is 145 feet, and it rests upon piers which are constructed somewhat similar in principle to those which have fallen.

12,635. Is this right, that pier No. 28 is the pier on which the southernmost end of the high girders was placed?—Yes, with the intervention of the lower gilder, which is still standing between the two.

12,636. That supports them both?—Yes, and the piers No. 27 differs somewhat in construction, but I do not think that it is necessary for us at present to refer to that pier.

12,637. The girder which now spans 200 feet upon the pier, and the line was carried for 100 feet to the north, does not differ to any extent from the girder on the pier, but upon the lower plate, similar in principle to those which have fallen, with the simple exception that it has six tiers of columns instead of seven. Pier No. 27 differs somewhat in construction, but I do not think that it is necessary for us at present to refer to that pier. The girder which now spans 200 feet upon the pier, and the line was carried for 100 feet to the north, does not differ to any extent from the girder on the pier, but upon the lower plate, similar in principle to those which have fallen, with the simple exception that the line was upon the top instead of upon the bottom, so that the strains of tension and compression were reversed. They consist of two girders which are about nine feet apart at their middle, and from centre to centre, but 14 feet 10 inches at the northernmost end over pier 26, being widened out at that point in order that they might correspond with the distances at which the high girders were placed which had to rest upon them.

12,638. Will you continue, apart from that, to describe the general character of the model?—Yes, but I think I should make this an observation that what I have said with regard to span 28, the last span standing on the southern side, applies also to the last span standing on the northern side, with the exception that upon the northern side it is 12 feet 10 inches instead of 145 feet; otherwise it is the same.

12,639. It would be convenient if you would describe the high girders; one of them will describe the whole, if you will describe them by reference to the model?—I will do so.

12,640. Pointing out the girders, the bars and platforms, the model or the plan?—First, with regard to the lower girders. There were 13 spans numbered from 29 to 41, supported at each end by the girder still standing and 15 intermediate piers, which piers are numbered from 25 to 40. Those girders consisted really of three divisions; that is to say, going from south to north, there were two, which were all united together. Those were technically called cover plates, and each of those spans was 245 feet. Then came another group, consisting of four spans, the two extreme spans of which were 227 feet, and the two middle spans each 245 feet. Then came another group, or division, consisting of four spans, each of which was 245 feet in extent.

12,641. Will you kindly do what I asked you to do on the model, to point out, for our instruction, the different parts of the bridge; with their technical names?—The girders, bars, platforms, columns, and so on. Each of those spans (pointing to the model) consisted of two lattice girders, placed 14 feet 10 inches from each other, and those girders consisted of two booms, the upper and lower booms, which were 27 feet apart from the extreme top and bottom. First of all, they were trough-shaped, in order to give them stiffness. They consisted of a horizontal plate two-feet in width, and they varied in thickness. Girders in the third, and on every pier they had to carry; the sides were formed by two vertical plates, called webs, which were 15 inches in depth, and they were placed about 18 inches apart, being united to the lower plates, the horizontal ones, by angle irons, the webs being stiffened by angle irons. The upper booms only differed from the lower booms in having at the bottom from 9 inches to 20 inches, each other, or back-shearing, as they stiffen the whole structure. The ends were formed of the same trough-shape, only being 18 inches wide on the face instead of 15; and, in the same way, they were braced by diagonal angle irons, just to preserve the parallellism of the side plates. I may add that there were some of the lattice bars which always had a tensile strain upon them, and some which either always had or occasionally had a compressive strain upon them; and as to those which are always in tension, they were simply bars in duplicate riveted, at the top and the bottom, to the vertical or web plates of the top and bottom booms.

12,642. Those which acted as struts had a compressive strain, and were stiffened like the columns. Those may be seen in the form of the letter H, consisting of two bars; externally with a web running between them, the whole being stiffened by four angle irons that united the three plates together. It is more properly an H-shaped or I-shaped column. I will touch them now, as struts (pointing to the model), and those which are in tension (pointing to the model); these are the lattice bars.

12,643. Some being in compression and some in tension?—Yes. At their intersections they were riveted to each other; they were not riveted to the lower plate; it was introduced for the purpose of bearing vertical suspension rods, which were riveted at their lower ends to the webs of the booms, the object of which was to lessen the transverse strain which would have come upon them by a weight rolling over them, as the rails would have been supported only at the points where the lattice bars were attached to them; and the transverse strain would have been doubled. The upper booms were bridged together by having, at intervals of 18 feet 6 inches, transverse I-shaped girders of wrought iron, and those were braced by means of angle iron ties and T iron ties riveted to the cover-plates, and which, by being disposed diagonally, enabled the two booms, really, to form lattice girders laid upon their sides (pointing to the model), so as to resist lateral strain. Below there were, at distances of about 5 feet 5 inches apart, fish-bellied wrought-iron girders, which rested upon and were riveted to the angle irons and the webs of the lower booms, and which served to carry the roadway of the railway. To differ from the lower members of the girders, there were diagonal irons, which were similarly riveted to cover-plates at the ends of each alternate roadway girder, and intersected and passed through an opening made in every alternate fish-bellied girder. Apparently, that was one of the objects of making them fish-bellied; and making an aperture in the middle of the web of the fish-bellied girder did not much diminish its strength. The additional depth given, of course, compensated for the hole, and they were equally strong, and although that hole was made it was a convenient way of carrying the braces through. There is only one object, and each girder is a whole of the structure, that is to say, the essential parts of it, with the exception of the braces which were introduced at the extreme ends of each span; they have been removed from the model; but there was a transverse beam at the end of the span beams, in fact, at the top of the third, in the third story down, and there were tie bars riveted to each of the upright vertical pieces which formed a truss, and avoided any tendency which those girders had to assume other than a rectangular form, in consequence of lateral pressure against the top.

12,644. Was there anything in either the cross bars or the tie bars against the north end of the high girders and the northernmost end of the high girders different from that in reference to the girders between those points?—No, they were all the same; but I should just for a moment mention that the lower girders upon which the extreme end of the high girders rested were 16 feet 6 inches in height, and
12,544. (Mr. Bidder.) Put it upon it as upon a shelf?—Yes, to allow a movement to take place in consequence of changes in the length of the girders which must result from changes of temperature.

12,545. Was there any attachment between the high girders and the pier upon which they rested?—Only in the case of three. I had better perhaps describe the way in which they did rest upon the pier, or rather I will describe the pier.

12,547. Will you follow out the description that you think best?—I think it will be better to take it in parts.

12,549. (Mr. Bidder.) Will you now describe the connection between the girders and the piers?—I think it will be better to begin with the bottom and go upwards. The foundation in the bed of the river of this part of the bridge (pointing to the model) consisted of large cylinders of wrought iron, filled with a core of brickwork and concrete; and, in passing, I may say, that having made a careful examination, I have no reason to believe that those piers have shifted or settled. The piers are placed in the bed of the river, and the piers rested only on the support of the masonry. The piers above the level of the bed of the river (pointing to the model) consisted of large cylinders of wrought iron, filled with a core of brickwork and concrete; and, in passing, I may say, that having made a careful examination, I have no reason to believe that those piers have shifted or settled.

The piers, above the level of the bed of the river, are placed in the bed of the river, and the piers rested only on the support of the masonry. The piers above the level of the bed of the river, and the piers rested only on the support of the masonry.

12,550. (Mr. Traguer.) Will you tell me how it is that the bases of masonry are placed in the bed of the river?—The masonry is set in Roman cement.

12,551. (Mr. Bidder.) You said that up to the top of the brickwork everything seemed to be of good quality and good workmanship?—Yes, that is so.

12,553. (Mr. Bidder.) Have you not made a slip when you said "Portland" for "Fortland"?—I should have said "Portland." Roman cement is now out of date.

12,552. (Mr. Traguer.) Above the brickwork, in reference to the masonry and the cement used, have you any observation to make with respect to the quality of cement?—Yes, I have this observation to make, that the joints are unusually thin. I think, I may say, that I found the joints to be nearly two inches thick, but I also found that, although the cement was of good quality, there had been very little cohesion between the cement and the stone.

12,554. How is that shown?—I have a specimen here, a small piece; but I have a specimen, and it may be seen, of about 4 feet in length by 16 inches in depth, being the whole of a vertical joint in cement which has parted from the surfaces of both stones without breaking. This specimen shows the impression of the surfaces of the stone. The place I hold in my hand is a piece of cement from the vertical joint of the stone under column No. 6, in pier 37. For facility of reference I have numbered these columns, and I shall always, in speaking of the columns, adhere to these numbers. The western pier is column No. 1. Passing round in the same direction as the sun, No. 2 is the first 15-inch column; No. 3 the next; No. 4 the easternmost 18-inch column; No. 5 the next 15-inch column, and No. 6 the last.

12,554. (Mr. Bidder.) Do you pass round the south or to the north?—To the north.

12,555. No. 2 is the north-west column?—No. 2 is the north-west column.

12,556. (The Commissioner.) And No. 3 is the north-east column?—Yes.

12,557. (Mr. Traguer.) Will you go on with what you were saying about the cement?—It will be observed that this specimen has upon it the marks of the stone. The stone is a very good sandstone, but the surfaces were sawn, which made it rather smooth; and I imagine from the appearance that the stone was not made wet before the cement was applied; but whatever the reason, the fact remains that the cement did not adhere to the stone in the manner that it should have done to give entire security.

12,558. Is that a defect in workmanship, or in the cement?—There is no defect in the cement.

12,559. Then it is a defect in the workmanship?—If the stone was not wetted that was an error in judgment.

12,560. The stone should have been wetted?—You cannot get a good adhesion without wetting.

12,561. It was not sufficiently wetted. You have produced that cohesion which there should have been?—I imagine that to be the case, combined with the smoothness of the surface of the stone.

12,562. There is no other suggestion as to that, arising from your observation, which occurs to your mind, other than you have given us?—No.

12,563. Was there a defect in the mode in which the work was done there?—I think so; I imagine the stone was not wetted; I can only draw an inference.

12,564. But an inference from what you saw?—Yes.

12,565. Will you proceed upwards now to the base plates?—The arrangement of these columns was in the form of two triangles—right-angled triangles—which really formed two independent piers, because they had no special connection at the top, and they might be regarded as two independent structures. The diameter of these external columns, Nos. 1 and 4, was 18 inches; their thickness was about 12 inches. The diameter of the four intermediate columns, Nos. 2 and 6, was 15 inches, and their thickness 12 inches. The base-pieces of the 18-inch columns were square, 4 feet square, and the base-pieces of the 15-inch columns were circular, 3 feet 6 inches in diameter. Each of the base-pieces was bolted down to the masonry by four holding-down bolts 18 inches in diameter at their upper ends, but having conical enlargements for about 16 inches at their lower extremities, and there being enlarged to 24 inches in diameter. They had no anchor plates, or mode of attachment to the masonry; that is, they had no abutting surface, but a cylindrical hole about 4 inches in diameter was formed through the two upper courses of masonry, making together 2 feet 6 inches, that being the depth to which these bolts passed. There was also a hole through the base-piece of the column for this bolt to pass through; and the bolt having been put in place, cement was run round it, which, by its adhesion to the stone, would prevent the subsequent withdrawal of the bolt, but having the angle of that wedged-shaped head was only about $45^\circ$ degrees, and, a strain being put upon it by the screwing of the nut, a very slight compression of the cement would enable that bolt to come home; and there are evidences in the structure that such did take place, because I found in some cases as many as six washers, each of about half-an-inch, under the nut, and still about three or four inches of bolt above the nut again.

12,566. Will you explain what the washer is for?
—I may again mention that the bolts are not always central in the large hole which they pass through, but are sometimes close to one side of the bolt; and in such cases the washer, or the nut, for there are not always washers, bore only upon one side of the base-piece, and did not make an efficient holding-down bolt. This action of these wedge-shaped washers was to burst the stone, and in one or two of the pier's stones have been so burst—burst upon the line of the bolt.

12,567. (Mr. Rider.) Will you explain, with a view to another question, what is the general ordinary purpose served by a washer?—The object of a washer is to hold other objects through a hole which is too large for it, or where the surface upon which the washer will bear is somewhat rough, that the nut may have a smooth surface to facilitate its being tightened up.

12,568. This bearing is better upon the washer then if you had no washer at all—Yes. If you have what is termed a base upon the work itself, which has been faced, and the underside of the nut has been faced, no washer is required to be introduced; the two surfaces will be smooth and even, and no washer will be required.

12,569. This bearing would be as tight as if it would be possible to make it as tight, and you could turn the angle axis with the axis of the screw. If the bolt bears upon one side, a transverse strain is immediately put upon the bolt.

12,570. How did you account for the existence of the unusual number of washers which you found on one of these bolts?—The inference I drew was, that the washer or the nut had been turned in the lathe, but they have not been turned in a lathe, or where the bolts have been turned in a lathe, but they have not been turned over their whole surface—a groove is left three inches wide, a depressed annular channel has been left on the face of the flange, three inches in width, and varying in depth from a quarter of an inch, or from nothing in some columns to three-eighths, or even more, in others. There was a resistance in a horizontal line which the bolt-holes have been drilled; the holes for the bolts are 7/16 inch in diameter, being an eighth larger than that of the bolts. In some cases, I may perhaps say generally, there were spigots cast upon the lower end of one column, which, by entering into the upper part of the one below it, formed a resistance to the horizontal movement of one column upon the other at the joint; but that is not universal, and I have seen several where that is altogether wanting.

12,575. (Mr. Rider.) You say spigots were cast upon the lower part of some of the columns?—Like the spigot and facet of the ordinary water pipe. The spigot is perhaps one inch in diameter.

12,576. (The Commissioner.) What some of the workmen call the male and the female?—Yes; this is the drawing which was put in at Dundee (exhibiting it).

12,577. That was not universal, as I understand you?—Not universal. The absence of a spigot at a particular joint, and the fact that the bolts were less in diameter than the holes where they had been drilled, together with the fact that there was a space which in some cases was three-quarters of an inch between the meeting surfaces of the flange where the bolt passed through, rendered the only resistance to the horizontal sliding of one column upon the other, the pinching-down action of the bolts themselves. The great importance of the power of the structure was, that there was a space which in the subsequent description which I shall give of the action of these braces inasmuch as the strut bore against one column and the tie pulled on the bottom of the one above it, any sliding action of one flange upon the other rendered those ties ineffectual.

12,578. (Mr. Trauer.) In your opinion, these flanges should have been faced so that over their whole surface they should have met exactly when placed in situ; they should have been in contact all over the face of the flange?—Yes.

12,579. The strength which would have been thereby afforded was wanted in respect of the annular channel of which you speak?—Yes; I ought to say, if there had been a spigot in every case, the spigot would have rendered the resistance of that annular channel, and the want of fitting of the bolts a matter of little or of no consequence; but it was the absence of the spigot, together with the existence of the annular channel and the weakness of the bolts with regard to their diameter, that rendered it a matter of consequence that would affect the ultimate strength of the structure. This is one of the flange bolts, which has been bent by the action I describe—the movement of one column upon the other has bent that bolt over.
12,580. Mr. Law. You say that the bolts were 1½ inch, and the bolt-holes drilled were 1½ inch?—Yes.

12,581. Is that a customary thing to drill the bolt-hole an eighth of an inch larger than the bolt that is to go into it?—It depends entirely upon the class of work that it is intended for. If the bolts are to be forged bolts, not turned, it is absolutely necessary that a certain amount of play should be given, as a 1½-inch bolt would not pass through the bolt-holes; for, as you were told to-day by those who had made the bolts, the iron supplied by the merchant varies slightly in diameter, and unless a certain amount of clearance is given in the holes many of the bolts would not pass through them.

12,582. Not finding any fault, I want to know from your mouth, in your opinion, it is good workmanship to have holes drilled of that size for bolts of those dimensions?—No; in a case of this sort my opinion of what should have been done is, that both surfaces of the flange, both the upper and the lower, should have been turned; that would have necessitated a slight dilatation of these columns, but I think that would have been an improvement. I think the upper and lower surfaces should have been turned, I think the bolts should have been turned, and I think that the under side of the heads and nuts should have been turned. My reason for saying that is, that the cross-section of this structure depended upon the non-yielding of this joint—by non-yielding, I mean against perpendicular, in the direction of the column, or the great strain which comes upon these bolts when any one of these columns endeavours to turn over upon its own edge. The security of these bolts, and the desirability that they should not yield anything when they are under strain, was a matter of so much consequence that I think all the surfaces in contact should have been faced.

12,583. But it is the want of the different things you have mentioned—the exact coincidence of the surfaces coming in contact with one another—that led to the yielding of the column in such a way as to break the bolts of which you have exhibited a specimen?—Yes. As bearing upon that, I should mention that, in consequence of the proportion which the height of the structure bears to the base of the column, any yielding of the external bolt—which is the most favourable that can be had—by the line of the inner bolts would be magnified fifty times at the top of the structure, so that a fifth part of an inch here would mean an inch at the top.

12,584. Having stated your objection with regard to the flanges, is there anything else about the flanges, or the position of the flanges, that you have to remark on?—With regard to the column itself, I may say that I found, in some cases, a considerable inequality in the thickness of the metal upon the two opposite sides of the column. In the worst case which I found, which was upon the sixth column of pier No. 6, the thickness upon one side of the column was half an inch, and the thickness upon the other was 1½ inch. I have some specimens of it.

12,585. Did you take specimens from that column which were exhibited at Dundee to the witness, Mr. Campbells?—Yes; and I have had that column brought to London, where it can be inspected by the Committee. The bolts would bring here, but I have a portion of it (producing it).

12,586. Were the specimens which were shown to Mr. Campbells specimens which you had taken from the pier which you have mentioned?—Yes, and from the column which I have mentioned—portions of the same metal.

12,587. Mr. Bidder. Which column is this?—The column which I am now exhibiting specimens of is the sixth column of pier No. 34.

12,588. Mr. Prayner. You have spoken to the thickness of that column in pier No. 34; will you kindly tell us, as you are on this subject, what was the result of your examination of other columns with regard to the thickness of the columns themselves?

—I did not find any other case in which there was so great a disparity between the thicknesses on the opposite sides; but a difference of half an inch, or ⅛ inch, of an inch, between the thicknesses is frequent in those portions of the bridge which still remain and are exposed to view, because much of the materials is below the surface of the water, and therefore I could not tell what the thickness might be on the face which is not exposed. The normal thickness of the column?—The 15-inch 1¼, and the 18-inch 1½,ths, full.

12,589. Mr. Prayner. The columns, if properly cast, should have been equal in thickness throughout the whole of the column.—Yes.

12,590. Have you any opinion as to the mode in which the inequality was produced?—Yes, it was evident, in some of the columns, that it was owing to the shifting of what is called the top flange. The mould consists of two halves, to enable the pattern to be taken out of the mould. The upper half, termed the flange, is moved into the column, and the exact thickness of the flange is determined by pins, to which it should be fitted again when put on, and, if through any carelessness, the flange is not replaced in the same position as it occupied when the pattern was in it, the thickness of the metal at that point becomes diminished, because what was before more closely fitted to the mould below is now too wide for the mould. When that occurs it leaves a mark on the outside of the column which may be seen, and in some of the photographs that mark is clearly visible. In some of the standing columns marks are to be seen which show that the flange has shifted materially. I find in some there has been a shifting to the extent of ⅛ of an inch.

12,591. Will you look at the photograph of pier No. 4, the view looking east; do you see a distinct line there?—Yes.

(The Commissioner.) When you say No. 4, that is not the numbering we have. Mr. Prayner. It is No. 4 of the fallen pier.

(The Commissioner.) That would be No. 32.

12,592. Mr. Prayner. That No. 33 is the same as No. 4 of those which have fallen?—Yes.

12,593. Does that photograph exhibit plainly enough one of those shifting?—Yes; it shows a ridge down the surface of the column.

12,594. And if you look at pier No. 6, which is No. 34 counting from the south, the west view, you see that?—Yes.

12,595. There is a sign of shifting there?—Yes; that is one cause of unequal thickness, because the core not shifting, any movement of the flange upon one side necessarily diminishes the distance between itself and the core upon that side and increases it upon the other.

12,596. While you are upon the moulding, let me ask you this question; you heard the evidence given by the moulders in Dundee?—I did.

12,597. You know what is technically called 'scabbing'?—Yes.

12,598. Is the result of that to put more than the proper quantity of metal where the scab takes place, and to reduce the strength on the opposite part of the column?—Yes; the result of scabbing is this—scabbing means a portion of the mould being washed away and carried with the molten metal through the mass of the casting, and, as it is very tough, it always remains upon the surface, and the molten metal rises with it to the upper part; and if found anywhere, will be found in that upper part, and, therefore, when the thickness of the upper part becomes much diminished, the fact that this material has remained there instead of the metal which very much diminishes the strength of the column. But it would have been better for me to mention, before I gave that explanation, another cause of unequal thickness of the columns, which is the rising of the core in consequence of its not having been properly secured in the mould. When you pour molten metal, which is eight times as heavy as water, into a mould, that buoyancy is very great, and it tends to lift the core with great
power; and unless that core has been securely held down, it will rise towards the upper part of the mould, forming an increased thickness below and a diminished thickness above. The double effect of that movement of the core is to reduce the thickness at the upper part of the mould—to cause the metal to chill there faster, because there is a thinner sheet of metal; therefore the moulder would always regulate the temperature of his iron by the thickness of the casting he was going to make, and if he were expecting to cast 1½ or 1½ inches thick, he would make the metal not hot if he was going to cast simply half-an-inch. The metal which was reduced to a thin film would have a tendency to cool, producing what are called cold shuts, not forming a perfect union on each side of the column.

12,589. Did you find anything, in your examination of the columns, to indicate the presence of those cold shuts?—One or two. Here (producing a specimen) is a nodula of cold metal which has been formed. The metal, as one would expect in the thin part, is very imperfect. Here is a flaw which extends through the thickness of the metal. Here is another, and here is another. The remains of this column are in London, and may be seen. It will be found that all the upper side of this column is of that description, perfectly full of air-holes and cinders. There are sufficient pieces here to show that those flaws were very extensive.

12,600. All those things tend to reduce the strength of the columns for bearing the consequent weight or pressure?—Necessarily, because the strengths which are given assume that the strain passes through the centre of the column vertically, but if one side is much thinner than another the column has a great tendency to bend, and is incapable of bearing the same amount of weight.

12,601. Was there anything else defective about the columns between the flanges?—No. I may mention that there are blow-holes, which, in many cases, result from the inequality to which I have referred, and result also from the fact that the columns were cast perfectly horizontally, and without a head of metal. It is a very good precaution to incline the mould, and to have a head by which the scum and scoria and air bubbles struggle upwards. The mould becomes filled with good metal, and the scum and scoria rise into the head, which is afterwards broken off.

12,602. You heard at Dundre the description of the iron that was used, and you heard that it had a great deal of scum, and that it was sluggish?—Yes.

12,603. What effect had that, in your opinion, upon the strength and resisting power of the columns themselves?—Necessarily, if the scum remained in any portion of the metal that was used.—If there was not a dead end into which that scum could rise, but the scum remained in the mould,—the strength and solidity of the casting would be impaired by it.

12,604. Do some of your specimens show the existence of that scoria, which should have been removed by proper scouring, if it was possible?—Yes. Most of the columns are very large and cinders, and scoria. I think that, in a structure of this importance, every column should have been examined with reference to the thickness, and there is no difficulty whatever in ascertaining what the thickness of the metal is. In a similar structure which I erected I had a quarter-inch hole drilled at opposite points at each end, which was plugged. That enabled a measurement to be taken; but you may always tell if there is any large difference by measurement at the face of the flange, or it is very easy to contrive a machine which shall give it you. It is one of the most simple mechanical operations to ascertain the thickness of any part of the column.

12,605. Do you think that the supervision of the casting at the Wormit Foundry was what it should have been when such defects as these were passed?—No, it could not have been.

12,606. Under careful supervision, could the thickness of the columns and their resisting power have been sufficiently tested before they were put into the structure at all?—Yes; there is no difficulty in ascertaining that the column is of sufficient thickness, and in columns for use in such a structure I think that should be done.

12,607. Is there anything else which you wish to say about the columns between the flanges?—No. I think I have said all that is necessary for me to say upon the columns.

12,608. Is the next thing in order naturally, the lugs which you have at each end of the column?—Yes. I will first describe the mode of bracing, and then I will return to the lugs. The columns were braced by having horizontal struts introduced at every joint, which struts consisted of double channel irons bolted back to back to a king channel iron, which was between them, and fixed by two I½-inch bolts. With regard to the mode of attaching those channel irons, I will observe that that they had no direct abutment, that it is to say, that ends did not bear against anything at all, but they were retained in their places and prevented from moving in reference to the columns entirely by the pinching action of the bolts.

12,609. Is this model incorrect, then, which seems to bring the channel irons flush with the columns? This model is too small to show such matters as that; but if you turn to Plate 51 of the official drawings, you will see an elevation in the corner, you will see written, "channel bars 6 by 2 by ½." You will also see the surface of the column hatched, and you will see that a distance of three-quarters of an inch occurs between the end of the channel iron and the surface of the column, and that that was as it was executed. Therefore, the model shows you the two bolts passing through the channel iron and clamping it to the lug. The whole security, therefore, depended upon the pinching effect of these two bolts; but the surface of many of the lugs is very rough and uneven, and furthermore the holes for the bolts to pass through the channel irons, not having been originally in such a position as to allow of the bolts being put through, the holes have been enlarged by some person not in a mechanical manner, that is to say, they have been punched out with a blunt tool, which has caused a bury upon the back-surface of the channel iron, which, in some specimens, I have in London, prevents the bolts from being driven an inch above the surface, and has, therefore, prevented the channel iron from coming into fair contact with the lug; and from the appearance of portions of the structure which remain, I find in the majority. I may say, of the cases the bearing of those channel irons against the lugs is very imperfect and unsatisfactory, and they would give a very small resistance to any effort which tended to cause the channel iron to move in reference to the column.

12,610. Will you tell me what opinion you formed as to the reason why the holes were enlarged in the defective way, or punched in the defective way, you have mentioned?—There is scum, and scoria, and cinders, and scoria. I think that, in a structure of this importance, every column should have been examined with reference to the thickness, and there is no difficulty whatever in ascertaining what the thickness of the metal is. In a similar structure which I erected I had a quarter-inch hole drilled at opposite points at each end, which was plugged. That enabled a measurement to be taken; but you may always tell if there is any large difference by measurement at the face of the flange, or it is very easy to contrive a machine which shall give it you. It is one of the most simple mechanical operations to ascertain the thickness of any part of the column.

12,611. I understand you that operation with a blunt tool upon the holes was an effort to bring into
12,612. "As there was some difference of opinion previous to the drawings the gib and cotters were not shown. Will you just describe what they are?—I observe in the official drawings the gib and cotters were not shown and that may have led to a little inaccuracy yesterday. In the drawing which was handed in the cotters were shown as passing through the legs, as though there were two cotters and only one key.

12,613. (Mr. Bidder.) Which drawing are you referring to?—To the sketch put in yesterday. I think it was so far correct that in some of the earlier columns on the northern part of the structure which were cast by Messrs. De Berge, you will find that mode of attaching the tie bars to the legs; but that does not apply to any but a single key. We are now considering. In every one of these cases we have two cotters and one gib. The gib is formed with two projecting ears, the object of which is to prevent the sling-plates falling away from the bar which passes between them, and the cotters are placed in this position being two wedges reversed; and, in consequence, one key being pushed upon the other increases the distance between the gib and the underside of the cotter. The gib bears only against the middle bar at its upper extremity; the cotter only upon the surface of the two sling-plates. The cotter being so arranged in their length that there is no bearing of the gib upon the cotter. The gib is part of the sling-plate or of the cotter upon the slot at the lower part of the bar. The gib bears against the plate, and the cotter against the sling-plate.

12,614. (Mr. Bidder.) I think it is the other way; the sling-plates are attached to the legs, are they not?—No, they are quite rigid in the upper end of the hole of the angle iron. The cotter bears upon the surface of the bar and the increasing the distance between the bottom of the cotter and the top of the gib by the driving in of the cotter strain is brought upon the upper end being obstructed. The cotters are rather wedge-shaped. The cotter is really wedge, and to prevent these wedges from shacking backwards their ends are split, and they are bent in that position in order to prevent them shifting up.

12,615. (The Commissioner.) Were those you have in your hand taken from the bridge?—These are all from the bridge; these are a complete set; they are in connection with each other as I put them.

12,616. (Mr. Trayer.) Having described what they are, will you tell us, if it is consistent with your own arrangement, what was their purpose and effect?—I have described their purpose and effect, but I will now describe what I think should call their imperfections. If you put these together you will see at once that they bear only at points; in fact, I have here one-sixteenth of an inch between them. In the same way the surface of the gib is very rough, and the cotters are roughly forged. This is a piece of sling-plate punched out in the roughest possible manner, and not refined it would have been any considerable strain came upon the gib and cotter, and the two pieces so arranged a considerable amount of yielding would take place from the simple crushing of those surfaces. But any such amount of resistance as would be derived from a mere calculation of what would be required to break the tie.

12,618. Shall the cotters be face so as to have borne exactly upon each other?—Yes, they should. I may say with regard to the sufficiency of their bearing surface that the area at the tie bar where it is weakened by the hole for the bolt to pass through is 1,625th of an inch.

12,619. (Mr. Bidder.) Is that the minimum area?—Yes; and, taking the iron at 21 tons to the square inch, it would require 40,320 lbs. to the square inch to break it. I see in the print at page 15 of the Appendix to my Report, the second line, it is poly tons; that is a misprint for lbs.; it is 40,320 lbs. to the square inch. But I should observe that the bearing surface in this case is about one-third of an inch by half an inch, or an area of 876 square inches. Furthermore, I should observe that wrought iron will only bear a compressive strain of six-sevenths of what it will for tension, and therefore that the strain which would have been required to break the iron in one of these keys would have been about 15,120 lbs., or something like seven tons. Now to the lug, the holes for the bolts for the sling-plates were cast, and they were not cast cylindrical. I have here two of the lugs which have been broken off, and it will be seen that the hole is very far from being square or cylindrical; that, in fact, the bolt simply bore against what is a lug in itself is not a desirable thing. It would be better to have had a different mode
MINUTES OF EVIDENCE.

12,635. (Mr. Bidder.) That column has not turned over?—No, it has not fallen over; but the strain has broken all the columns in that pier, and shifted those columns which had not epiots to the extent of three quarters of an inch.

12,636. (Mr. Trayner.) Did you make any observation of the thickness of the metal at the edge?—Yes, it was about its proper thickness; there was no evident weakness there, but from the fact of its going it was the weakest.

The Court adjourned for the usual period.

On re-assembling,

12,637. (Mr. Trayner.) You have described the flanges, the legs, and the bars; what is the next point in the construction of the bridge which you wish to go to?—The 15-inch columns are further braced horizontally at every joint by diagonal rods of 14 inches in diameter, which ends are through cast-iron quadrants, which are held by the same bolts that hold the channel irons. The cast iron quadrants through which the ends of those rods pass are secured by means of the same bolts as those which hold the channel irons, and if you refer to page 32 of the official drawings you will see a half-full-size drawing of those that were used on the line of bolts. Every joint is at an angle of 45 degrees with the bolts which hold it. The space into which the castings had to get between the bolt and the channel iron was quite sufficient metal could not be left round the bolt. I exhibit the end of one of them in which it will be seen that the thickness of the metal is only about half-an-inch.

12,638. (Mr. Trayner.) Thickness of the metal where?—Between the sides of the hole for the bolt to pass through. I may say that in every case where any strain has come upon these rods the casting has broken; it has all become detached by the breaking of the quadrant, which was an imperfect model of connecting them.

12,639. (Mr. Bidder.) Will you point out which part of drawing No. 32 you are referring to?—This (pointing to the drawing) is the tie-rod, this is the quadrant, this is the channel iron, this is the leg. The quadrant was secured by these two bolts passing through the return flange; the piece of metal which I hold in my hand was that piece. The thickness between the bolt and the channel iron, instead of being about an inch, as shown there, was never more than half-an-inch; they have broken in every case.

12,640. (Mr. MacNalty.) Will you show me what you have just been describing to the Court?

The Witness did so.

12,641. (Mr. Trayner.) Will you kindly explain the bearing or importance on the structure of these rods?—They in no way affected the strength of the structure against a lateral strain tending to throw the pier over. The object of these was to avoid the racking motion, but they did not affect the strength of the structure to resist the overturning force.

12,642. In what respect is the deficiency of that metal which you have shown a matter-bearing upon the question we are now upon, or going to come to?—The only way in which it would affect the strength of the bridge would be that the bolts which held these horizontal struts, which were already weak and imperfect, were made still longer, and had an
additional rough surface to crush against, and would therefore be less secure in their pinching action than before. They have on one or two of those bolts which have been severely nipped. This is one of the bolts (producing it) which have been sheared off at each side by the pull or thrust of the struts upon them.

12,646. Would the structure have been stronger if those bolts had not had to pass through that additional piece of 14-inch iron?—Yes; they would have pinched the struts into securely into contact with the lugs.

12,647. In this way they led to a weakening of what had a particular bearing upon the strength of the structure?—Yes; they had but a slight influence. The mode of bracing which I have described was adopted in every one of the seven stories of buildings by the pier consisted. Those independent groups of columns were surmounted by a box girder in the shape of the letter “L,” shown upon the plan, which will be distinctly seen on sheet 30.

12,648. (The Commissioner.) When you say the letter “L,” do you mean the two arms being equal?—Yes, as in the plan “L”; it is in this shape (putting it in the shape of the letter “L”).

12,649. (Mr. Trayner.) You call them box girders?—They are box girders; because, if you look at the transverse section at the bottom right-hand corner, you will see that they are in the form of a hollow box—usually called box girders—those girders were strengthened by a metal web to enable them to resist the thrust they were exposed to. Those “L” girders rested directly upon the 18-inch columns, but the 15-inch columns passed through them. The object of that was that in the temporary erection of the bridge other columns might be placed on the top for the purpose of enabling the lifting apparatus to be put high enough to lift the girders to the requisite height above the other parts of the structure. I mention that, because, in some of the evidence at Dundee a little confusion appeared to arise from not knowing what was meant by the lifting columns; the lifting columns were those which were put temporarily on the top of the 15-inch columns to enable the girders to be lifted in their places. That is the reason why the 15-inch columns passed through the box girders. They had a flange appearing above them, as you can see upon sheet 30. The dotted lines exhibit the temporary columns which were afterwards taken away.

12,650. (The Commissioner.) With corresponding flanges?—With corresponding flanges.

12,651. (Mr. Bidder.) The 18-inch columns did not pass through the girders?—The 18-inch columns did not pass through, but rested upon a wrought-iron plate, and the attachment of the columns to that plate was such as it might have been. As it is shown in the middle figure on the right-hand side, it shows eight bolts upon either face. But I have one of those plates in London, which was lifted from the bottom of the Tay, in which those holes are shown to be most irregular, and very much enlarged, and which shows that there were four bolts to hold each column instead of the eight, by which, as I shall show hereafter, the strength of the structure was very much affected.

12,652. (Mr. Bidder.) Four bolts to each column?—Yes, and those only upon the outer margin. Having spoken of the temporary columns which were used, those columns were put to enable the columns which I have indicated; and if you turn to sheet 27 you will see that the channel struts are shown in the section; you will also see upon sheet 31 that there are three sets of lugs upon each of the 15-inch columns.

12,653. What do you call those short girders?—I should call them temporary lifting girders; I would call them deep longitudinal lifting girders, as distinguished from transverse girders upon which the hydraulic press was rested.

12,654. (Mr. Trayner.) You did not find many of those remaining?—I did not find any of them remaining; they were not intended to be there permanently.

12,655. (The Commissioner.) They were only there during the raising of the bridge?—They were only used during the construction of the bridge. The existence of the flanges to which they were bolted has led to a false impression that they were parts of the design which were put in, when, in fact, as I would make with reference to the box girders is, that as the piers are constructed they really consist of two groups of three columns each, instead of forming one connected structure, and, if these box girders, forming a kind of entablature had been made the means of uniting both groups together, the strength of the structure would have been increased by that means, and there would have been less effect of the wind in disturbing the pressure upon those groups of columns, which I shall explain hereafter. Passing upwards, there were upon the tops of the L girders longitudinal cellular girders, which are shown on plate 29; and the position of those girders was such, being equivalent from the 18-inch column and the pair of 15-inch columns, that any weight put upon these cellular girders was equally divided, one half going upon the 18-inch column and the other half falling upon the two 15-inch columns. Those cellular girders carried the massive cast-iron plate. There were similar cast-iron plates bolted to the under side of the girders, and between the two there were at the ordinary joints eight cast-iron rollers five inches in diameter and two feet long, having flanges which guided them in their motion and prevented their being thrust laterally aside.

The rollers had a live frame; you will see it on plate 30. You will see that the axles of the rollers were connected by a little framework of angle iron, which preserved them parallel in their places, but did not in any way impede their rolling.

12,656. Preventing their rolling beyond a certain point?—Yes; there was a very slightly raised piece at the ends of the lower plate which prevented them from rolling if they had any inclination to do so; but, in this respect, there really was nothing to lead them to pass right away; they were only kept apart by their ends to prevent one roller overrunning another.

12,657. (Mr. Bidder.) Before you leave the plan, the model before us shows another age of vertical cross bracings lying in a plane parallel to the length of the bridge; I want to know whether that does not make the column weaker?—Yes, and it is shown upon the plans. I meant to express that when I said that every column was united to its adjacent one, which is the fact. This column is adjacent to that (pointing to them); in every direction in which it was possible to brace them they were broached, and you will see that shown upon the drawings.

12,658. In which drawing is that shown?—You will see it upon sheet 26; there only the central line of tie bars are indicated, but you will see that the bars which pass between column 1 and column 2 and column 5 respectively are shown as being shorted, and behind them you will see they have indicated; and if you turn to sheet 27 you will see the channel struts are shown in the section; you will also see upon sheet 31 that there are three sets of lugs upon each of the 15-inch columns.

12,659. (Colonel Folland.) This model shows that the channel iron are wanting in column 4 and column 5 for four lengths of the columns?—That has been temporarily taken out to enable these girders to be raised, their place being temporarily supplied by the deep girders which, to a certain extent, braced the structure, which then had only to carry its own weight.

12,660. They were not left out?—They were not
left out; they were all replaced; they had to be taken out stage by stage as the girders were lifted, and, though they had all been taken out for four lengths: in this model, I think most likely in the expansion of the work they were only taken out for each length as it was necessary: for the time, not because forces would dictate their being put in story by story as the girders passed upwards. I was going next to explain the mode in which the separate girders of each span were united into groups of four and five to under them continuously—they were raised separately. 12,661. (Mr. Trayner.) Each span was raised separately, and being lifted into place, the outer and was lifted to the extent of five or six inches by hydraulic presses placed underneath. There were three cover-plates put upon each side of each boom, and it was intended, I suppose, in the original design, that rivets should have been put in, and that those should have been riveted up, and thoroughly secured before they were again lowered into their place. That is the ordinary way of bringing the normal strain upon a series of girders which are supported at intermediate points, and producing what is called continuity—that is to say, the initial tensile strain upon the upper boom (as Mr. Basset explained, and the initial compressive strain upon the lower boom) at its meeting, in order that the bridge may be the better able to sustain a rolling load passing continuously over it. That continuity gives it stiffness.

12,662. (The Commissioner.) Tending to tighten it up?—Yes, to produce the effect of continuity. If you compare the drawings of the lattice girders, you will find that the lattice bars are differently proportioned in the end girders to what they are in the intermediate ones; the outer half of those girders is of lighter proportions than the other half, because it had to resist the strains which this principle of continuity put upon the girders.

12,663. (Mr. Trayner.) Before you go any further, what is the effect of that so-produced continuity on the piers over which that initial strain is brought to bear?—If it had been effected, the effect of it would be to produce a greater strain upon the pier, which is quite obvious; if I lift this up by means of an hydraulic press, if I then put more or less in that direction, and I take those pressures away, this by its deflection will come down, but a strain must necessarily have been produced on the pier which supported it; and I observe in the calculations which have been made by Dr. Pole and Mr. Stewart they say they have taken into account the effect of this extra bearing upon the pier. When I come to explain the strains upon the piers and the effect of the structure as bearing down upon them, you will see that the stability of these piers to resist the lateral strain depended upon the weights placed upon the top of them as one element, and therefore it has to depend also upon the stability of the bridge. In my calculations I have not, however, taken that effect into account, and I have omitted to do so for this reason—that in the evidence which was given at Dundee it was stated that, instead of these cover-plates being riveted on at the time the girder was raised, they were bolted through with service bolts, and that service bolts were not put until the girder was lowered, and that the bridge was used for the passage of heavy battle trains.

12,664. It may be convenient to note that that evidence is at question 6494 onwards?—The reference to the securing of the cover-plates temporarily by service bolts is at question 6494, and the reference to the putting on of the bolts is at questions 6291 to 6295.

12,665. That is the reason why, in your calculation, you do not give effect to the alleged continuity?—If those service bolts had been nipped with sufficient force to produce the effect intended, they never could have been got out. The rollers of which I have been speaking were placed under the girders at piers Nos. 31, 35, and 39, that being a security, as it were, that those girders should not eventually work in one direction by the action of expansion and contraction—each division of girders being bolted to one pier, the others were left free. At the divisions between the spans, there were no cover-plates whatever, and there was no connection between the lattice girders. The only continuity of any sort was that of the longitudinal beams upon which the rails were laid, and the rails themselves were held by the permanent way. I have now to describe the platform.

12,666. (Mr. Trayner.) A single moment—you have described the rolling bearings—there were two other kinds of bearings; would it be convenient to describe them now?—I have described them. I have described the fixed bearing, the rolling bearing, and the expansion bearing. I now pass to the platform. Along each margin between the way-beams there was a half timber forming a kind of abutting piece for ballast; between that and the way-beams there were 4-inch planks; the planking was covered with asphaltite, and a thickness of two or three inches of ballast was laid to protect the whole structure from fire. The permanent way was such that there were raised at every three feet—double chairs—which carried both the running rails and a rail of similar section acting as a guard rail, and raised about an inch above the other, both carried by the same chair and both of steel weighing 75 pounds to the yard. There were further, to insure the gauge of the line, flat wrought-iron plates which were placed between the covering pieces which were supported at intermediate points, and producing what is called continuity—that is to say, the initial tensile strain upon the upper boom (as Mr. Basset explained, and the initial compressive strain upon the lower boom) at its meeting, in order that the bridge may be the better able to sustain a rolling load passing continuously over it. That continuity gives it stiffness.

12,667. (The Commissioner.) That is to say, there was an incline?—Yes, an incline upwards, which was continued over——

12,668. Until we got to pier 39?—That continued over spans 29 to 33; from the next span, No. 30, up to the pier 30 the line still rose, but at a diminished inclination of 1 in 490. It then for six spans continued level, which brought it to pier No. 36, and it then fell at an inclination of 1 in 130 for one span; and the remainder of the fallen part, and a considerable length of the remaining portion of the bridge, fell with a gradient of 1 in 78-86, so that the summit level really extended over six spans. There was a little confusion upon that point with some of the witnesses, but I think it arose from the fact that the summit was of some extent, and they sometimes spoke of it as the approach from the north, and sometimes as the approach from the south. In my calculations I have not, however, taken that effect into account, and I have omitted to do so for this reason—that in the evidence which was given at Dundee it was stated that, instead of these cover-plates being riveted on at the time the girder was raised, they were bolted through with service bolts, and that service bolts were not put until the girder was lowered, and that the bridge was used for the passage of heavy battle trains.

12,669. (Mr. Trayner.) But the summit of the bridge upon these spans was from pier No. 30 to pier No. 36?—Yes, it is indicated upon sheet 9; you will find it there. The change of gradient has been omitted to be shown upon sheet 7; it should have been shown over pier 30 as changing from 1 in 490 to 1 in 130. I think that that completes the whole of the description of the structure which it is necessary to give.

12,670. Now there was one matter you spoke of which I would like you to deal with further. When you were describing the gibs and cotters, did you find that something had been done to alter their condition from what they were to be? In examining the structure I found that in many cases narrow packing pieces, packing pieces of wrought-iron, a quarter of an inch thick and half-an-inch wide had been introduced either between the coter and the gib, or between the two cotters themselves, and I was subsequently informed that this had been done in the manner which was described by Mr. Noble yesterday.

12,671. You got from Mr. Noble a note of the
TAY BRIDGE DISASTER:

12,672. You can tell me about how many of these packing pieces would go to the lb.?—About 10; evidently, they were just cut off roughly, but averaging 10 to the lb., so that 5 lbs. means 60 packing pieces.

12,673. In the month of November, I forget the exact day, but I had 7 lbs. of iron more, and that would yield 70 packing pieces.?—Yes.

12,674. And on the 2nd of December he bought 10 lbs. more—how much of that he used we do not know?—No; the 30 and the 70 would together be equal to 120-pieces; and I presume those would be at the time because other iron was bought. Mr. Noble produced, I think, about 17 feet of iron still remaining over; and told me what had been used for other purposes, from which I estimated that about 150 would probably have been employed in the whole of the structure, but how many were employed in the piers supporting the higher girders and bow many in the piers supporting the lower I am unable to say.

12,675. I would observe, however, that in No. 29 pier, which is the first-pier that fell, the whole of the tie-bars which were attached to column No. 5 had been so taken up with packing-pieces—in two of them the packing-pieces still remain, in the other the packing piece had come out, and the tie had also moved to the extent of another quarter of an inch.

12,676. (Mr. Bidder.) Do you say that you found two-in which the packing piece had gone?—I found one.—That was the tie-bar, which passes from column 5 at the bottom to column 6 at the top on the south side. No. 28.—In that case the packing pieces were in the two ties which passed from column 5, columns 3 and 4 respectively the packing pieces were still there. It showed that the whole of the ties which met at the bottom of that column had moved to such an extent as to allow the introduction of these (producing some specimens). I have seen No. 5 which I picked up upon the pier as having, tumbled out of such portions of the ruins as had fallen upon the piers.

12,677. (Colonel Yolland.) Which piers do you refer to?—The piers which still stand.

12,678. Which columns?—The whole of the 12 piers which are now in ruins. I found upon the piers which had supported them, and as having come from those parts of the structure which had not fallen into the water.

12,679. (Mr. Trayner.) The first of these packing pieces were cast in the month of October 1878?—Yes.

12,680. The bridge was opened for passenger traffic in the preceding May?—Upon the 31st of May.

12,681. What, in your opinion, had led to the loosening of the croters or to the necessity for these packing pieces?—The racking of the structure. The opinion I have formed is that the vibration caused by the trains, and the lateral strain which would have been set upon this structure by the wind rushing horizontally from the east and west, would have racked the structure sufficiently to produce this loosening; and I was not surprised at this racking taking place, because I found there were so many points at which the attachments could yield. A very small yielding in one of the attachments would produce a very great yielding in the structure itself. For example, the angle which the ties make with the column to which they are attached is such that the useful result of the tensile strength of the tie to restrain the upper part of the column from moving in a horizontal direction is very nearly one-third (it is about 0.333) of the whole tensile strain; and any movement in the tie would be magnified in the same ratio; that is, to say, that if the tie were elongated a quarter of an inch, it would allow nearly three-quarters of an inch horizontal movement in the top of the column. These ties had a greater effect in

restraining the column (pointing to the model); in those the effect was only about threes or less of the strain upon the bars.考查 the model, it was about three-sixths of the strain upon the bars; therefore, any crushing up of the surfaces of these ties would allow a very large extent of motion or racking in the column.

12,682. What would be the effect of such a yielding, as you have mentioned just now in one of the lower columns, upon the upper columns?—I do not think how much would the effect of the yielding be magnified when you reached the top of the column?—Seven times, but I should tell you the effect of the elongation of any one bar would not be to allow the top to pass over; it would be restrained by these columns. The necessary movement would stretch to the same extent for the column which moved to preserve a straight line. The effect which might be produced would very likely be to throw the column out of a vertical position, and that would lessen its strength, because it would bring a binding action upon it instead of a purely crushing action; it would mean that the strength of this column would be reduced from that of a column of 10 feet in length, if it was properly treated, to that of 20 feet if it took place at this point (pointing to the model), or of 30 feet if it took place at two points.

12,683. The effect would be that the power to resist superincumbent or lateral pressure upon the bridge would be diminished in proportion to the distance down the column at which the yielding took place?—The diminution in the strength of the column by the increase of its length is something under the square of that increase. It is as the 1:8 power of the length of the column; so that if you double the length of the column you make it about 3½ times as weak as it was before.

12,684. These ties were essential to the rigidity of the columns, and, therefore, to the stability of the bridge as a structure?—Absolutely so.

12,685. Do you think that was a matter which should have been under constant and careful supervision?—Yes. The structure has a character, of course, should be very carefully watched.

12,686. Do you think that was a matter to be left to a man who was instructed merely to regard the scouring of the river, and who took upon himself the duty of looking after the strength of the ironwork?—I would go so far as to say, if I had been responsible for the structure, I should have appointed a person to look after it.

12,687. As a matter of fact, would you have left that matter to the supervision of such a man as Mr. Noble?—I should not have hesitated to leave it to Mr. Noble's supervision, because he is an exceptionally careful man, and a man of whom I have some knowledge; but I would not have left the remedy to him. I would have left the structure with safety to his inspection, because I know him to be very careful, and, I think, of sufficient intelligence to undertake the duty of inspection.

12,688. Do I understand that you would have left the duty of inspection to the person 

concerned, with instructions to report to you, as the engineer, anything that occurred?—Yes, no doubt.

12,689. What opinion have you formed as to what occasioned the necessity for these packing pieces, as soon after the opening of the railway?—It is perfectly evident that the necessity arose from the tie-bars being over-stressed, and the elongation of these pieces ceased to be slack, the inevitable consequence was that the structure remained distorted.

12,690. It had become distorted?—These bars could not have slackened without the structure having moved to a sufficient extent to have produced the slackness; and if you put in a packing piece which took up that slackness, it is quite true that you have braced the structure in its then position, but in that position it is distorted, and possibly less capable of carrying the superincumbent weights put upon it.
12,691. Would the running of trains across that bridge at an excessive speed tend to produce the slackening of these cutters and render necessary the packing pieces? —Yes. I do not think that this slackening was produced by any movement in the tie-bars; but, by their shifting, because of the very small angle which they make and the fact that they were probably rusted and painted together, and that the ends were spread and had been spread in contact with the thin plates that they passed through; it was not at all likely that they would shift in themselves. But what did happen was that the girder had been shifted, through they will be seen to be 0.329 of an inch apart for the greater portion of their length; in fact, they merely touch at points.

You have four bearing surfaces. You have the bearing-surface of the bolt above, with the angle edge I have described, bearing against the thread of the screw, so that if there should be a crushing which bearing against each of these things it would fully account for the condition of things.

12,692. Take it from me that the company were authorised out and ordered the trains to run at a rate of 25 miles an hour. Now, if that speed was raised to something near 40 miles an hour, would that tend further to account for the slackening of the structure in the way you have described? —I think so. I think that the train passing over would rattle the structure, but that the great influence would be produced by strong winds blowing against the side of the structure, which would tend to push it over, and that would produce a strain tending to elongate all these ties; and then when the wind blew from the opposite direction the ties which had been strained before would be pushed back, and the tie-bars which had been loosened would rattle.

The fact that the tie-bars began to rattle was really an indication that the strain had taken place since Mr. Noble last observed the structure; and I think if accurate record had been kept it would probably have been found that there had been a high wind, or something of the sort, in the interval.

12,693. In considering (which you will have to do more particularly by and by) the causes which led to the destruction of the bridge, would you exclude altogether as a factor the speed of the trains, or would you take it into consideration to some extent? —It is a very important factor as influencing the strains which came upon the structure.

12,694. Did you find in your examination any of the columns which were not directly perpendicular in their bearing upon the one below? —No; I did not; but that reminds me that I omitted in my description of the columns to say that in the turning of some of the flanges—other sufficient care had not been taken, or the object had been to turn out some bad metal; but the inner part of the flange, in line with the metal of the column, was so much wanting that the column only bore on the outer edge of the flange upon a margin of about 0.4 of an inch (that I found in two or three of the 18-inch columns), and the concrete had run, in consequence, over the remaining surface of the joint, the flange only being in contact round the margin.

12,695. (Colonel Polland.) Throughout? —Throughout, the whole extent of that column; that was so with two joints of the same column.

12,696. (The Commissioner.) Which column was that? —That was one of the columns which have been referred to also in Mr. Day's paper; he had been under the impression that the joint had been opened, but that was not the case; he had mistaken what happened. That is column No. 1 of pier 34, or, rather, I should say, the one I have described is column No. 34, that is the one which has both the joints in that state; but column No. 1 of pier No. 34 was very similar indeed.

12,697. (Mr. Barlow.) Two joints in column No. 34, and one joint in No. 34? —Yes, the bearing in one was 4¼ inches, and in the other 4½ inches of an inch round the margin.

12,698. (The Commissioner.) What I understand then is, that it was not from the flanges being separated, but from the want of metal actually in the interior part of the flange? —That is so; there was a channel which separated, as it were, the two margins, the inner and the outer; and the inner margin had been turned down, and it had no bearing whatever.

12,699. There was only a support of about 4½ of an inch? —That is so round the outer margin.

12,700. (Mr. Trayner.) Did you observe whether the girders met directly over the centre of the pier on which they rested? —With regard to the fallen portion I am unable to speak, because all evidence upon that point is gone this afternoon.

12,701. That I know, but I should have said, of that which is now standing? —Of that which is now standing I have observed that many of the joints are considerably off the centre of the piers; I have not my notes of that matter here. I have put that together as keeping it separate from the structure fallen down. I shall be prepared to give you information upon that point to-morrow.

12,702. (The Commissioner.) You will give us information upon that? —Yes, Sir; I have your instructions to give evidence upon that point.

12,703. (Mr. Bidder.) This model is erroneous in that respect, because it represents the girder as going right across? —Yes.

12,704. (Mr. Bidder.) You do mean laterally? —Yes, horizontally.

12,705. But there are two ways of going horizontally? —Yes, east and west; it deviated east and west. The centre lines could not be compared in any other direction. I also found that the directions at which they met seemed to indicate that there was a change of direction in the girder at that point.

12,706. (Mr. Trayner.) Did you form any opinion as to what had caused that deviation? —I supposed that it was a want of adjustment in the position of the piers; the space of the pier was so restricted that there was no room for any adjustment on the pier itself; if the lower part was out of position the upper part became necessarily so. From the very nature of the mode of construction of these piers (for the hexagonal brickwork was floated out and deposited) it would have been quite impossible, unless they had fixed timber guides, to have insured the exact position intended, and I think that this was for the whole of the want of adjustment of the structure as it now stands. I think that, instead of having ascertained the exact position of the piers before they ordered the lattice girders and constructed them, it is evident that the lattice girders were prepared for these positions, not as they were, but as they ought to be, and therefore they overshot the proper line.

12,707. I am not sure that I follow you about that difference of line between the higher girder and the lower girder? —They should have formed one direct line, but the lower girder was pointing more to the west than the upper girder; the upper girder deviated towards the east.

12,708. Was there any change or deviation in your opinion, arising from want of original careful and proper adjustment, or was it in any way arising from...
Mr. H. Lee. a shaking, or oscillation of the structure?—No; it was constructed so, and riveted together in that position.

12,710. (Mr. Bidder.) I do not understand what you mean by "riveted together in that position." The higher girder would be the lower girder; would not the lower one be the lower girder?—No; the lower cast-iron plate was bolted to the lower girder; the upper one was bolted to a wrought-iron plate, and those were necessarily in line, because the rollers could not have been put on unless they were, and then the upper girder was riveted out of position upon that upper wrought-iron plate. I hasten to say that I was in London.

12,711. (Mr. Trueman.) I do not know whether you have told us upon which of the piers the girders were fastened?—I did; it is upon the notes.

12,712. You said just now that the state of the base rendered careful adjustment impossible. Will you tell me what is your objection to the mode in which the foundations have been laid? What is your objection to the foundation as existing?—I have no complaint whatever to make against the nature of the foundations. I only consider that the base of the pier is too narrow for a structure of this sort, because it necessitates such slanting angles being given to the tie rods that, as I explained, their effect is reduced to one-third.

12,713. To what extent would you have thought it right to increase these bases?—That is a very large question.

12,714. Then let it have a very large answer?—I should have altered the disposition of these columns, and instead of putting one column externally I would certainly have put two, so that the ties might have been direct, so that the whole four columns might be in the same plane, and therefore that the ties should be in the direction in which they would have to resist the strain. By the double angle their strength is now reduced by twice the size of the angle which they take up.

12,715. Does this happen to know whether by the original design those piers which have fallen were originally intended to have been brick piers instead of iron?—I only know that it is a matter of hearsay.

12,716. (Mr. Bidder.) I take it that we have to deal with the piers that it was actually executed.

12,717. (Mr. Trueman.) Assuming that these piers were originally intended to have been built of brick, and were altered to iron, would that necessitate, in your opinion, any alteration of the original design of the base?—If a brick pier might have been built of it, the Tay Bridge in which the masonry is not the base, the internal strength of it, then I suppose it would have been increased in that way wonderfully—it would have been three or four times increased. And I should also say that those ties are mere ribbons, and therefore resist the tensile strain; but had they been struts, as well as ties, that one operation would have doubled the strength of the structure—that is to say, No. 1 to No. 4; the strength of this part would have been increased in that way wonderfully—it would have been three or four times increased. And I should also say that those ties are mere ribbons, and therefore resist the tensile strain; but had they been struts, as well as ties, that one operation would have doubled the strength of the structure—that is to say, No. 1 to No. 4; the strength of this part would have been increased in that way wonderfully—it would have been three or four times increased.

12,718. (Mr. Bidder.) If you had been in charge of this work, you would then put a third set of these ties, and the weakest part of the structure is only a compressed surface of three-quarters by a quarter of an inch, and therefore a bar of 3/4 inches was quite unnecessary to take part in transmitting that strain.

12,719. (Mr. Bidder.) This is your Report with an Appendix (asking a question)?—Yes.

12,720. The report is a true report?—It truly conveys my impressions and opinions, and narrates facts which I have observed.

12,721. As regards facts it is correct?—Yes.

12,722. And as far as opinion is concerned it accurately represents your opinion after careful consideration?—Yes.

12,723. Now, the next question we have to come to is involved in the Appendix, that question of resilience; you said to me you would rather not go into that; is that your wish still?—No, it is only that I should be glad to have the results of some experiments which I am hoping to try to-night at Messrs. Kirkaldy's; there has been great delay about the experiments, and before I give evidence upon the effect produced upon a structure by certain winds I should like to have the facts before me, but I can go on with all the earlier facts in the Appendix.

12,724. (Mr. Trueman.) In the meantime I will put in the Report and the appendices (handing in the same to the witness). Tell me, if you please, what objection do you find, or what fault do you find, with the design of the bridge, always bearing upon the catastrophes that has happened?—I think that the base is too narrow for the strain which had to come upon it. I should have increased the width of the base.

12,725. (The Commissioner.) The base of the piers?—Yes; that is to say, the base of the pier viewed as a whole—viewed as a rigid structure; and I should have altered the mode of attachment of all the struts and ties.

12,726. (Mr. Trueman.) That is to say, what mere ties now would have made struts as well?—Yes; I do not know that I can better show what I would have done under similar circumstances by stating what I did do in the erection of piers of nearly the same proportions as these in height and base, with three large towers erected for the purpose of carrying water tanks.

Mr. Bidder. It seems to me, if I may point it out, that we are getting rather wide of the question now, because I apprehend the question for the Commissioner to inquire into is the circumstances of the construction of this Tay Bridge and the causes which led to the accident which happened. There may be ten million alternative ways of constructing bridges, some of which may be better, and some of which may be worse.

(The Witness.) Then I will give a general reply, and not take a particular instance.

(Mr. Bidder.) Because if the witness gives a particular instance I might have to criticize that.

(The Commissioner.) The second observation which Mr. Law made was, "I should have altered the mode of attachment of the ties and struts.

12,727. (Mr. Bidder.) In other words, you object to what was done here—by the "attachment" you mean by the "lugs"?—Yes; I was going to say what I did, but I will state what I would have done without stating what I did it. I would not have had any lugs or any fillets in the angles to the flange, all of which tended to make unsound castings, and which prevented the facing of the upper edge of the flange.

(Mr. Bidder.) When Mr. Law says, "I object to that as an element of weakness," that is quite ad rem, and he may go on to show that that contributed to the accident; but when he goes on to say that one thing or another might be done, I submit that that is irrelevant to the inquiry. The question is, having regard to the mode in which the bridge was constructed, was that defective so as to contribute in any way to the accident which followed. It is not in the least relevant to this inquiry to show alternative modes of construction which Mr. Law has given.
"weakness?" and Mr. Law would say, "I consider "it an element of weakness, because I should have "done so and so." (Mr. Bidder.) It will not make it an element of weakness in the sense of contributing to this accident because there is some other way in which it could 'be done, nor less because there is not.

(Mr. Bidder.) If the mode of construction contributed to the falling of the bridge, it is obviously relevant, and we cannot find out whether it contributed to the falling of the bridge unless we find that it was faulty in design. (The Commissioner.) The question which Mr. Law is entitled to answer, as it appears to me, is this: You say that the attachment of the struts and ties was defective. In what respects was it defective? He says they are defective because they are attached by hugles. Of course, you would say, "How could you attach them?" (Mr. Bidder.) If I say that in cross-examination it might be irrelevant, to answer it. (The Commissioner.) If you do not ask it then, it goes against you. (Mr. Bidder.) The question I should ask would be, if it was defective, how did it contribute to the accident? (The Commissioner.) It comes to the same thing.

12,728. (Mr. Trayner, to the witness.) You were explaining how the faulty construction contributed to the fall of the bridge. You have explained that the mode of attachment of the struts and ties was defective?—Yes, inasmuch as the struts had no stubs or thorns to thrust against, nor had they bolts which acted as steady pins; by which I mean bolts which were accurately and perfectly filled the hole both in the channel iron strut and in the lug of the column. 12,729. (Mr. Trayner.) Before you leave the lugs, I want to ask you a question. Have you done with them?—No. I think that the defect in the diagonal tie-bars was in their not being struts as well as ties, that is, they were incapable of resisting the compressive strain; and that the bearing surfaces of the cotters against the tie was too small. I think that the flanges should have been faced upon both sides; that the under side of the heads and nuts, the bearing surfaces of the heads and nuts, should have been faced, and that the nuts should have been turned to fit the holes. I think that the L girders should have been connected into one piece, and that the connection of the 18-inch columns should have been more perfectly made with them. I should also say that I think the bolts should have been drilled in the lugs, suppose lugs to have been used, and that pinning the nut by getting a small screw into the side of a screwed bolt; and I consider that the holding-down bolts should have been secured by anchor-plates and carried to a greater depth.

12,780. (The Commissioner.) Then you also mentioned something about the connection between columns No. 1 and No. 4?—But with regard to the existing structure, I have not yet described that. I consider that the mode in which the horizontal diagonal tie-rods were connected was also defective. They were not properly connected, or were connected in such a manner as to interfere with the strength of the struts and not to be capable of taking the strain of the area represented. I have nothing else to add in that respect. 12,781. But you have not mentioned also that question of connection between column No. 1 and column No. 4?—That was a suggestion which I understood I was not to make.

12,782. No; you say it is an element of weakness that has not connected?—Yes; it would have added very greatly to the strength, and at a very slight cost, if diagonal ties had been carried from the lower point of one column to the upper point of the next in a direction perpendicular to the axis of the bridge. It would have increased the strength of the bridge enormously.

12,783. (Mr. Trayner.) Now you have, I suppose, exhausted your view of the defective design from the base up to the L girders?—Yes.

12,784. Is there anything above the L girders wherein the bridge would have been better designed as tending to strengthen, or the absence of which tended to weakness?—No; I may say I should not have designed the girders of that open lattice form, but if they have been very carefully proportioned, and the permanent way appears to have been very carefully laid, and to have been in thorough good order.

12,785. What I was rather pointing at was this: you have referred shortly to that which is described in your report, and I wish to know, as an element of strength; would you in carrying out the bridge have allowed that course to be adopted which the witness Orm described as having been adopted? Presuming that to have been part of the construction, would you have approved of that, namely, removing bolts and putting in rivets?—That was a matter of workmanship and not of design; but I should not have approved of it, because it was rendering ineffectual what you desired to effect.

12,786. If that was part of the engineer's design, it was an element of weakness as depriving the girders of the element of continuity?—Yes; but I do not think it was so, but was rather an element of rapidity in working by the contractor.

12,737. Was that an element of weakness which might have contributed to the accident?—No, I do not think it affected the structure, but it did affect the pressure of the girders upon the piers.

12,788. (The Commissioner.) Would not distributing the weight, but it would have brought more weight upon some piers and less upon others—it would have distributed it, but not so as to make it more equal, but more unequal.

12,789. (Mr. Trayner.) Did you not commence your objection to the design by speaking of the base?—Yes, I said the base was too narrow; but I was speaking of its narrowness in its direction at right angles to the bridge.

12,749. If that be so, I do not wish to take you over the particulars of the defects in execution, because those you have already dealt with; you have stated the mode in which they were done, and so on? Is there anything else you wish to lay before the Commissioner?—There is one other thing with regard to the bolts. The nuts of the bolts were unusually thin; for instance, the holding-down bolts were 1-inch, and the proper proportion for the nut to that bolt would have been about three inches, whereas they were barely 2½ inches, and were only of the same proportion as the nuts to the 1½-inch bolts, which were not more than two-thirds of the usual substance of a nut. And that nut, it will also be seen, had a burr here (producing a nut) which was never removed, and which effectually prevented their coming into contact with any holding-down power. Those defects ran through the 1½-inch bolts which are used throughout the whole of the structure. There is only one size of bolts; the nuts are both short in length and very thin in substance. The raised burr round the nut would have been removed if it had been faced; as it was, that prevented complete contact. And when it is remembered that small spaces increased 50 times the movement at the top, it becomes very material; a very small force would crush that burr, and that being crushed would make 50 times that amount of movement at the top of the columns; that being nearly a 20th of an inch, it means nearly 2½ inches at the top.

12,741. Have you said what would have been the thickness of that metal?—About half as much again.

12,742. The strength of the nut has, of course, to be taken at the diameter of the iron in the thread. Is its strength would be the mean between the two; the triangular threads have strength; there is a certain well-known thickness which is generally used by engineers.
12,748. Have you a tracing showing the movement of the south-westernmost girder in falling?—I have. The lower plate, which had been bolted on to the south-westernmost girder which fell, was found upon the pier No. 28, having fallen vertically at the time of the disaster, having become detached with a portion of the lower boom of the girder by a blow which it received in falling. It was picked up, and I have brought it to London, and it was seen by the Court last night; but I have here a tracing which shows very carefully certain markings which are upon it, and if that tracing is laid to-puzzy-curvy it shows clearly the way in which the girder moved as it fell. I would convey one observation which I made yesterday, and I am giving it to Mr. Gilkes for calling my attention to it.—I mentioned that the two girders were not conformable to the angle west; but Mr. Gilkes has pointed out that that arose from the fact that the two lower girders were spread out, being 9 feet at one end and 14 feet 10 inches at the other, in order to bring them in the width of the higher portion, and therefore they were not in the same direction.

12,745. (The Commissioner.) That is, they were first at an angle and afterwards they came parallel?—Yes. The observation which I made with regard to their not being in position, applies, but what I said with regard to the deviation in angle must be taken in connection with what I have just said. This tracing shows that after being laid on white paper, white paper, you will see the way in which the girder moved when it fell. (The witness described the tracing to the Court.) This shows that as soon as the rollers had been carried across a distance of about 20 inches, then, and not till then, were they drawn off in the direction of the bridge, and there are similar markings upon the lower roller plate upon the easternmost side, which indicate a similar movement of the girder; the girder moved bodily to the eastward for about 20 inches, and then was drawn off the pier. The upper part of the pier—north, the lower part is south, the left-hand is west, and the right to the east. As soon as the rollers had arrived at this point (pointing to the tracing) they evidently fell from under; some of the rollers were found upon the pier. The girder then came down forcibly upon this, and the two rivets upon the bottom boom produced these scores.

12,746. (Mr. Barlow.) Those you attribute to the rivets underneath the girder?—Yes; they are parallel. By the violence of the blow the two easternmost corners were broken off from the plate; the violence of the blow detached the upright post from the girder, so that it fell separately into the river. The portion indicated by the dotted line of the lower boom, with a wrought-iron plate to correspond in size with the cast-iron plate, remained attached and now remains attached to the cast-iron plate. (The witness described the tracing to Mr. Sidder.)

12,747. (Mr. Trayner.) Have you any further remark to make upon that tracing?—No.

12,748. You will kindly turn to the specification, which is dated the 1st May 1874, relative to the contract between the North British Company and Messrs. Hopkins, Gilkes, and Company?—I may remark generally that the spans of the portion of the bridge which has fallen were to have been 200 feet as originally specified; they were afterwards enlarged to their present dimensions.

12,749. (The Commissioner.) That you derive from the former specification?—No, from this specification. On the first page it enumerates the number of spans and the respective openings.

12,760. (Mr. Webster.) Fourteen spans of 200 feet?—Yes, instead of 18, as they were subsequently erected. The first remark I would make is, that with regard to the cast iron at the bottom of page 6 of the specification, it is specified "that from time to time, on demand of the engineer, the cast iron shall be tested," and that the iron shall be of such a mixture that a bar with a transverse section of 2 inches by 1 inch, and plated edgeway on bearings 3 feet apart, will not break with a less strength than 8,000 lbs. applied in the centre. The only remark that I have to make upon that is, that that is a very good and a very high test. The results of 285 experiments of Professor Hodgkinson and Mr. Fairbairn have a mean of 12,756 lbs., so that a high standard was fixed for the strength of the cast iron.

12,751. (Mr. Trayner.) Whether or not the iron bears that test is a matter which we will come to afterwards?—That is a matter which the experiments which are now being made will show, as far as the specimens which are being subjected to examination are concerned.

12,752. In the meantime you observe that the specification required a good quality of iron?—The specification required a good iron; in fact, a high quality of iron.

12,753. Then what have you to say with regard to the brickwork?—With regard to the brickwork, there is nothing said about the stone being wetted.

12,754. Before you say anything further with regard to the brickwork, I will ask you a question under the head of malleable-iron girders. It is on page 9 of my copy. I am referring to the three paragraphs before "Bed plates and expansion rollers." (The Commissioner.) It is on page 7 of my copy. (The Witness.) We have a different printed copy. 12,755. (Mr. Trayner.) Will you find "Bed plates and expansion rollers"?—That follows "Malleable iron girders." 12,756. Take the paragraph beginning, "The rivets holes in the whole of the plates..."—&c. must be punched quite true and fair?—I have...
marked those passages. Had not I better go through the specification, otherwise I may omit something?

12,754. Very well, go through it in your own way—I was referring to page 6 under the item "Brickwork." I was going to say that there is no mention made that the stones should be wetted before the cement was applied, but it would result by implication, because it is specified that "all bricks immediately before being used shall be thoroughly saturated with water, and all plaster dirt removed from their surface." That is essential to the proper adhesion of the cement to either the brick or stone.

12,755. But even if it was not specified that the stones were to be wetted, the mere fact that cement was to be used would necessitate all the proper methods of working?—Yes; one would not set a dry stone upon cement. Under the item of "Stonework," it says "the belt of stonework for the piers of 200 feet spans, and shown on drawings at high water level, to extend the full diameter of each column." I do not quite understand that, unless it means that the whole upper surface was to have been covered with stone, but it has not been so carried out if that is the meaning. The margin for about 4 feet is of masonry: the central part is of concrete. Then it goes on to say "Each stone must be so placed in official contact as possible, and the joints made to indicate and close the full distance of each belt."

Upon that I have to observe that the stones were fairly faced throughout their whole joints, but that the joints were very wide, being in some parts as much as 1½ inches wide.

12,756. (Mr. Barlow.) The vertical joints?—Yes, the vertical joints, and some of the bed joints were also very thick: it also specifies "These stones to be 5 inches in thickness not less than 2 feet 6 inches, and chiseled dressed on all beds and joints," but in the execution two courses of 15 inches were adopted instead of 200 feet 6 inches, and that did make a practical difference in the official contact, as well as a large amount of danger of the whole structure giving way, upon the movement of the base pieces attached to them.

12,757. (The Commissioner.) Is it not the case that this portion of the contract was drawn upon the assumption that all the piers were to be of brickwork?—No, this specification contemplated the mode of construction which had been adopted.

12,758. Where do you find that, in the specification, or in the contract?—Upon the first page, "The piers for the spans of 60, 80, and six of the 120 feet spans, to be of brickwork in cement; those for the remaining 120 and 200 feet spans to be of brickwork in the lower part and east-Iron columns in the upper part." I am informed that these iron columns have not been adopted.

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12,762. Yes, I see that is so?—And though there is no detailed specification of the 200 feet spans, there is a detailed specification for the piers for the 66 feet spans, and they approximate to the piers which have been built.

12,763. (Mr. Barlow.) In the former specification it would appear that they were to have been of brickwork?—Yes, I think they were, but insufficient as that did not relate to any part of the structure which has fallen, I did not consider it necessary to make notes for giving evidence upon that. I therefore observe that instead of the one course of 2 feet 6 inches, there were two courses of 1 foot 6 inches, for the upper part, and courses of 1 foot 1 inch, 1 foot 6 inches, and that the joints and beds were only in some cases chisel dressed. The practical bearing of that is reference to the adhesion of the cement, the roughness of the surface of the stone, the more perfect being the adhesion of the cement to it, and to the part of the wear and tear and roughness of the sawn surfaces of this stone. It did go on, "The stone connecting the columns at this level to be of the same thickness and workmanship as the belt, and to extend into each column not less than 2 feet." I do not quite gather the meaning of that requirement. Passing on to the Mullion iron girders, paragraph 6 under that head reads, "The wrought-iron plates, bars, angle and T-irons used in the construction of the girders for this bridge must be of such make and quality as shall be specially approved by the engineer, and of such strength, that one square inch of sectional area shall support a tensile strain of twenty-one tons without breaking." The only portion of the wrought iron work the testings of which I know the result of at the present moment are the three tie bars which were broken last night in the presence of Mr. Gilkes and Mr. Stewart, and which averaged a strength of 15½ tons to the square inch. They broke very uniformly.

12,764. (Mr. Barlow.) Will you give the three results?—The first that was broken gave way through the sling plates, bursting through the sling plate where the bolt passed through it. It broke with a strain of 56,692 lbs. upon a sectional area of 1.025 square inches.

12,765. (The Commissioner.) How many tons does that give to the square inch?—About fifteen, that is the lowest of all, and I think that that broke at a lower strain than the real strength of the iron, from the fact that the two sling plates clearly had not even been bearing upon that bolt, because two distinct reports occurred: there was one breakage, and then afterwards, with the increased strain, there was the other, and therefore it is evident that there had not been an equal strain, and that is a thing to which the structure itself was specially liable, because the screw end of the bolt which went through the two sling plates would certainly yield before the other, and I think there would be an unequal strain upon the two sling plates, and that might account for the fact of the huns giving way, and it would put a much greater strain upon the lug upon the one side than upon the lug upon the other. That was what led me to say that turned pins would have been preferable to bolts, that is to say with the holes bored in the same section, 12,766. (Mr. Hallow.) Will you give us the ton to the square inch?—I have not taken that out. The third broke in a similar manner to the second, through the bolt hole in the web, and broke with a strain of 56,692 lbs. upon the square inch.

12,767. (Mr. Barlow.) That is the smallest result?—That is the smallest. That gives a mean strength of 57,578 lbs. upon a sectional area of 1.025 inches, being 15.8 tons to the square inch.

12,768. (Col. Yolland.) That is the average?—Yes, that is the mean.

12,769. (The Commissioner.) Instead of 21 tons?—It is specified to be 21 tons. That is the specification. I go on to say: "Such bars as the engineer may select from time to time must be thoroughly examined in the presence of himself or his deputy; and if any break under a less tension than that which is specified per square inch, as before mentioned, none of the plates, bars, &c., supplied by the same iron company shall be allowed to be used in these girders."

12,770. (Mr. Traynor.) That was disregarded obviously?—That involved something more than the rejection of the work: it was a kind of penalty to be inflicted upon the person who supplied it; and if any break under a less tension than that which is specified per square inch, as before mentioned, none of the plates, bars, &c., supplied by the same iron company shall be allowed to be used in these girders.

12,771. That has been disregarded, that stipulation has not been fulfilled?—The specimens broken have not come up to the weight. We have yet to test the iron of the girders.

12,772. (Mr. Bidd.) Do you say that was disregarded?—I do not say that of my own knowledge. It was stated in the evidence. I heard evidence to that effect.

12,773. (Mr. Traynor.) There is no objection, I take it, to the question I put. (To the witness.) The tests you have already spoken to, which were made in your own presence, show that that part of the specification was not carried out?—No, they do not show...
that, they show that those particular bars were not tested, but the specification does not contemplate that the whole of the iron should be tested.

(Mr. Bidder.) I was not objecting to your question, witness, Mr. Trayer, but I was objecting to Mr. Law giving evidence upon a matter which he could have no knowledge of.

(The Witness.) I should have said I did not know how far they were tested.

12,774. (Mr. Trayer.) These tests which you give just now represent what took place in your presence last night, were the bars which were so tested bars within this part of the specification?—I presume so, because there is no other item which would include the wrought ironwork of the piers.

(Mr. Bidder.) Surely this paragraph applies to the iron-in the girders of the bridge. As I understand what you tested last night were the tie-bars in the piers.

(Mr. Trayer.) We can easily put that right afterwards.

(The Witness.) There is no other allusion to any other ironwork beyond the bolts, which I shall come to presently.

12,775. Have you any further observation to make upon that paragraph?—No.

(The Commissioner to Mr. Bidder.) Are you going to contend that the wrought-iron plates, bars, and angle T-Irons, used in the construction of the girders, and these alone, are to bear a tensile strain of twenty-one tons, and that there is nothing in the specification to what this power shall be the power of the girders?—Do you say that this portion of the specification refers simply to the plates, bars, angle T-Irons, to be used in the girders, and that those are to bear a tensile strain of twenty-one tons, but that the specification does not provide for any tensile strain to which the piers are to be subjected?

(Mr. Bidder.) Honestly, I am not in a position to answer that question; before we have done, perhaps I shall be able to do so. I only made the observation that you referred to the girders and not the piers. I am not in the position to carry it any further at present.

12,776. (Mr. Trayer.) Does the specification, which you have considered from end to end, contain any provision for the tensile strain which the bars are to bear in the columns as apart from the girders of the bridge?—It does not; looking at it as a whole I should certainly interpret it that this stipulation was intended to apply to all the wrought ironwork that was not in the bolts. I think that would be the correct interpretation of this specification.

(Mr. Bidder.) If this stipulation does not apply to it, there is another provision in the specification applying to bolts and inasmuch as that wrought ironwork is a principal part of the structure, I should think that ought to be covered by this requirement.

(The Commissioner.) This paragraph: "The rivets in the holes of the plates, bars, angle irons, &c., must be punched quite true and fair, and when the parts of the girders to be riveted together are fitted into position, the rivet holes must be perfectly true and fair with each other. That these holes punched in the wrought iron in the piers and in the channel iron struts; it might be in a similar way be contended that this requirement did not apply to those. But I would observe that these holes, and also those in the plates upon which the eighteen-inch columns rest in conjunction with the L-shaped girders are the only holes I have had an opportunity of examining, and they have been punched very irregular in many cases, and not conformable with the parts which they were to fit; they have evidently been enlarged for the purpose of enabling a rivet to be passed through.

12,778. Enlarged in the way you mentioned yesterday?—Yes; I think the Court had an opportunity of seeing some of them last evening. It then goes on to specify the quality of the iron of which the rivets are to be made. I have no remarks to make on that at all. There are no means of testing what the quality is; the riveting in the 'girders does not appear to have failed. Then in the next paragraph I find: "All bolts to be made of Lowmoor iron, or such other make as shall be specially sanctioned by the engineer; and to be neatly finished, head and nut, and not projecting more than half an inch through the nuts; to be carefully forged and screwed and made to fill the "bolt holes." That is a requirement, not usually made; it is very rarely that bolts, except for special purposes, are required to be made of Lowmoor iron.

In the specification it was required that they should be of unusually good character.

12,779. (Mr. Bidder.) That applies to the girders?—To the bolts—there are scarcely any bolts in the girders; it would apply to the bolts that connect the parts of the piers—the bolts for the connection of the cast-iron roller plates. I think I am accurate in saying that the only bolts used in the girders permanently are for the connection of the cast iron roller plates to the girders.

12,780. (The Commissioner.) It is under the heading of "malleable iron girders."—The inference is then that is meant to apply to the whole of the structure, that the qualities of iron specified here are meant to apply to similar works in the piers.

(Mr. Bidder.) How "malleable iron girders" means "piers" I am at a loss to understand.

12,781. (Mr. Trayer.) Is there any other provision in the specification with reference to bolts, whatever other part of the structure they were to be put into, except that which you have just read?—No, it says "all bolts," it does not say all bolts are to be used in the girders. It is quite true that it comes under the head of "malleable iron girders," but if I found in a specification the words "all bolts to be made of Lowmoor iron," I should require the contractor so to execute the work.

12,782. In fact, another instance, in addition to the one you have already pointed out of the specification itself requiring extra good work or quality of material?—Yes, it is so.

12,783. But in point of fact you say Lowmoor iron is very seldom used for bolts?—It is very seldom used for bolts.

12,784. But there being the condition that if they were not made of Lowmoor iron, they were to be made of such other make as should be sanctioned by the engineer, you would interpret that as meaning something better than ordinary iron?—Yes, I should interpret that to mean that they were either to use Lowmoor iron, or get the special sanction of the engineer to use some other iron which they designated to him; that is what I should understand that to mean. It then goes on to say that they were to be neatly finished, head and nut; I have found several of the nuts which had a burr upon the lower side; similar to that which I exhibited yesterday, and the importance of which I yesterday explained. This paragraph wind up with the stipulation that the bolts were to fill the holes, and that, as I explained yesterday also, I consider a very important requirement, and one that should have been carried out.

12,785. With reference to that, let me ask you this.—Would it be impossible for the bolts, having punch or any workmanlike thing, to fill up bolt holes which were to large for the bolts used with caulking?—You could not do it, the existence of the head and nut would prevent it; at least you could do this, you could do such a thing as caulking the space round the bolt before you put the nut on, but it is not a usual proceeding.

12,786. If that was done that was not workmanlike?—No, I have seen no indication of its having been done.

12,787. Something was said about caulking.—I think what that referred to was this: the apprehension was that owing to the vibration in the structure, because you cannot avoid vibration in a tall rectilinear structure of this kind with trains running over it, the jar might cause the nuts to work loose, and so after they had been screwed down so tightly as they could...
be, or as properly as they should be, then with a tool the screw was upset or knocked down somewhat after the fashion of riveting, to prevent that nut being turned back again; that was the causing that was referred to.

Will you proceed with your remarks on the specification?—I have nothing further to observe upon the specification.

12,769. Let me call your attention to the last paragraph but one in the specification, that provides that the whole of the works were to be executed to the entire satisfaction of the engineer?—Yes.

12,770. That gave the engineer complete power over the workmanship as well as the material?—Undoubtedly; it is always the case.

12,771. Will you now turn to your own report which was laid yesterday; there is something on page 4 of which I would like you to give us a little information about?—I should first say that I omitted yesterday to state that as the gradient of the line varied, the calculation did vary slightly; and I would have said the highest were 83 feet in height from the top of the base piece to the under side of the girder, and that the lowest one, which was the farthest north that fell, pier No. 40, was only 81 feet 8 inches; and I may say that most of the strains upon the lower part of the columns would vary, speaking approximately, in the relative proportions of those figures: 81 feet 8 inches to 83 feet.

12,772. (The Commissioner.) In the table which you gave at page 4 of your report, do the heights 83 feet 8 inches, 83 feet 8 inches, and so on, mean the height from immediately under the girder to the stone work?—No, from the top of the base piece. Those base pieces may be locked on as far as any strain for turning over the piers is concerned, as being the foundation upon which they would turn; the heights are from the top of the base piece to the under side of the girder. If five feet is added, that gives you the height above the brickwork, or above low water.

12,773. (Mr. Trayner.) I observe at page 4 you say the height from the top of the upper course of the masonry, to the under side of the lattice girder varies from 80 feet to 81 feet 8 inches?—Yes, I see that it is so—it is from the commencement of the ironwork—the 8 feet is occupied by four courses of 1 foot 3 inches; the base piece is included in that measurement.

12,774. It is from the top of the masonry?—Yes; perp. No. 26 and 41 were less in height on account of the lower gradient.

12,775. Would you now give us some information as to the forces or pressures to which this bridge was subjected?—Yes, I have stated in my report that there were four forces which might set upon it, and to which it was exposed—that resulting from change of temperature, which has been disregarded in this investigation from the weight of the structure itself; that resulting from the weight of a passing train; and that resulting from lateral pressure occasioned by the wind.

12,776. You leave out of view at present altogether, as we have hitherto been doing, the change of temperature as affecting the bridge?—Yes, I do not think I may directly bearing upon the cause of the accident.

12,777. Which is the next of the four which you would observe?—The weight of the structure itself. At present pass over the first section of the Appendix to my report, the calculations of the various resistances, because I wish to be able to correct those before the experience of the fact are now brought to me; or which have been made yesterday at Mr. Kirkaldy's; so that I may be able to substitute for my quantities those which the result of the experiments will give, it will save going over the assumed quantities and then having to correct them afterwards by those which we find to be the quantities.

12,778. Before we leave that I may take it that that section A was based upon the assumption that the construction was of the specified strength?—Yes, that is so. In page 6 of the report I say: "There are so many doubtful elements, the values of which have to be assumed in attempting to determine the amount of the strains to which the several parts of the piers would be exposed by the action of a powerful force and pressure, that it is impossible to arrive at any positively definite result." Of course, the more those assumptions are replaced by the result of experiments, the more definite will be the result obtained.

12,799. But in the assumptions upon which you made your calculation in page 6 of the Appendix to your report, you assumed everything to have been done in conformity with the specification?—I did.

12,800. You will leave that till the actual results are ascertained for Mr. Kirkaldy's experiments?—Yes, which he has promised to give me to day. I pass on to section B, which gives the weights upon the different parts of the structure.

12,801. (The Commissioner.) Have you assumed in these calculations that these ties and bars in forming the piers would be capable of bearing a strain of 21 tons?—Yes, there were two assumptions which I made, which the experiments that are now making will enable me to replace by positive data. I assumed an ultimate strength of 21 tons to the inch, and I had regard to the law of sic tensio, but the extensions have been carefully measured as the strains were increased, and therefore we shall be able to replace assumption by the actual result.

12,802. Will you go now to section B?—Section B gives the weights first of the superstructure, I have very carefully computed from the original drawings of the lattice girders which were supplied to me by the Court their weights, either from weight, or measurement, or computation. I have made the best estimate I could of all the other parts of the superstructure, and the results are given at page 18 of the report. Those results show that the total weight upon the rolling stock on one 24 feet 6 inch intermediate span was 644,900 lbs., or nearly 288 tons. That is a little in excess of the weight as given by Mr. Stewart and Dr. Pole, only to the extent of between 2 and 3 tons, I think, and that may be accounted for by the fact that I have taken an intermediate span and I think they have taken an end span, and as I explained yesterday, some of the ironwork is heavier in the intermediate span than it is in the end span. That is the weight I have taken in the last of the successive calculations. Then I have the weight of the pier. I have computed that also from tracings which were furnished to me by the Court, and the result is that I make the weight of a 15-inch column from the base piece to the column in the case of the 16-inch column, and of an 18-inch column 31,570 lbs. That is a little less than the weights which have been given by Mr. Stewart and Dr. Pole, but they do not appear to have computed the weights, but they have gone rather from the invoices of the iron as supplied. The weight of concrete filling I have also estimated as 9,800 lbs. in the case of the 15-inch column, and of the 18-inch column, and that gives us a total for each of the 15-inch columns of 36,750 lbs., and for each of the 18-inch columns of 45,750 lbs., making the total weight of the pier, excluding the whole of the ironwork in the pier (because, I should say in speaking of the weight of a column, it is the total weight of half the tie bars and channel, iron attached to it) 234,140 lbs., or nearly 105 tons, as against 110 tons as given by Mr. Stewart and Dr. Pole. I then pass on to the weight of the train, and the information upon which I make my calculations is taken from the weights upon the tracing handed in by Mr. Brown, the engineer of the North British Railway Company. With regard to the weight of the passengers, I see Mr. Stewart and Dr. Pole were under a little misapprehension; they have assumed that the whole of the passengers were distributed through the third-class carriages; but the return handed in by Mr. Morris, referred to in point 129, shows that in the second-class carriage there were collected 1,130 tickets that were exhibited as...
belonging to season ticket holders, and one other ticket was exhibited, making eight passengers. At page 7, of the body of the report, it is stated that from the evidence of those who collected the tickets there were eight second-class passengers, and in the calculation of weight, a weight of 140 lbs. for each person; and I have also ascertained that in the luggage van there was a weight of 900 lbs. The result of these calculations, adding the weights of the passengers, the engine driver, the fireman, and the guards, is given on page 19 and 20 of the Appendix to my report, and I make the total weight of the train, with the persons in it, 269,532 lbs. or 120 tons.

12,863. Will you give me the weight of the second-class passengers and their luggage which you have assumed beyond the weight given by Messrs. Pole and Stewart?—I do not know what weight per person those gentlemen have taken, but I rather think they have got a less number of passengers than I have.

(Mr. Bidder.) They have 70.

(The Witness.) I have a total of 74. From the return handed in by Mr. Morris it would appear that there 50 third-class tickets collected; five third-class tickets were issued, and six for Broughty Ferry which were not collected, which made a total of 61 persons, because I have looked upon two half tickets as representing one person.

12,864. (Mr. Bidder.) Do you take half tickets as representing one person?—Two half tickets as a whole person. There were five tickets; I have consequently made five allotments; there were two second-class tickets and an exhibit ticket, which would make eight; the eight added to the 61 would make 69; then there were the three guards, the fireman, and the engine driver, making a total of 74. Those I have taken as distributed in this manner—2 upon the engine, 61 in the third-class carriage and three in the second-class carriage, and there in the luggage van, and I have also taken 500 lbs. of luggage into the luggage van.

12,865. (The Commissioner.) I think, in the first day’s evidence, the figures given us were 57 tickets collected; 5 or 6 going to Broughty Ferry, and 53 to Newport?—Yes, but in that document there is a clerical error.

(Mr. Traynor.) There were some tickets not collected of people going to Broughty Ferry and Newport.

(The Witness.) I admit those.

(The Commissioner.) Fifty-seven tickets collected, of which 10 or 11 were for the driver and the stoker, 5 or 6 going to Broughty Ferry, and 5 to Newport, that makes altogether 72 or 73. That is what we made it then.

12,866. (Mr. Traynor.) The difference of two passengers is not material?—There were two season tickets to be added; it is 74.

12,867. (The Commissioner.) 74 or 75?—I have taken 74, and the result is that I get a total weight of 269,532 lbs. or 120 tons.

12,868. (Mr. Traynor.) Just compare that with the total given by Messrs. Pole and Stewart. As against your 269,532, what do they make it?—I do not think they give it. I see they make this remark at page 14: ’We have added to the given weights,’ and in using the words ‘given weights,’ I have no doubt they refer to those given by Mr. Drummond—’We have added to the given weights of the vehicles an allowance for 70 passengers distributed equally in the third-class carriage. These were to be assumed, not in the second or first class. Calculating then on these data, we obtain the following results,

12,869. They do not make any mention of the weight they give to the 70 passengers so distributed?—They do not.

12,870. Then will you go to the next point?—The next question to consider is how much of that weight was borne by any one pier, because the length of the train was something less than the width of a span. The maximum strain that would be put upon any one pier would depend upon its position. I have found that the maximum strain upon the pier would be produced when the front of the buffers was 43 feet in advance of the centre line of the pier. The heavier portion of the train being in front, in consequence of the engine and tender being in the forward part of the train, that would give the greater portion of weight, and I have ascertained that any particular weight placed upon a portion of the girder bears upon the two piers in the ratio of the two distances from the point where the weight is applied, to each pier respectively, so that if it were in the middle it would be half; if it were in a quarter distance it would be upon this, and so forth (drawn to the model), and upon that basis I have arrived at the conclusion that the largest pressure which a train so loaded could have produced would have been 210,850 lbs., and that would have occurred when the buffers of the engine were 43 feet in advance of the centre of the pier. Upon that I would observe this: subsequently to the making of these calculations, upon the running of the train, the company have discovered that there was a slight error in the original statement of the order of the carriages, and they found that the first-class carriage was interposed between the two first third-class carriages, and not between the second third-class carriage and the third third-class carriage as was supposed; but that would make no practical alteration in the subsequent calculations. That completes all that I have to observe in reference to the weight of the superstructure of the pier, of the train; and of the portion of the train borne by the pier, those being data which are afterwards used in the calculations subsequently on the pier. In computing the area that gives the action of the wind upon the structure, I first take the action of the wind on the superstructure without a train, and in calculating the area I have made a slightly greater amount of area of the windward side of the lattice girders than Mr. Stewart and Dr. Pole made. I have taken them 1,930 square feet, whereas my figure is 2,036, but that really only represents a strip four inches high, the whole length of the girder, and, therefore, I think very likely the difference has arisen from their having used in the running rail and my having measured to the guard rail, which is higher and very possibly also from the greater thickness that there is in the plates of the lower members of the beams in the intermediate girders as compared with the external ones.

12,871. It is a small difference; it is eighty-six feet altogether?—Eighty-six feet who. I have taken, represents a strip four inches wide. It is very important to know the height at which that acted, and therefore, I calculated the separate parts and measured the centre of pressure of each of those parts, and multiplied one by the other, and by dividing the sum of all those products by the total surface, I got the mean centre of pressure as being 11½ feet above the top of the rollers, those being measured above the top of the rollers because, as shown in drawing No. 5, which is appended to the report, that is the final point at which these forces are taken as being applied to ascertain their influence upon the stability of the structure. In computing the surface of the inner girder I had to consider how far it would be advisable to give the greater weight windward one, and I have adopted the views of Mr. Stewart and Dr. Pole, which quite commenced themselves to me as being the best which could be adopted; and I also thought it would be far better for comparing results where the matter was one entirely of speculation; and the result does give 598 square feet. The centre of pressure of that surface is 17½ feet above the same point, the top of the bearing rollers. The strains and the heights are figured. I then pass to the effect which the wind would have on the train. I found the mode I have adopted was the most convenient mode of computing this, because there are half-a-dozen
ways of computing the strain, all of which would arrive at the same result, but there was great convenience in taking it in this manner, ascertaining how far the lateral pressure of the wind would be upon the upper part of the structure and how the force of the wind would tend to disturb the equal distribution of the weight upon these rollers, to reduce it in fact to vertical and to horizontal pressure, and then to compute the effect upon the structure by their moments. That will be seen to be convenient henceforth. Therefore I have first computed the effect which the wind would have upon the superstructure alone in altering the weight which would be borne upon the two rollers, because it is evident that the tendency of the wind would be to lift the weight from the one set of rollers and to put precisely the same amount upon the others—to lift the weight from the western rollers, because I am always speaking of the west as the windward side, the wind being from that quarter at the time—to lift the weight from the western rollers and to place it upon the eastern rollers. If the wind had been sufficient to have overthrown those girders, at the moment of their overthrow the whole weight would have rested upon the eastern set of rollers, but I have reduced the height of the wind's impulse, and adopting as the heights, the heights, and the centres of pressure which I have stated, the result would be that the force of the wind multiplied by the coefficient of 2,226 would express the weight taken off the west rollers and put upon the east rollers.

1542. That is without the train?—Yes. The details of the calculation are given in the Appendix, to my report and I need not go into them. The next inquiry was the action of the wind upon the train and I first computed what the effect of the wind would be upon a train fully exposed to it, and I give the results in the table which is given at page 22, in which, in the first column, I have stated the moment of stability of each windward carriage. I have given the weight as previously communicated, making the allowances for the several passengers. Then multiplying that weight by half the width between the rails (which I may remark I have taken at 3 feet), because of course it bore upon the centre of the rail and, gives is that stability; the moment of stability of each windward carriage is shown in the third column. I have then taken the average side surface of the carriage. That is given upon Mr. Drummond's tracing. I had to compute the whole in order to find the centre of pressure, and in one or two instances I differ somewhat, but these calculations have been carefully checked, and I think upon the whole, is not unfair. I have added an offset to that of those who made the calculations upon the tracing, because a rough computation shows that it is somewhat too small. I should observe that part of these surfaces are rounded, and that therefore they had, as Mr. Stewart and Dr. Pole have shown, to be reduced to an equivalent flat surface; and their view is in accordance with the supposition, that a cylindrical surface only, having a base, is circular, and inclined to the axis to it as the force of the wind multiplied by the cube of the angle which the wind makes with the plane multiplied into the area of the circle described with the radius equal to the height. The force of the wind is equal to the force of the wind multiplied into the square of the sine of the co-sine of the same angle. Upon that principle these computations have been made, and they accord with the law given by Dr. Pole and Mr. Stewart. I have therefore reduced the circular surfaces, and the reduced side surface of the carriage is shown in the fourth column. Then in each case I calculated the height of the centre of the pressure above the rails in the same manner as I did in the case of the girders, and it comes out to be a mean for the whole train of 6 feet, but it varies in the different carriages—it is about 4 feet in the carriages proper, but it is, of course, much lower in the case of the tender and the locomotive. These heights are contained in the sixth column. The seventh gives the result of the two preceding columns multiplied into each other; but that does not take into account the effect of the wind upon the curved surfaces of the roofs of the carriages in holding them down, and that is not an inconsiderable element. In the eighth column I have given the reduced roof surface everywhere of the wind acting vertically upon the curved surfaces of the roofs, which, in the case of the first-class carriage and the hindmost third-class carriage and the guard's van, is not inconsiderable. I have then taken the horizontal distance from the east rail of the centre of the wind pressure on the roof, and that is contained in the ninth column. The tenth column gives the moment of a unit of wind pressure acting vertically to retain the carriages on the rails, which is contained in the 10th column, and that is not important. The difference between columns 7 and 10 gives the real moment of a unit of wind pressure tending to overturn the carriage, and the result is given in column 11, which is the moment of a unit of wind pressure tending to upset it, and would therefore express the wind required, or any excess required to be required to upset the carriage. I have been particular in going through that, because it is a very important item, and I differ in the result from Dr. Pole and Mr. Stewart with regard to that particular carriage, which is the most important one, namely, the second-class. I do not know whether they have taken the action of the wind upon the roof, they have not certainly taken it at the time if the other carriages and the second-class, I think, taken most likely our results would then check. The results of these calculations shows that the second-class carriage would require in the open 5268 lbs. to overturn it, and that the force required to upset the other carriages, putting out of the question altogether the windage and tending of the carriages, and to upset them, would vary from 42 to 63 in the case of the third-class carriage to 45 20 lbs., in the case of the guard's van. I have then further to observe that the train was partially screened by the girders and having computed the surface of the girders within which the train would be, I find that that amounts to 5th of the whole. Therefore, the whole train is shown in the second column, the force of the wind as that which would really act upon the train, and that shows that at least 40 lbs., in fact 41 lbs. of wind would be required in order that the second-class carriage should have been overthrown by it in the condition in which it was at the time of the accident. I ought to say this, that I have deduced rather less than six-tenths in the case of second-class carriage because I imagined it to be in that position of the girders where it would be the least sheltered, and I found that that was between 3rd and 4th of its whole surface; and therefore, in the case of that particular carriage I have assumed only a seventh and a half part of the wind's force to have been deduced from consequence of the shelter afforded by the windward side of the girders; and the result is that 41 lbs. would have been required to upset the second-class carriage. The effect of the wind upon the side of the carriages of the train in disturbing the equilibrium of the weights upon the two rails would be similar to that which I have already mentioned in the case of the two single carriages. There would be against the side of the train the force of the wind multiplied by 1536 feet. This would be applied at a height of 10 2 feet above the top of the rollers, or 6 feet above the level of the rails. The effect of that would be to take a weight represented by 1536 multiplied by the force of the wind upon the weight of that area in column 18, and it would be reduced again in the same proportion as the weight of the train in consequence of the whole of it not being borne by the pier. The result of that would be the force of the wind multiplied by 1536 lbs. We have also to deduct the action of the wind in tending to keep the train upon the rails, which would also add to the weight of the train bearing upon the western rail and slightly lift it off the eastern. The total weight then of the train borne by the pier would be 210330 lbs. plus 67 multiplied into the force of the
wind as representing the additional pressure put upon it by the force of the wind upon the roofs of the carriages. That line then to be divided between the two equal parts, the weight of the train would be equally borne by both girders, but if more pressure was thrown upon the eastern rail that would put a greater weight upon the eastern rollers, and take a corresponding weight off the western rollers. The result is that the pressure taken off the western rollers by the action of the wind would be the same as that which would reduce the pressure of the wind multiplied by the exposed surface of the east girder from 1,186 square feet to 757 square feet; and taking half that, upon the same principle as before, as being that which would express the effort of the wind, allowing for the shelter of the windward girders, it would give an effective area of 578 square feet, the centre pressure of which would be 22-54 feet, being higher now than it was before, because the train shelters only the lower part of the inner girder. With a train upon the superstructure proceeding precisely on the principles already laid down, the effect of the wind, in taking weight off the west rollers, and adding to the east rollers, would be the force of the wind multiplied by 22-54 feet, and the additional downward pressure should have a horizontal pressure acting at the level of the rollers equal to the sum of all the areas, or 3750 feet multiplied into the force of the wind. That is less than the result arrived at by Dr. Pole and by Mr. Stewart. It might be as well, perhaps, to refer to their estimate for a moment.

At page 13 of their report you will find that against my 3750 they estimate the surface exposed to the full pressure of the wind at 3818. The sum of all the areas which I have taken above the level of the top of the rollers amounts to 3750; the sum of the areas taken by Mr. Stewart and Dr. Pole amounts to 3818, viz., being 68 square feet. 12,813. (Mr. Frayser.) Is there the difference between your computed surface of resistance to the wind and Mr. Stewart's very material? In that percentage it would affect all the calculations in the ratio of 3750 to 3818. When I say all the calculations it depends on the height of the centre of pressure which have to be made in the calculation, but which is not stated. With regard to the action of the wind upon the piers, I again adopt the views of Mr. Stewart and Dr. Pole for purposes of calculation. I thought it better to adopt the same mode of estimate. The cylindrical surfaces of the columns of the pier were taken at half, and the effect of the tie bars and struts I have taken as being equivalent to one-fourth of the exposed area looking windwise upon the pier, which is precisely the area adopted by Mr. Stewart and Dr. Pole, and the result is that the surface I find to be 382 square feet against the 400 feet of Dr. Pole and Mr. Stewart, the height of the centre of pressure from the top of the base piece being 18 feet. I then placed the wind upon the complete structure, and adding together the various surfaces as given at page viii. of the Appendix to my report; it shows that the total surface of the whole of the structure without a train would be 3,029 superficial feet multiplied by the mean centre of pressure of 74 feet. It is that I have, of course, taken the moment of the wind in the lever ratio afforded by the height from the base piece to the top of the rollers, because in the unequal distribution of weights, I have already discounted the additional effect that would be produced if I had considered the moment of each force at the height beyond which the wind pressed against it. No. 2 drawing shows the resolved strains of unequal distribution caused, by the wind reduced to vertical strains shown by the arrows, with the quantities written against them. The area, without the train, is 2,629 feet, which inscribed by 80-7 feet, being the height of the top of the rollers above the base piece as explained before. And then I have taken the moment of the pier by its height, and dividing the sum of the products by the total area it gives me for the height of the centre of pressure of the whole structure without a train 75-64. Proceeding in precisely the same manner when there is a train upon the bridge (and I should say drawing 6 exhibits the strains when there is a train upon the bridge with the distribution of the feathered arrow, which is explained by a note), the total surface is 4,143 feet exposed to the action of the wind, and the resultant pressure acts at a height of 77 feet above the level of the top of the base pieces. Those figures give the two moments which express the effect of the wind to overturn the structure, and in the case of No. 3, when there is a train the force of the wind multiplied by 228,587, as that moment of effort and when there is a train the force of the wind multiplied by 319,022, the result being expressed in foot lbs. That being the horizontal resultant, I then pass on to state what the vertical strains would be. The mode of computing those has been already explained in Section C, and the results are given under different heads in Section D. The results show that the downward pressure, first take the structure without a train or without any wind, that the vertical load upon each of the 18-inch columns, No. 1 and No. 4, resulting from their own weights and the weights of the portions of the tie bars and struts and superstructure would be 116,302 lbs., or nearly 62 tons and a third. Then the sectional area of the 18-inch columns being 63 inches 92 tons and a third, would give a strain upon those columns of 1-465 tons per square inch, and upon the 15-inch columns, taking the sectional area of those columns at 49 square inches it would give a strain of 1.06 ton per square inch, which, of course, are extremely small strains; less than their own weight, and they take the effect of a train, but without wind, we shall increase the load upon each of the 18-inch columns to 259,377 lbs., or 115-80 tons, which would increase the strain to 1-838 tons per square inch; and upon the 15-inch columns we should increase the strain to 142,653 lbs., or 63-86 tons, giving a strain of 1.43 tons per square inch. The effect of the wind pressure without any train would be to take off a certain amount of weight from the west rollers, and put it on the east in the manner described and the amount described already; and the effect of the distribution of that is shown by the table at page 26, which I need not read. Similar computations are made of the effect that would be produced by the wind pressure with a train on the bridge, and the table which is given subsequently at page 27 in the appendix to my report, and the table at page 7 in the body of the Report show what would be the weight in one case borne by the east and west rollers, and in the other case borne by the individual columns in the different portions of the structure. Then the wind pressure of 10 lbs., 20 lbs., 30 lbs., and 40 lbs., upon the side of the structure. Having that data I have proceeded to calculate what would be the pressure of the wind required to overturn the pier without an out, and without any holding down bolts, and without the pier righting force, and it is a very simple calculation, and does not involve any theoretical assumptions, because I have supposed that it was so perfectly trusted that there was no possibility of distortion in the structure, that it would turn over as a solid body upon the centre of column No. 4, the wind blowing from the west, and that there were no holding down bolts. This is not a calculation of any very great practical moment, because it supposes a condition of things that could not have occurred, seeing that the bolts are there and that the structure could not be rigid in that sense, but I only thought
it is desirable to make the calculation, in order that I might check my own results with those of Mr. Stewart and Dr. Pole, and so far as they go that check may be considered tolerably near. The result of their calculation, as given at page 20 of their report is, that with the wind, but without a train upon the pier, under the conditions assumed, 97 4 lbs. would be the wind pressure required to overturn the pier; my calculation is 56 38 lbs. Passing on to the pressures that would be required to overturn the pier with a train upon it, making the same assumption that there are no holding down bolts, Mr. Stewart and Dr. Pole find that the force of the wind would have to be 384 lbs. whereas I make it 324 lbs. In either case, the weight of the train would add to the stability of the pier, at the same time it gave an increased surface which was more than equivalent to the increased stability that it produced in the pier. 1 pass over, for the present, the remainder of these calculations for the same reason that I passed over the first section of the Appendix. I say that is to say, because it involves the values of the resistances of the bolts and tie bars which I shall be in a position to deduce from the actual experiments to-morrow.

12,814. (Mr. Barlow.) There is one little table at Mr. Stewart's report referred to the stresses upon the diagonal bars. Have you any of yourself, to show what I mean in what I term the resistances in the first section. I have classified it under "resistances of bolts", "resistances of the flange bolts to the overturning of the columns," and then I pass on to the "resistances of the tie bars," which involves also not only the resistance they would offer to a strain in the direction of their length, but the resolved strains. But those involve assumptions of their power of tensile strength and their ultimate strength. I could go through the theoretical considerations, but I think I had better deal with those figures when I know the results of the experiments which are being carried on, or it would involve going over them twice. Those calculations of resistances are found in section A of the Appendix to my Report.

12,815. (Mr. Trayner.) Have you exhausted your observations upon the Appendix to your Report so far as you got to Mr. Kirkcaldy's results?

I think I had better deal with those figures when I know the results of the experiments which are being carried on, or it would involve going over them twice.

12,816. There are some observations in the Report which I should like you to direct your attention to, namely, what you have reported as to the defects in the present standing structure? That would be really a repetition of what I gave yesterday. I think I stated all that yesterday.

12,817. But there is something on page 9 of the Report which you have not spoken to, to which I would like you to give me a full explanation about, the fourth paragraph from the top?—That applies not so much to the defects as to the evidence afforded by the state of the rains as to the manner in which the structure was overthrown; and I think for that purpose I should require the book of photographs. I am quoting first the Report.

12,818. (The Commissioner.) That is the fourth pier?—Yes, that is the pier which over the train was just passing at the time of the falling of the structure; and it will be observed that the effect of the forces which operated in the structure fell, was to thrust back the columns towards the west, and leave them as they were there shown, hanging over the nose of the pier.

12,819. (Mr. Trayner.) Which of the four views are you looking at?—That is shown in the two views looking north and south.

12,820. (Mr. Bidder.) Of which pier?—The fourth pier; or pier No. 32 in the numbers which we have used hitherto. They have been arranged in the book. Had the structure broken at its base, where of course the effect of the wind, under ordinary circumstances, would have induced it to break, then these columns would have been carried over (as they are in the greater part or in some of the piers) with the structure; but in this case it evidently failed at a higher point, as it did in most of the other piers, and in some of them to the extent that some of the lower parts are standing—it evidently failed at a higher point, doubling up and throwing back the lower portion as it fell over into the river. Instead of turning upon the lower part and carrying the whole structure with it, it turned upon a point higher up, and pushed back these columns, and in the case of the first standing pier, plate 1, where two tiers of columns are left.

12,821. (The Commissioner.) That is pier No. 29?—Yes; it is evident that it commenced to break about the lower columns, and upon that I would make this observation this, it would be found, in almost every case, that each pier turned upon a point or points more or less coincident with the outward line of bolting, that the strain was not a turning of the whole structure upon the eastern column, and the lifting up of these columns by the effort and the action of the tie bars, but that it was rather a turning of each column upon its own base. An explanation of the phenomenon will show that in almost every case the column is so broken, leaving the wedge-shaped piece produced by the compression of the column upon its eastern side. It will be seen in the case of pier No. 29, plate 1 of the photographs, that the columns are so broken at their base, but it is evident that before they had passed far, a weaker joint had itself broken, and that the first tier of columns, that they eventually gave way and left this part of the structure standing, although very much damaged, to the extent of its columns, being broken by this turning strain at their bases, and the tie rods being mostly wrenched away by the lugs, being torn away by the movement of the columns clashing and writhing. Now, as to the means of preventing it, and which I have shown as distinguished from those which were of no use in preventing the structure from being thrown over by a westly wind. Those ties have been broken, or the lugs torn away from the columns to which they were attached. The same thing is seen in the next pier but one, which is pier No. 31, or No. 3 of the photographs—they are the columns in the same way have turned over upon their points of attachment to the lower tier of columns, that is No. 3 of the photographs and No. 31 of the members which have been adapted throughout. Obviously, as these columns are nearly eleven feet in height and the actual height is 77 feet, each of these columns would diminish the strain by about two-sevenths of the whole weight of the column to break in the second tier of columns means that it broke with five-sevenths of the strain at the bottom that was required to break it higher up, and inasmuch as it did not break here (pointing to the photographs), it shows conclusively that that was the weakest part, which enabled that to break where the resistance was less; and the same applies to pier No. 31 which broke at the top of the first column. In fact, throughout, the state of the pieces of the columns remaining upon the base pieces, shows that the columns did turn over upon their own bases as separate columns, and were not lifted bodily as part of a more or less rigid structure. As pier No. 29 and in the case of pier No. 31, they had been so lifted or turned over, they were thrust back again by the fact that the structure had failed, and was turning over at a point above the base-piece. Had the pier been turning over upon the base-piece there would have been no effect tending to thrust over any of the columns, but the fact that there are some of them pushed back from their base clearly indicates that the point at which the pier was turning was at one of the points above the base-piece.

12,822. (Mr. Trayner.) In these piers which broke above the lower column, as in Nos. 29 and 31, you said that that upper part which broke away fell over with the girders easternward?—Yes.

12,823. Whereas the column below it was forced back upon the top of the pier, and is lying there now?—Yes. In some cases the windward columns followed the girders, and were found lying on the top of it. The girders appears to have fallen through, and some of the columns still connected by flanges were found.
lying upon the upper or westward side of the fallen girders.

12,824. Probably you have explained this, but if you have I have not quite followed it. Would you kindly say to what you attribute the different mode of falling upon the part of the upper column from that which was followed by the lower; what led the upper column to fall westward with the girder, and the lower column to fall down below? I find it is the case of the particular part of the column partially weak and must have been considerably weaker than the corresponding parts of the other joints, below it, because the strain increased merely in the ratio of the length of the columns as you pass downwards, and for it to break at a higher point instead of at the lower proves that there would be some diminished resistance at that point which enabled it to break there instead of breaking below.

12,825. Assuming that the one column which went with the girder to the eastward was carried over either bodily or by the weight that was falling over to the eastward, the other column which fell to the other way was crushed out to the westward by the pulling of the heavier matter to the east?—Yes, it was pulled back, because the moment I put a weight upon a vertical column and throw it over the effort at the bottom of that column is a move in the opposite direction.

12,826. (The Commissioner.) You bring all the pressure to bear upon the eastward side at the end of this, and that tends to force the column at the other end of it in the other direction?—Yes, the weight being resolved at the hinge of the pivot into a vertical and horizontal thrust, the direction of that horizontal thrust would be away from the direction in which the object was falling.

12,827. (Mr. Trayner.) Does that in any way illustrate the observation I understood you to make yesterday, that the strength of those piers would have been greatly enhanced if they had been practically made into one pier each, instead of being two piers practically as they stand at present, two groups of three columns each?—The connexion of the entablature above would have prevented to some extent the wind disturbing the equilibrium of pressure so far as it was able to do it; it would not have been a distinct structure; but it would not have produced any very great increased amount of resistance to the pier being thrown upon, upon what may be termed the "parallel line" supposition, that the columns moved over parallel, turning upon their bases, turning really upon the eastward line of bolts and putting a strain upon the girder which was attached to the westward column, and the eastward column in the top.

12,828. Of course if that defect was sufficient under pressure to bring the pier down, it would have come down, although that box girder at the top had been considered all round?—Yes.

12,829. But given the box girder in such a position as to make each of these piers one pier instead of two piers, would not that have assisted materially in resisting the effect produced by the undue pressure upon the weak joint?—Not very materially. What would have assisted it more materially would have been a less efficient connexion of the upper part of the 18-inch columns to the top girders, because whereas either bottom extremities they tend to turn upon the eastward line of bolts, lifting themselves off and resisting that effort by their own weight multiplied by the distance of the centre of gravity from the eastward axis of stress at the top the moment of stability results from the weight of the superstructure multiplied into the distance of the centre of effort upon the column, from the westernmost bolts; furthermore, that action is resisted by the other bolts of the flange, the westernmost bolt, which is the furthest, exerting a resistance which is as the square of its distance from the eastward bolts, as compared with the resistance offered by the others—therefore the importance of the bolts being as far from the turning point as possible, becomes evident. But as the top of the 18-inch columns, the bolts by which the tops of the 18-inch columns were attached, were upon the windward side as far as column No. 1 is concerned, so that the resistance to column No. 1 being turned over was much less than it would have been if the bolts had been put equally round the column. That defect in the mode of support affected the stability of the structure more than the want of connexion in the two L girders.

12,830. You mentioned yesterday a similar, and what you called an inexpensive, mode of strengthening the bridge by additional ties?—Yes, and this was done in this manner, that the effective strength of any one of these tie-bars (meaning by its effective strength, the effort which it really exerts to prevent the column being moved horizontally at its point of attachment) is to what it would be if the tie had been attached horizontally, directly as the length of the tie is to the horizontal distance of its two points of attachment.

12,831. (Mr. Bidder.) You mean the other way up, do you not?—Did I invert the proportion?

12,832. (Mr. Bidder.) Yes; it is less than it would be, not greater?—I mean that it is reduced in proportion to the length of the horizontal distance of the points of attachment measured in the direction in which the strain is to be exerted.

12,833. (Mr. Trayner.) Would the existence of such ties as these, have tended to protect the bridge against the weakness which, in your opinion, it seems to have accumulated to?—If a tie had been attached to the lower part of column No. 1, and carried to the upper part of column No. 4, it is evident that it would have made a very much less angle—that it would have been much more direct, and that the ratio of its own length to the horizontal distance would have been very much less than in the case of these existing ties whereby the ratio is that of 4 to 273, and the effective resistance decreased in that proportion.

(Mr. Harlow.) Might I suggest that the position of the girders in the water would throw some light upon the particular point of turning which Mr. Law has just been describing, the position of the girder in the water as regards its distance from the pier; perhaps you would explain the reason.

(Mr. Balfour.) We have plans of that.

(The Witness.) If you have plans I would describe it. (A plan being handed to witness.)

13,834. (Mr. Trayner.) You have now the plan before you showing the position of the fallen girders and the train, and you have heard Mr. Harlow's question, will you now apply the information which this plan affords to that question, and give us your views of how far it bears out that idea?—I think that this plan shows it exceedingly well.

(The Commissioner.) Is this plan furnished by Mr. Trayner or by the railway company?

(Mr. Balfour.) We supply the plan in pursuance of our resolution to give every assistance to the Court.

(The Witness.) It will be seen here that the girder varies in its distance from the pier measured horizontally, lying always to the eastward of the pier. It will be seen that the distance varies from 16 feet in the case of the pier No. 29, which was the pier in the case of pier No. 35. Now if you will suppose—yes, and it would be so, that the lower the point upon which the pier turned when it broke, the further it would be thrown off, the longer the radius about which it was turning. Now if we look at No. 28, which is the pier which did not turn at all, we see by the marked tracing that it moved horizontally a certain distance, and evidently before it had left the roller plate, had been driven sufficiently far to escape the transverse wrought-iron girders, which is still seen perfect, or rather in that pier it destroyed both girders and fell for a certain distance about a third of the pier, it was not driven sufficiently far from the pier it had been resting upon, to avoid that destruction of the ties. Looking at the first photograph you will see that the
end of the girders fell through a certain distance—and then was carried over and was thrown outward, for the reason that it was attached to the remainder of the girders which was being carried outward and turned over by pier No. 29. Now turning to pier No. 29, if we look at that we find that is the closest of any case, and that, of that is the reason, is the reason of turning from the base, it turned over two stories up, and so fell more close, more two columns of girder are left there. Now it will be seen at each of the points where there were expansion joints, the girders again approached much closer to the pier than in other places. In the case of pier No. 33, where it is only 21 feet, I have again approached to see what the condition of things was. In this case—shall we find that the columns there have been pushed back, because I think it indicates that it broke at a higher point. Now, if you look at the view "looking north," you will see there two columns: built together, which are lying prostrate, and you will see that the part of the wedge-shaped piece of the base of the column is still attached to the east iron piece, and the column has been pushed back to a distance which is equivalent to about 2 feet 6 inches. There again you see distinctly that it turned over at the second tier—there are the two columns complete, and it has been pushed back to a distance to the eastward of two feet. The same thing—probably—will occur at No. 37 pier, that is view No. 32, and if you look at the view "looking south," you will see that the column there has been broken away, leaving the wedge-shaped piece upon the base piece, that is to say, column No. 2, and has been pushed back; just to the same extent. And another thing is clear about these two pierir, which illustrates how far this triangular pier operated as an structure. You see the westward column, No. 1, has been lifted, with the stone attached to it upon the two columns as a fulcrum, and has turned over; that is so in both these piers. No. 33 and 37. The columns No. 2 and 3 are in the same condition, and column No. 1 is lifted more higher. And we shall find also in one of the piers that the base piece has been pushed absolutely off, and has fallen into the water by that thrusting back action—that is in pier No. 39; it is the base piece and the stone to which it belonged has been pushed back and has fallen into the water, and the columns are projecting over to the westward.

12,885. (Col. Pollard.) Were any of the columns found on the westward side of pier No. 32 in the water?—No, they have not fallen.

12,886. There were none found in the water?—They are hanging. I will not say that they are none in the water; I know of none in the water.

12,887. In the first five spans, do you know any of columns being found upon the western side of the pier No. 39?—No.

12,888. Not in any case?—I do not know of any being actually pushed into the water; the base piece in the case of column No. 39 has been so pushed over and has fallen, but I believe that to be the only instance in which any part of the structure has been absolutely pushed into the water, although in one or two cases portions overhang and have just been saved from so being pushed in. Take it from what we see that the distance at which the girder is found horizontally from the eastern point of the pier, may be taken as more or less indicative of the point at which the structure gave way.

12,889. The greater the distance, the lower the column was fractured?—The lower the point at which it turned.

12,890. (The Commissioner.) How is it that we see on every occasion that the expansion joint is nearer to the pier?—For this reason that you will see at these points that the ends of the girders were broken, showing that they acted there as they did at the time of the standing pier, that they were partly driven off and fell through the structure, knocking their ends off and so falling almost perpendicularly. You will see upon the tracing that the ends in every case were damaged—that is I think, explanatory of that—I have not seen this particular case, but I think a little study of this may lead us to that conclusion—that when they fell they apparently knocked off the ends of the girders by the blow with which they came upon the structure of the pier when they fell from the rollers. They shattered the booms across and so were enabled to fall—in fact they were detached from the pier as it were, but did sufficient damage in falling through it to overthrow it. The standing piers have been very much shattered, especially that on the northern side, but they were stayed by the horizontal girders resting upon them. The most, however, is so far shattered that it required to be shored up with timber to render it safe. Some of the columns are broken across, and all the ties upon the external face—all the ties which had a tensile strain upon them—both those upon the eastward face and a very large number of them upon the northern side have been broken across.

12,894. (Mr. Trapper.) Does the position of the train, or any part of it, as found in the bed of the river, tend at all to substantiate or confirm the view you have been expressing? Your assistant was present, was he not, when the engine was lifted?—I think my assistant saw the position which the carriages occupied, and that I can look at the photographs, which I should like to have before me—the photographs which show the position of the carriages and the girders.

(The Commissioner.) What do the red crossed lines on the plan indicate?—They show the girders which have been lifted. The Court will see the details at which they were lifted.

(The Commissioner.) I see immediately to the southward of pier No. 82, "Van and portion of two "carriages, lifted April 18th, 1880," but that is white. (Mr. Balfour.) That is hatched red on my copy, but that was after the lithograph was prepared. It should be done on your copy.

(The Witness.) Looking first at the photograph of the roof of the guard's van, I am not quite certain of when that was picked up, but I almost think it was picked up on the Monday morning following the catastrophe, being found floating. I think the Court have seen the largest piece of that in the station-master's office, or one of the offices at the station.

12,848. (The Commissioner.) Yes, we did.—The observable feature about that is that it is cut across very closely at an angle not exactly of 45 degrees, but I should say something approaching say 50 degrees, and I have no doubt whatever, from the appearance of it, that it was so cut in being carried through the uppermost, westernmost, side of the pier—that it was cut across, and that the middle piece was cut out by coming between the vertical pieces of the lattice of the fourth span, and that the largest piece rose (going to the other end of the model) through this (pointing to the model)—that it was so cut at the time of its falling.

12,849. (The Commissioner.) Then when it fell it fell on its side, so that that which would be the vertical eastern side is now the lower side; is not that so?—Yes, the eastern side is on the ground, the western side is the upper part; and, assuming for a moment that when the bridge fell the carriages were upon the rails, the moment the structure fell from underneath the train all tendency to turn over in the train would be at an end. These tend to fall perpendicularly, that is to say, in the position in which they stood upon the rails; they were only tending to turn over by reason of their flanges being in contact with the rails, the wind acting against them, and they being held at the bottom—in that way they would tend to turn over; but the engine and tender I do not think would have turned over, and some of the carriages were found with their wheels downward; the moment they fell detached from the railway there was no tendency to turn over.
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12,844. Do you mean the instant they touched the water?—No, long before that; the heavy tender would fall much more rapidly than the lighter second-class carriage. Moreover, a body in motion would not fall with nearly the rapidity that a body in quiescence would. If I project a cannon ball with great velocity, the motion of it will be relatively very small. If the train had been in great motion it would not have fallen so readily as the structure which was quiescent: the falling of the bridge was quite sufficient to detach the flanges from the rails, and the moment they were detached

12,845. (Mr. Bidder.) Do you mean to say that a cannon-ball in motion takes longer to fall 16 feet than a stone dropped to fall 16 feet?—No, but if you put two matters one under the other, one being quiescent and the other in motion, the body which is quiescent will have fallen faster than the other; one will fall perpendicularly, and the other will describe a parabola.

12,846. They would part company?—That is all I say, they parted company, and by virtually parting company the flanges of the wheels were no longer in contact with the rails.

12,847. You do not suggest that one would reach the ground before the other, I suggest that by virtue of the motion of the carriage the one would reach the ground sooner than the other.

12,848. (Colonel Yolland.) You mean supposing one body is moving at a very high velocity and the other simply set in motion at the same moment, the first would travel in a perfectly horizontal plane, while the other would fall 16 feet in a second?—Yes.

12,850. The one moving with a very great velocity would probably deviate not one-fourth of the distance in a vertical direction in a second?—No, I think it would have been suspended.

12,851. (The Commissioner.) Would not the principal of gravity be acting upon the cannon ball in motion as well as upon the other lighter ball equally?—Yes, perfectly it would. Having thought the matter over, I may add that I think that very likely from that cause they might not part and that they would fall equally; if it were a rectilinear motion it would be different; if it were a rectilinear motion it would not be; it would therefore be to the only reason why the one would fall quicker than the other would be that the iron girder as a whole offered a very small resistance as compared with the bulk of the carriage. I think there is no doubt whatever that as soon as ever it began to fall forward the light carriages would part company from the rails, and the moment they had parted company there was, of course, no further tendency to change the particular position in which they fell, merely taking gravity into account.

12,852. (Mr. Trueman.) In what position do you think the carriages fell?—I do not think I have any photographs or otherwise, was the engine found in relation to the rails?—I do not think I have any photographs which show that.

12,853. Take it from me as an assumption that the diver found the engine attached to the rails, that he was in contact with the rails upon which it had been running. Now, assuming the position of the engine at the bottom of the river to be such as I have suggested, would that throw any light upon the question you have just been considering as to the mode in which the bridge came down?—I think it would. I think that the engine had fallen with great rapidity, and perhaps tended to carry the girder down with it, and, as compared with its great weight, would be quite upon a par with that of the girder itself, and they would not tend to part company.

12,854. Can you give an opinion upon this matter. If the train had left the lines and had been blown off the lines so as to force its way first against and then through the eastern girder, would the engine have been found in the position you have assumed it to have been found in?—I do not think that under any circumstances the locomotive could have been blown off the rails or would have probably been induced to leave the rails because some other part of the train had gone. I do not think the train was of sufficiently heavy character by getting off itself behind the engine to have carried off either the tender or the engine.

12,855. Is there anything in this plan which shows the position of the engine and tender to suggest to you that the train had gone off the line—and forced the girder over?—No. I find that the four carriages immediately behind the engine are represented as though they stood upon their wheels; and in the photographs of some of them they did. I take it from the plan that they were so found. Certainly those that were so found would be quite consistent with my impression of what would have happened.

12,856. The carriages upon this plan are all shown to be within the girders?—Yes, they are all shown to be within the girders; there is no doubt (whatever position they may have occupied before they reached the water) that immediately upon striking the water the light carriages would have detached from the rails, and the fact that they are not now found in the roof upwards, and the fact that the roof of the van was clearly, what I may call, cut in passing out through the upper side of the girder as it lay prostrate, indicates to me that those carriages did fall more or less in the upright position which they had occupied upon the rails.

12,857. At what point in time are you suggesting that the roof of the guard's van was cut?—That soon as the guard's van struck the water it was there detached until the girder came upon the top of it, smashing it up and cutting the roof in the direction shown upon the tracing.

12,859. Was not the girder falling over upon it and cutting it down at the time when they left the perpendicular height of 88 feet above the river?—No, such an action as that could never have happened, that a girder should fall upon the top of it.

12,860. That the van having reached the water, of course when it fell it would be burst up, and the girder coming down upon it with the whole of its weight, at the moment that the guard's van was cut, that any part of the train, or the guard's van, or the engine, or the tender, or the junction of the van, would have been induced to split, it would have been broken up into matchwood otherwise.

12,861. (The Commissioner.) It had ceased to move forward when that cut was made?—Yes, it had ceased to move forward when the cut was made.

12,862. (Mr. Trueman.) Have you seen or learned anything which has led you to think that the train, or any part of the train, had not been in motion before the structure gave way?—No, I have not. I observe that in one of the other carriages the end of the carriages appears not to have been injured, but that the middle parts are gone, and I think that is consistent with its being swept up against the side of the lattice bar—that the ends did not happen to strike, that is a third-class carriage. I observe the end there is very perfect. I think had that struck the girder whilst in motion, the ends must have been carried away. I have not seen anything myself to indicate that the carriages left the line, and in the face of the calculations and the figures I do not think it could have occurred, because I think the structure must have been overthrown by a larger frigate than that, and have put the lighter carriage, namely, the second-class.

After a short adjournment.

(The Commissioner.) I am sorry to have kept you waiting, but we have to consider the evidence to be produced upon a very important question, namely, the wind pressure, and I intimated when you, Mr. Bidder, were not here, that we proposed to examine the
Astronomer Royal, Professor Stokes, and Mr. Scott, and possibly Mr. Ralph Abercrombie, if his health should permit him to come; and I said that if there were any others that you particularly wished, who have given much attention to the subject, we should be glad to see them.

(Mr. Bidder.) I do not think we have any other names to suggest.

(The Commissioner.) I think they are about the best names we could possibly select. I think Mr. Stewart will tell you so. There is another interruption I have made. I think we shall not sit on Saturday; it might perhaps be convenient for Counsel to know that, because both my colleagues have other duties to perform, and they would be glad to have one day.

(Mr. Bidder.) It would be a convenience to us, because of course we can make our arrangements accordingly.

[To Mr. Bower.] Would the Court allow me to ask whether anyone concerned desires that Mr. Noble should be kept, because we do not desire to send him to his duties unless we are assured by the Court and by the parties, that he will not be again required.

(Mr. Bidder.) I do not think I shall have any questions to ask him.

12,863. (Mr. Trarjer, to the witness.) I think we have finished the question of the girders and the position of the train?—Yes; I would only direct the attention of the Court to the four photographs which are headed "Broken Girders—At the West Ferry," from which they will see that the carriage is standing upon its wheels, the girders are in the girder, and that it has been displaced in the middle, and that the two ends are more or less perfect. Now if it had been carried in motion against the girder, of course the ends would have been swept away.

12,864. (The Commissioner.) Which is that?—It must have been a third-class carriage, because the position of the carriage is not exactly the same as that of the platform, and it is not a first-class, therefore it must have been a third.

12,865. (The Commissioner.) Before you leave the subject of that photograph which you are speaking of—"Broken Girder at the West Ferry"—you will observe that these carriages are standing upon their wheels?—Yes.

12,866. And you will observe that the permanent way is at the right hand side?—Yes, the whole structure is lying upon its western side.

12,867. But the carriages are upright?—Yes.

12,868. Therefore they must have righted themselves—evidently if they had been against the girder it is not possible that they got off the rail or whether they did not get off the rail?—It is rather a proof that in the falling of the girder these carriages fell more or less in the position in which they had stood upon the line—that although the girders in themselves, as a structure, fell over, the carriage retained its vertical position.

12,869. (The Commissioner.) I do not understand that quite if they had both fallen over together the side of the carriage ought to have been upon the side of the girder, but if the girder in falling had revolved and fallen upon its side, and the carriage had followed down upon it, its wheels would have been upon the outside of the girder.

12,870. When the girder fell into the water, as it struck the surface of the water, the water would immediately strike, the lower side of the carriage, the pressure on that side would be much greater than it would be upon the girders, and so it would tend to raise it?—It would do so; and I think that accounts for the failure of the middle of the carriages are gone—that when it struck the water it was carried up, and the intersecting girder, which you see above, forced its way into the centre of the carriage.

12,871. But is it no proof whether the carriages were on or off the line?—I think it is, because if they were on the line, then it would have been the side of the carriage which was carried up, and it would probably have fallen again upon its side.

12,872. Would it not have fallen down upon its base in consequence of the greater weight of the wheels?—Not if it had gone over with the girder still in contact with the rails, it would have struck the water upon its side and it would have fallen upon its side, I think.

12,873. Would not the carriage itself have contained a quantity of air which would tend to make it float, whereas the wheels being heavy would tend to keep it down?—I doubt whether it would have fallen at an angle in that way; it might not have fallen vertically upright, and, as you observe, it is very close to the upper side of the girder.

12,874. (Mr. Trarjer.) I thought your observation upon this photograph was rather to call attention to the fact that the sides of the girders were not injured comparatively, while the ends of the girders were?—No, not of the girder; of the carriages. I said if a carriage in motion is blown off the rails, and comes in contact with the lattice-bar, the first part to suffer would be the ends, whereas in this case it is evident that the injury to that carriage arises from it having been carried with violence against the lattice-bars, which dashed upon the side of the carriage until the platform came in contact with it, and then it was carried down in that way upon the girders into the river, and then when things subsided it fell into the position in which you now see it.

12,875. (The Commissioner.) This goes to show that the carriage probably when it came in contact with the lattice or the girders was not actually in an onward motion?—That is so.

12,876. (Mr. Trarjer, in considering the weight or the security of this structure, have you given any effect to the existence of concrete in the pillars?—No, I have not. I must qualify that by saying that I have estimated the dead weight of concrete as affecting the stability, but I have not taken it as adding to the transverse strength or the bearing strength of the columns; and I have supposed that the concrete was so unequal in its quality, that we could not depend upon having its assistance in any particular pier—as a rule, I have found it good, but in exceptional cases I have found it nothing but sand, of that quality that it ran out—in one or two of the piers the columns hang over the sides of the pier in a vertical position, and the concrete has run out of the column, leaving a little sand upon the surface, showing that as far as that column was concerned it was only sand, and, at many of the joints, the concrete is of that quality that you could not have relied upon it having increased the resistance of the column either to being sheared or to its own weight over.

12,877. We have exhausted the subject of the fallen piers. Now you made a careful examination of what are now standing?—Yes, I have made an examination to a certain extent, not, of course, with the same minuteness as I did of the fallen portion, but if I have examined certain points in connexion with the standing structure, and in deference to the wish of the Court I will give information upon that matter.

12,878. (The Commissioner.) We should be glad to have it?—The first point I would observe upon it is in reference to the position of the joints of the girders and the centre line of the columns. I shall refer to the official drawings for the numbers of the piers, No. 8 pier, which falls upon sheet No. 2, is a roller bearing.

12,879. That is a brick pier?—Yes, the roller bearing and the girder there are continuous by virtue of the cover plates riveted on to them. At that pier the joint is about 2 feet to the south of the centre of the pier.

12,880. (Mr. Bidder.) Is that the joint of the continuous girder?—Yes, the joint of two continuous girders. I may say that of course if the girders were continuous and bore over the whole surface of that pier a deviation of that sort would not be a matter of much consequence, but insasmuch as it is upon roller plates, the centre of the roller plate corresponds with the centre of the junction of the girder, it means a deviation of the line of pressure to the same extent,
because the rollers have been displaced, and the bearings shifted so much on one side of the pier.

12,892. (Mr. Bidder.) How many girders are continuous in the group of which that forms part?—

12,894. (The Commissioner.) That is to say, the expansion joint?—Yes.

12,895. (The Commissioner.) I should account for that in this manner: I have no doubt that the difference of the exact position of the cylinders which were sunk to form the foundation of the pier, made it necessary that the piers themselves should not be at the distance which were originally intended, and it would appear as though the girders had been made for the original distance intended, and not from the position which are obliged to be adopted ultimately in consequence of the position of the foundations.

12,896. (Mr. Bidder.) What pier is this?—The south pier, the first of the single line of columns, and those columns are 20 inches in diameter in themselves, the cap being 2 feet 3 inches, and they are out of line, they are twisted; they consist of two very well ordered spans, and a racking column, the line there being curved with a radius of, I think, 22 chains. The inclination of the line at that part is 1 in 73:56, if I remember the decimal correctly. The next pier is No. 59, which is a single line of columns, and is an expansion joint, and is 4 inches to the south.

12,897. Do they meet exactly?—There is always a space between where it is an expansion joint.

12,898. Then the proper way to state it would be, what bearing the north girders have upon it, and what bearing the south has?—These, I have stated, now are taken by looking from above, judging by the line the distance of the centre of the opening from the centre of the column; at the distance I was shing-up underneath the bridge I measured that. Then in pier No. 70, which is a sliding joint, it is 7 inches to the north of the centre; it is merely a bearing joint. There are no rollers in this portion; it is merely a sliding surface. And in No. 75 there is an expansion joint; there it is 6 inches to the south of the centre. That is the way I have seen what I have seen, so far as the position of the joints. I have then an observation to make upon the pier which are of the type of piers Nos. 17, 18, and 19, upon an oval caisson, a hexagonal pier of six vertical columns, arranged on plan very similarly to the columns under the girders which have fallen, but with this difference, that the external columns are only 12 inches in diameter in themselves, are carried up vertically to the last joint but one, and then, to use a nautical phrase, "tumble home" to a square entablature.

12,899. A raking?—Yes; the four columns which carry the weight of the structure have a square box entablature connecting them, and the four girders rake up to that one to give it lateral support; but the defects in that construction is that there is no efficient tie across at the point where the change of angle takes place, and therefore there is very little dependence to be placed upon those external columns.

12,900. You mean no connexion between No. 1 and No. 4?—No connexion between the pier itself is 2 feet 8 inches long, and the piles are 12 inches, and that cap there is a cast-iron plate, which is 20 inches in length—the cap of the column is circular, 2 feet 8 inches in diameter, it has a recessed depression in it, and upon that depression a plate 2 feet 6 inches long rests, and upon that the external girders rest, but there is no attachment of any sort either between the girders, it being there an expansion joint, or between the girders and the plate.

12,902. How many columns are there there?—There are six arranged on plane in a similar form to the larger piers, and I find that the masonry portion of the piers is so restricted—

12,903. (Colonel Yolland.) How many columns are there there?—There are six arranged on plane in a similar form to the larger piers, and I find that the masonry portion of the piers is so restricted—

12,904. (Mr. Bidder.) What pier is this?—The south pier, the first of the single line of columns, and those columns are 20 inches in diameter in themselves, the cap being 2 feet 3 inches, and they are out of line, they are twisted; they consist of two very well ordered spans, and a racking column, the line there being curved with a radius of, I think, 22 chains. The inclination of the line at that part is 1 in 73:56, if I remember the decimal correctly. The next pier is No. 59, which is a single line of columns, and is an expansion joint, and is 4 inches to the south.

12,906. (The Commissioner.) Another expansion joint?—Yes. In the next pier at No. 60 the joint is to the south of the centre, but I have not any dimension. Pier No. 65 is an expansion joint, and there it is from 5 to 6 inches to the north of the centre.

12,907. Do they meet exactly?—There is always a space between where it is an expansion joint.

12,908. Then the proper way to state it would be, what bearing the north girders have upon it, and what bearing the south has?—These, I have stated, now are taken by looking from above, judging by the line the distance of the centre of the opening from the centre of the column; at the distance I was shing-up underneath the bridge I measured that. Then in pier No. 70, which is a sliding joint, it is 7 inches to the north of the centre; it is merely a bearing joint. There are no rollers in this portion; it is merely a sliding surface. And in No. 75 there is an expansion joint; there it is 6 inches to the south of the centre. That is the way I have seen what I have seen, so far as the position of the joints. I have then an observation to make upon the pier which are of the type of piers Nos. 17, 18, and 19, upon an oval caisson, a hexagonal pier of six vertical columns, arranged on plan very similarly to the columns under the girders which have fallen, but with this difference, that the external columns are only 12 inches in diameter in themselves, are carried up vertically to the last joint but one, and then, to use a nautical phrase, "tumble home" to a square entablature.
burden to go into criticisms of other parts of the bridge, which nobody can suggest have the remotest connexion with the accident which occurred. Now, the piers which Mr. Law is now criticising are Nos. 13 and 14, which are away from the beginning of the accident. It may be that his criticism is a judicious one, and that the design of these piers may be in some respects faulty; but, as regards myself, and those who are interested in discussing the case before the Court, are we to address our minds to discussing these criticisms, which, after all, do not bear upon the question before the Court? Suppose these piers, Nos. 17, 18, 19, and 20, which are different in construction from the others, are not constructed as Mr. Law would design them, does that in any way touch the question of what was the cause of this accident?

(The Commissioner.) Might it not be a matter for one's consideration in advising as to whether or not this bridge is to be reopened in the state in which it is?

Will the public expect us to consider this as one of those matters connected with the casualty?

(Mr. Bidder.) Of course; if that is so, if you are going so far as to report upon what it is judicious should be done in future.

(The Commissioner.) We are not going to say how the bridge should be built.

(Mr. Bidder.) Or what alteration should be made in a future bridge; that is another question.

(The Commissioner.) We should guard ourselves very cautiously with regard to the existing structure of that kind of bridge should be rebuilt, and that the part left standing should be left standing as it is. Is not the view that the Board of Trade take in the matter?

(Mr. Thomson.) I confess that the whole of this information elicited from Mr. Law was elicited at the desire of the Court under the instructions which we received. And if I may venture to give my opinion, it may be of considerable consequence. Evidence bearing upon the condition and execution of the work as far as it is standing, may throw some light upon that which we can only in some measure guess at, namely, the condition of the portion of the bridge which is thrown down.

(Mr. Bidder.) But it does not appear to me that a consideration that the Board of Trade is giving now did follow out the instructions of the Court. What Mr. Law has given evidence about: was the condition of the standing columns of the cast-iron piers, because you may naturally infer from the condition of that which is standing the condition of that which is no longer standing, but I am not aware when we are discussing the design of another part of the bridge which is confessedly a different design from that which we have to consider, the fallen part. As far as regards the other part of the bridge, or a comparison of the mode of construction to the details of the work of which it is composed, I can, quite understand the relevancy of that; but I am not aware when we are discussing the design of another part of the bridge which varies from the part that is principally in question, I fail to see how I am to connect it with what is in my mind as the great subject of inquiry here.

(Mr. Barlow.) I do not myself see how to draw any line between criticising at all any other part of the bridge, for having all the design left standing, it seems impossible to separate them. Take the case Mr. Law last referred to, of having the four girders with the single-top in order to connect the girders.

(Mr. Bidder.) But let us assume that that particular arrangement is a very bad one, of putting a single column with two girders on the top of it, they not standing upon the top of it, does that help us at all in coming to a conclusion, because this is not upon a single column? You might as well inquire into the condition of the Dundee station, for all that relates to this inquiry.

(The Commissioner.) It appears to me that there are two questions in this. Was the bridge properly constructed, and were the materials of which it was composed good materials? The first is the question of construction, and it seems to me extremely difficult for us in considering the construction of this bridge to separate the former part from the other part; and as regards the materials you have admitted that his criticism is a judicious one.

(Mr. Bidder.) I quite see the relevancy of that.

(The Commissioner.) Moreover, I should have thought that both the company and Sir Thomas Bouch would be only too glad (this is a matter with which Mr. Gilkes has nothing to do) to have the expression of the Court in some way or other as to whether or not that portion of the bridge which is now standing is in such a state as that it ought to remain standing. Do I express your opinion, Mr. Balfour?

(Mr. Balfour.) Quite so, sir.

(Mr. Bidder.) I hope you will not misunderstand me. The suggestion which I made, rather in the nature of an objection, you will not suppose to come from Sir Thomas Bouch, but it really was my own, because I felt I was becoming overwhelmed by the multiplicity of the questions which were being raised, and I felt it would be desirable if possible to confine the case within somewhat narrower limits.

(The Commissioner.) We are not anxious to enlarge the scope of the inquiry the least beyond what is necessary, but there are so many questions to be considered that I feel a difficulty in drawing any line and excluding any evidence.

(Mr. Bidder.) Rather than that should be thought, I would rather ask that the evidence should be taken otherwise.

(The Witness.) I was about to observe that the hexagonal brick piers upon which these superstructures are placed are so small that there has been a difficulty in obtaining space for the base piece of the outside columns in some cases. The mode of uniting the 15-inch columns, which carry the weight, with the piers in those cases is somewhat different. They all stand upon a large base plate of cast iron, which is in four pieces, and is united by joints in the middle of the spaces between the columns, and the base pieces for the external columns are separate. They are circular, 3 feet 6 inches in diameter, and resting on a space in which the pillars are put into No. 17. For instance, the circular margin projects over the stonework to the extent of 6 inches on both sides.

12,903. (The Commissioner.) Not the pillars but the base?—Not the pillars. The pillars are well within the masonry, there being a margin of 13 inches to the base plate, but one holding bolt will be very near to the angle of the pier, and the base is so restricted that the diagonal tie-bars have only a horizontal distance between their points of attachment of 2 feet 9½ inches, and that reduces their effective horizontal strain to almost exactly a quarter of that which their real tensile strain would afford—227 in the relation between the horizontal distance of attachment and the horizontal distance of the point of attachment in the direction of a right angle to the course of the bridge, that being the ratio of the strength of the tie bar and its ultimate use for strength in preventing horizontal movement at the top of the column. No. 27 is the last pier but one that is standing upon the southern side, and it seems to me, though I have not described, that has six tiers of columns, the upper tiers racking in the mode which I have described, and there are indications in the stones under the columns, Nos. 1, 2, and 6, of having lifted.

12,904. (The Commissioner.) The stones at the base?—The masonry of the pier.

12,905. (Col. Volkland.) That might have happened in the falling of the other part of the viaduct, might it not?—It may have occurred at the same time, but I do not think any strain could have been transmitted through, which would have resulted in that. It is not the last pier, it is the last but one. It probably would have occurred at the same time. The joints of
the stone under column No. 1 are broken. There is very little shifting, if any, but the joints are broken.

12,906. Does it look as if it had been done recently?—Yes, as far as I can see, the edges of the fracture are sharp, and the joint of the bed plate, by which I mean the square bed plate which I last described which passes under the base of all the four vertical columns, the joint of that bed plate upon the cement is open a little upon the west side, and on the west half of the north and south side as having indicated the same tendency to rise upon the same principle. Here is a packing piece which has been made which shows the cracks referred to in Mr. Noble's evidence, and the manner in which they have been bound round.

12,907. Is that a horizontal joint?—It is a horizontal joint, the joint of the bed plate in the basement being formed in cement.

12,908. (The Commissioner.) That is filled a little?—Yes, and I am indicating that there had been a yielding of one of the tie-bars, I found a packing piece in the basement attached to column No. 6, that is to say, one of the packing pieces which have been so much spoken of.

12,909. (Mr. Builder.) Was that the bar between No. 6 and No. 1 or between No. 6 and No. 3?—Between No. 6 and No. 2; the gib and cotsers at the lower extremity of the bar which extends from the bottom of column No. 6 to the top of column No. 2. This is in No. 28, which is the last pier standing in the east, there is a packing piece introduced into the tie-bar which runs from the bottom of column No. 6 to column No. 1.

12,910. (Col. Yolland.) Between the gib and the cotter?—Yes, it is in that case between the gib and the cotter; a short piece 2½ inches long. In column No. 6, this tie-pier, No. 28, there is a blow hole, or at least a hole of 4 inches by 2½ inches, and of nearly half an inch deep. Then with regard to pier Nos. 28 and 45, passing now to the north, the foundations of these piers consist of two square piers of brickwork, one of an arch, and I have been furnished with a sketch which shows the bearing which the pier is to carry by that arch. I do not know whether the two lower piers respectively, and which shows that the bearing upon the east of the square piers is 8 feet 8 inches, but upon the westernmost it is only 4 feet 8 inches; this is No. 49 pier, and No. 45 is very similar.

12,911. (Mr. Builder.) What does that show?—It shows the bearing upon the superstructure. These piers are square piers of brickwork, and this superstructure is carried by an arch of which these forms the piers or abutments (pointing to the sketch).

12,912. (The Commissioner.) Is the centre of the arch immediately under the centre of the girders?—No, the centre of the superstructure is under the centre of the girders.

12,913. That is what I mean?—The arch does not correspond with the superstructure; it would deviate about 2 feet from the centre line.

12,914. Is the railroad curved at that point?—No, the railroad is straight at that point.

12,915. There would be no outward thrust?—No, you see it is a superstructure of iron, with six hexagonal pillars similar to the 1 inch last described.

12,916. A superstructure of iron not of brick?—Of iron columns braced, precisely similar to those I have last described with the raking columns at the top.

12,917. (Mr. Barlow.) You do not apprehend any ways of safety from the fact of its being so built?—It is hardly a satisfactory support. I think that a girdler across to connect the two piers would be a desirable thing. Of course there are remedies to those things, a tying together of the lower piers so as to make one would remedy that state of things partially, they are so tied I think, several of them, on the southern side. Then I have here a sketch which has been made which shows the cracked columns referred to in Mr. Noble's evidence, and the manner in which they have been round bound.

12,918. (The Commissioner.) Was that drawn by yourself?—It is drawn by one of my assistants and measurements checked by myself.

12,919. We should like to hear something more about it?—The first column is pier No. 78, in sheet No. 16, it consists of four vertical columns carrying the load, encased in brickwork, as I described, with two raking columns on the outside, because at that part the line is curved with a radius of 224 chains, and in that pier two of the columns are cracked.

12,920. And bound?—And bound. The south-west corner in the second tier have been rounded it; there is no crack visible, but the column has bad places in it near to the place where the bond has been put. The south-west column in the same pier in the first tier—

12,921. May I ask what you mean by the first and second tiers, because I find there are only two tiers?—I refer to the height; there are three tiers, including the one covered with brickwork, but apart from that there are two.

12,922. What do you call the second tier?—The first and second are these (pointing to the model).

12,923. The first is the one immediately above the brickwork?—Yes, the first is the one immediately above the brickwork. Now this is in the first tier, and on that column there are two bands, the cracks are close and scarcely visible, but the column has bad places as I have described. Passing on to pier No. 76, which falls upon the next sheet 17, and which is similarly constructed, there are two columns cracked there, the south-west which in the first tier is the upper one, it has two bands round it, and there is a crack which extends from 6 inches above the upper ring to 3 inches above the lower flange in a nearly vertical direction and admits the blade of a knife, and on the north-west column and on the first tier, that is the lowest one, there is a vertical crack which extends from 1 inch above the top ring to 4 inches, being in fact about 4 feet 6 inches in length, it is straight and vertical and admits the blade of a knife.

12,924. (Mr. Barlow.) Is that hooped?—It is hooped with three bands. Upon that column there was originally a further cast which I imagine was for the purpose of having sliding flanges for adjusting the length, as this portion of the line was inclined and each column varied, and, I think, for convenience probably, they had metal patterns and sliding flanges. I could only account for it in that way, that they have feathers, but that feather has been broken off very roughly indeed by blows from a hammer; and has left the column in an uneven state, and with many crevices; in it where it has been broken out. I have this further remark to make, that in the south-west column of pier 76, the second tier, the bottom lug is broken, and the gib and cotsers are wanting in the tie bars; in these lugs the mode of connexion is similar to the tracings which was handed up to Mr. Webster, I think, on the first day, that is to say, that the cotsers and gibs pass through the lugs themselves. Those lugs are very much stronger than the lugs in the other part of the construction, and are of a totally different shape, but in this instance one is broken off at the lower end of the slot, and the gib and cotsers are gone.

12,925. The tie-bar there is non-effective?—The tie-bar there is non-effective.

12,926. (The Commissioner.) Then, of the four pillars two are cracked?—Yes, and the tie-bar is wanting for one of those columns. That comprises the observations which I have to make upon the structure, because my instructions were general, and I have not made that particular inspection of the standing portion of the structure that I did of the fallen.

12,927. (Mr. Tragorn.) You have yet to verify by the actual results of Mr. Kirkaldy's testing what is contained in your first section of the Appendix to your report?—Yes, and the last two or three sections of the Appendix to division D. I shall be prepared to give the results of those experiments tomorrow morning.

(The Commissioner.) Now I suppose, Mr. Webster,
you would not like to cross-examine the witness until his examination-in-chief is completed?

(Mr. Webster.) It is both my learned friend Mr. Bidder's view and my own that it would not be right to do it.

(The Commissioner.) I do not think it would be right to call upon you to do so. Under these circumstances, unless you have a short witness upon some other matter, I do not think we can go any further to-day.

(Mr. Trayner.) I am sorry to say that none of the witnesses who have yet to be examined can in any way be called short.

Adjourned till to-morrow at half-past 10 o'clock.

THIRTEENTH DAY.
Thursday, 22nd April 1880.

Mr. HENRY LAW further examined by Mr. TRAYNER.

12,928. You were to continue your evidence to-day on the basis of the facts ascertained by Mr. Kirkaldy's test?—Yes.

12,929. Are you in a position to do that?—I have only yet received from Mr. Kirkaldy a statement of the results of his experiments upon six bolts, and although I was promised by four o'clock yesterday afternoon the results upon the tie-bars, I have not yet received those from him.

12,930. You are not then in a position to proceed with your evidence at this moment?—I am not in a position to complete my calculations. I have reduced as far as possible the strength of the bolts. I do not know whether it is desirable that I should say anything upon that, but I am not in a position to give any results at present, because I have not anything with regard to the rate of extension of the tie-bars, nor their estimated strength.

(The Commissioner.) I should state that the Court has received from Mr. Kirkaldy a statement of the result of the tensile strains upon six bolts. (To the witness.) That is the document, I think, to which you refer?—Yes, I have a press copy.

Counsel ought to see that as soon as possible.

(Mr. Trayner.) Perhaps it would not be desirable to proceed with Mr. Law's examination bit by bit in this way.

(The Commissioner.) I cannot call upon counsel to cross-examine Mr. Law until he has given the whole of his evidence. (To Mr. Bidder.) I presume you would like to cross-examine Mr. Law before the examination-in-chief has been completed.

(Mr. Bidder.) Before answering your question, Sir, I should like to know what there is still in reserve, and then I shall be able to answer your question. Time is of some value, and if it does not really prejudice me, I would be quite willing to go on as far as I could.

(Mr. Trayner.) I can answer that question. The answer is this: All that remains for Mr. Law to be examined upon is the result of these tests bearing upon those which have already been given, and which—

(The Witness.) But the whole question of the strains that would overthrow the structure depends entirely upon that.

(Mr. Trayner.) Then Mr. Law would be examined again after these are obtained upon the rest of his report, which bears upon this question of the strain, and that would conclude his examination.

(Mr. Bidder.) I presume it amounts to this, that he has given all his evidence with reference to the calculation of the strain on the bridge, and the force tending to overturn it subject to this that upon the result of these tests a certain numerical factor would depend, which comes into his calculations.

(The Witness.) No, it has a much wider bearing than that.

(Mr. Bidder.) All I mean is this. If Mr. Kirkaldy's tests showed a breaking strain of 15 tons to the inch, that would be the figure to introduce into your formula, and if it were 10 tons to the inch, that would be the figure, but I cannot understand whether it being 10 tons or 15 tons would alter your theory.

(The Witness.) It might alter the circumstances under which the structure was overthrown, because it will be readily understood that the structure is sure to be overthrown by that resistance which is the least. There were three or four ways in which it might fall, and that way which offered the least resistance would be the way in which it would fall. The most important factor in the whole question is, the extent to which the tie-bars would yield under increments of strain, and that is exactly what we have not got.

(The Commissioner.) There is also another point, there was a portion of this report which was specially omitted, and upon which there was no special examination.

(The Witness.) It is that which expresses my opinion of the force required to overthrow the structure under different circumstances.

(Mr. Bidder, to the witness.) Which part of the report are you referring to more particularly. I have not it in my mind?—It is that relating to the effort which the struts would have in resisting the overthrow of the structure.

(The Commissioner.) It is section A in the Appendix to your report.

(The Witness.) Yes.

(The Commissioner.) All the different heads under section A, and there was something in section B, I think.

(Mr. Trayner.) No, section D, from sub-section C onwards.

(The Commissioner.) Yes, upon which Mr. Law has given no evidence at all.

(Mr. Trayner.) Mr. Law stated that these calculations were based upon theories, whereas these theories will be made facts or be corrected by the facts as ascertained by experiments.

(The Commissioner.) Of course we would all be very sorry indeed to lose a day, but I think there would be a difficulty in Mr. Law being examined piecemeal, and then being cross-examined until he has really given all his evidence first. I should state that I have received letters to-day from the Astronomer Royal, and also from Mr. Scott, and I think on the whole Monday next would be the most convenient day on which to examine them. Of course we must consult the Astronomer Royal's convenience, and I think Monday next will be the most convenient day to examine him, and Mr. Stokes, and Mr. Scott too. We might fix the morning for them, so that they should not be detained unnecessarily.

(Mr. Trayner.) Is it quite certain that Mr. Bidder is not now to cross-examine Mr. Law upon any part of the evidence which he has given? Does my learned friend, Mr. Bidder, quite understand the answer which
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I gave to his question as to the extent to which the further examination of Mr. Law would go.

(Mr. Biddie.) I think I do. I may tell you that what was in my mind was this, that if it were a mere question of supplying certain constants by the results of the tests, I should be quite willing to take the whole of my cross-examination now rather than lose time by liking to cross-examine Mr. Law and afterwards find that a fresh theory or a fresh formula had been started. Mr. Law has explained to me, and I think I understand what he means, that on the results that Mr. Kirkaldy gives him, both as regards the extension of the bolt and the extension of the ribs, his final conclusion as to the way in which the structure gave way depends, and under those circumstances, although I must say I should very much have preferred to have gone on now when I am ready with his cross-examination, I think I must ask you to let the examination-in-chief be completed before we open the cross-examination.

(Mr. Webster.) It is essentially necessary that that should be so, because with reference to whatever the contractor's position may be, we certainly do wish to have the final view of Mr. Law as to the weak point before we cross-examine him, because we have our own views upon it, and I do not think it would be right if our views should be unfolded till we have finished the examination-in-chief.

(Mr. Biddie.) There is one matter that has occurred to my mind, and which I should like to mention and to draw the attention of the Court and Mr. Law to, and I do it more particularly with the object of suggesting that the attention of the contractor should be turned on Monday to be drawn to it. It is a question easy to ask, but it is a very difficult one to answer, and it is this: I do not think that it occurred to Mr. Law, I am not sure to what extent it is of importance, namely, with reference to the action of the wind upon the surface of the train, and as a theoretical question, as simply as I can, the question I should like those gentlemen to turn their attention to is this: Given a wind of a certain velocity, will the pressure of that wind upon a square foot of the surface of a carriage in rapid motion be the same as the pressure of that wind would be upon the square foot of an anemometer at rest. There are theoretical reasons that occur to my mind which make me think that it would be greater upon the train, taking area for area. Supposing you have a wind which, upon a fixed anemometer, indicated a pressure of 20 lbs. to the foot, there are reasons which lead me to be rather inclined to think that that wind would exercise more than 20 lbs. of pressure upon a foot of surface, passing rapidly through the air transversely to the direction of its own motion.

(The Commissioner.) That will be a matter for cross-examination, which nobody could answer better than Mr. Stokes and Professor Arey, and I will take care that their attention shall be drawn to that point. At the same time I think on the theory of the resolution of forces, it would depend very much upon the fact whether the wind was rather ahead of the train, or in the rear of the train.

(Mr. Biddie.) I think not. I do not think you will say it is a waste of time if the gentlemen's attention is drawn to it now, they will have a little time to think over it before they go into the box. I will tell you exactly what is in my mind. Supposing that a wind is blowing in the direction of that arrow (pointing to a sketch), at right angles to this, which I suppose is an anemometer, a square foot of surface exposed to the wind and at right angles to me, that the same thing must happen there which one can see with one's own eyes happens in the case of a surface exposed boldly to a stream, that is to say, there is a certain serial bow made, as in a case of a stream there is a liquid bow made, and to some extent there must be the same effect as if you had actually put a wedge in front of that square surface. It would be an easy calculation to show that the effective pressure transversely upon this surface would be less than if this figure head were taken away; it would be less than if there were no bow there. Then comes the question that when a train is passing rapidly transversely to the wind, it is always coming to a fresh place, and getting the full impact of the wind.

(Mr. Webster.) It is getting a succession of direct impacts.

(The Commissioner.) Yes, and therefore it is a very important question in this case, with a view to the general proposition, which we cannot avoid, namely, whether or not the allowance for wind pressures upon bridges is or is not properly made.

(Mr. Biddie.) Yes.

(Mr. Barlow.) That is the case that would arise in a windmill sail.

(Mr. Biddie.) Yes, that would arise in a windmill sail. I am not aware whether there are any observations that would help one.

(Mr. Barlow.) I think so.

(The Commissioner.) With a cup anemometer, the anemometer would be continually moving.

(Mr. Webster.) It would be moving in a different way.

(The Witness.) The forces can be resolved by those formulae which I have already given.

(Mr. Webster.) The question is whether there is a series of forces coming upon the same object.

(The Commissioner.) Without any intermediate buffer?

(Mr. Webster.) Just so. (To Mr. Law.) We might ask you to go to Mr. Kirkaldy with the view of hastening the testing?

(Mr. Law.) That I propose doing, and then devoting my best attention to the matter. I shall be ready certainly by to-morrow morning.

(The Commissioner, to Mr. Balfour.) You would not like to begin with the cross-examination of Mr. Law until his examination-in-chief is concluded?

(Mr. Balfour.) This is a part of the case that I hardly think I am interfering in, but whatever course the Court think it would, of course, assent to.

(The Commissioner, to Mr. Trayner.) Are there any further witnesses that you propose to call now?

(Mr. Trayner.) No—on behalf of the Board of Trade. I have no witness to examine to-day, I relied upon Mr. Law's examination and cross-examination taking the whole day.

(The Commissioner.) There was a gentleman whose name was mentioned, if I remember rightly, at Dundee, a Mr. Grothe, who we were told was employed on a Spanish railroad, and could not attend to give evidence before us, but that if time were given, he would be able to come over to this country for the purpose of giving evidence; and we were told that he was very anxious to give evidence.

(Mr. Trayner.) I may state that the North British Company, following out the wish expressed by the Court, took means to secure the attendance of Mr. Grothe, and Mr. Grothe is now in Court, and if the Court desire to have any information from him, or if the Board of Trade, or any of the parties desire to have any information from him he is here to give it.

(The Commissioner.) Before we go any further may I ask for whom Mr. Grothe acted as agent—for Sir Thomas Bouch, or the Company?

(Mr. Trayner.) As the resident engineer of Messrs. Hopkins, Gilkes, and Company.

(Mr. Webster.) Not quite so. Mr. Grothe was originally employed before Messrs. Hopkins, Gilkes, and Company had anything to do with the work. Mr. Grothe was one of the gentlemen whom, upon Messrs. Hopkins, Gilkes, and Company taking to the work, they were requested by the Company, so, and I desire to state at once that they had the most perfect and full confidence in Mr. Grothe and in the way he did his work. Those are the circumstances under which Mr. Grothe came in.

(Mr. Trayner.) I think I was correctly answering the question put by the Court, which was, what was Mr. Grothe's position?

(Mr. Webster.) Messrs. Hopkins and Gilkes took him over; but in taking him over, they desire me to
say that they had perfect confidence in him, and that they were thoroughly satisfied with him. You may remember that, when this question arose, the contractors were not represented. Mr. Balfour was good enough to do what was necessary to get full information before the Court. Mr. Grothe, it appears, is here, and the contractors, if Mr. Trayner want to examine him, I shall be only too pleased; and if he does not, probably the contractors may at some time or other examine him.

(The Commissioner.) When we were at Dundee, Mr. Balfour put into the box Mr. Campbuz and Mr. Beaty. As you (Mr. Webster), to a certain extent, for that purpose, Mr. Balfour, so far as the contractors are concerned, is it your wish now, in order that there should be no loss of time, to put Mr. Grothe into the box?

(Mr. Webster.) Appearing now for the contractors, I certainly should not put Mr. Grothe into the box until the general case for the Board of Trade was completed, because if Mr. Grothe appears as a witness for the contractors, I shall certainly rely upon Mr. Grothe's evidence with reference to what has been put forward by Mr. Law at the present time; therefore, I shall not at all, on behalf of the contractors, be willing to put Mr. Grothe into the box until Mr. Law's evidence, cross-examination, and re-examination, has been completed. Any course that the Board of Trade determine to take I cannot, of course, interfere with.

(Mr. Balfour.) Perhaps I may be allowed to mention that Mr. Grothe has been allowed to come here only for a very short time, and at the greatest possible inconvenience to his employers, who are the Great Thamsis Copper Company, and we are told that it will hardly be possible to keep Mr. Grothe here beyond a few days.

(Mr. Webster.) I am quite willing that lie should be called, only the Commissioner put to me whether I should put him into the box. At present I am not in a position to put anybody into the box, but I am only too willing that Mr. Trayner, or anybody else, should call Mr. Grothe.

(Mr. Balfour.) The position of the railway company now is very much that of bystander; all the persons interested are here. We have the designer, and we have the contractors for the execution of the work, and my position therefore is not to take an active part in the matter at this time. Therefore, I do not think it would be fitting, or reasonable, that I should intervene in any way; but we thought that we were loyally carrying out the wish of the Court in getting Mr. Grothe to attend; but I cannot undertake to keep Mr. Grothe here above a day or so.

(Mr. Trayner.) As a kind of appeal has been made to the representative of the Board of Trade, I should like to say a single word about this. At Dundee, Mr. Balfour put into the witness box Mr. Campbell and Mr. Beaty, who were the engineers directly under Mr. Grothe at the construction of this bridge, and you will find on the minutes of the evidence that Mr. Balfour stated on the 2nd of March the reason why he could not then examine Mr. Grothe and Mr. Reeves, as they were abroad, and also another, whom I need not name at the moment. The Commissioner may think of course we express no opinion as to whether "Mr. Grothe or Mr. Delpatt should come forward or not—that is a question for you to consider;" and Mr. Balfour said, "Certainly, Sir, but they are not accessible to us at this moment." For the Board of Trade I am not now in a position to call Mr. Grothe; but I have had an opportunity of inquiring what Mr. Grothe knows as to the facts connected with the construction of the bridge, or the facts connected with its falling, if any; and I have had no opportunity of examining him as to his opinion upon the matter; and having put certain witnesses forward to speak to facts, and also certain witnesses to speak to opinions formed upon the observations they have made, I am not, as advising the Board of Trade, at this moment, disposed to put into the witness box a man whose evidence may be exceedingly valuable and exceedingly reliable when given, but whose evidence at this moment may, for any thing I know, be of a kind entirely different from that which has been given, not that I desire to press one particular view upon the Court more than another.

(The Commissioner.) You do not know yet what he is going to say.

(Mr. Trayner.) Just so. The Court wishes to get at the truth, and so do the Board of Trade.

(Mr. Webster.) Just let me remind you, Sir, of what the position of the parties in this case is. The practice on these inquiries has always been that persons have been put into the witness box, and questions put to them to elicit their story, and certainly it is hardly consistent with the usual practice for the Board of Trade to decline to call a gentleman because they do not know which way his evidence is going to tell. On the part of the contractors, at present do not know whether the contractors will call evidence at all; but knowing that Mr. Grothe is here, and only having known that during the last few hours, I say at once I am perfectly willing, as far as the contractors are concerned, that either through the Court or anybody who represents the parties, Mr. Grothe should be examined once.

(Mr. Bidder.) I must say that I think Mr. Trayner should remember that he is not counsel for a plaintiff struggling for a verdict, but that he represents a great public body, whose object is simply to ascertain the truth, whether it be one way or the other.

(Mr. Trayner.) Mr. Webster and Mr. Bidder have both not done me the favour to attend to what I said, for I said distinctly that I did not appear in the position of a prosecutor, but that I was desirous to assist the Court in the investigation of the whole facts, few as they were, and it was not because I was here to maintain a certain proposition or a certain theory that I declined to examine Mr. Grothe. If the Court think that we Mr. Grothe to be examined, and anyone tenders him, they can put him into the box, and anyone who desires to get information from him can then elicit it.

(Mr. Bidder.) I must point out to Mr. Trayner that it is not the time for us to tender any witnesses. When the Board of Trade have closed their case and called all the evidence they think material, it will then be for my learned friend Mr. Webster to advise the contractors and engineer respectively, to consider what evidence we can call before the tribunal to help the tribunal to a right understanding of the case.

(The Commissioner.) I may observe that in an inquiry of this kind we are at liberty to call any person we choose afterwards.

(Mr. Bidder.) Certainly. I protest at once against any responsibility being cast upon us for the calling or not calling at the present moment of any particular witness, and if it should turn out beforehand that Mr. Grothe cannot be had because he cannot be called to day, we must not be held responsible for it.

(The Commissioner.) It appears to me, and I think also to my colleagues, that in an inquiry of this kind even if Mr. Trayner were to call Mr. Grothe into the box, and put such questions as might arise to elicit the truth, Mr. Webster and Mr. Bidder would have the liberty to cross-examine him, and of course Mr. Trayner would have the liberty to re-examine him, and then Mr. Trayner would bring out any evidence that might arise from the answers he had given in cross-examination. It is not intended that during the proceedings to call Mr. Grothe now, but at the same time I should be very sorry, for my own part, that Mr. Grothe, having come over to this country, should go away without being examined.

(Mr. Balfour.) I may say that I understand that the maximum measure of Mr. Grothe's stay is till Tuesday next, and unless he is examined to-day I may say, on the part of the railway company, that I cannot undertake to retain him.

(The Commissioner.) It is the opinion of the Court
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that Mr. Gröthe, having come to this country for the purpose of attending this inquiry, ought not to be allowed to leave without giving his evidence, and under those circumstances, if Mr. Trayner is prepared now to put certain questions to him so as generally to load his evidence, I think the Court would be very much obliged to him for doing so.

(Mr. Trayner.) If the Court directs Mr. Gröthe to be called, I shall be quite glad to go on with his examination.

Mr. A. Gröthe.

Examine by Mr. Trayner.

12,932. Will you kindly tell me what you are at present?—I am at present general manager of the Tharsis Mines and Works in Spain.

12,933. (The Commissioner.) You are a civil engineer?—Yes.

12,934. (Mr. Trayner.) At the time when Messrs. de Bergue entered into the contract with the North British Railway Company for the erection of the Tay Bridge, were you in the employment of Messrs. de Bergue?—Yes.

12,935. And you were then, I suppose, appointed by them as resident engineer at the Tay Bridge Works?—Yes.

12,936. Their contract was dated in May 1871?—The 8th of May, I think.

12,937. And how long did you continue, on behalf of Messrs. de Bergue and Company, to superintend the works?—Till they relinquished the contract.

12,938. In 1874?—Yes.

12,939. Were you thereafter retained on the bridge as resident engineer by the new contractors, Messrs. Hopkins, Gilkes, and Company?—Yes.

12,940. And from that time until the time you left you were in the employment and pay, I suppose, of Messrs. Hopkins, Gilkes, and Company?—Yes.

12,941. Could you give me shortly a general notion of your duties at the bridge?—Do you mean while I was in the employment of Messrs. de Bergue or of Messrs. Hopkins, Gilkes, and Company?

12,942. All the time. I suppose your duties did not vary under Messrs. Hopkins, Gilkes, and Company from what they had been under the previous contractors?—My position was slightly different with Messrs. Hopkins, Gilkes, and Company.

12,943. What was your position with Messrs. de Bergue and Company first?—With Messrs. de Bergue and Company, I was one of the managers of the concern both at Manchester and Cardiff, and a central office in London; it was a special part of my duties to superintend the building of the Tay Bridge, but my position with the firm also enabled me to exercise supervision over the purchase of all the materials and the manufacture of parts of the bridge in the works of the firm either at Manchester or at Cardiff.

12,944. With Messrs. Hopkins, Gilkes, and Company, what was the difference in your position?—With Messrs. Hopkins, Gilkes, and Company I was purely manager of the bridge works, and as such I had nothing to do with the purchase of any materials except such as were got from local supplies, as wood, bricks, and cement, while all the ironwork, other manufactured or rough, came from one of the Middlesex bridge firm.

12,945–6. Then, you had less control or supervision of the material supplied—that is to say, so far as the iron was concerned—while you were employed under the second contractors than you had under the first contractors?—Yes. I also had less control in other respects, because anything I did in the purchase of materials other than iron, was of course subject to the approval of the firm; and I also had the advantage of Mr. Gilkes' occasional visits and supervision, and it was with him, as already stated, the director of Messrs. Hopkins, Gilkes, and Company, that I consulted first on all matters of importance either verbally or in writing. While with Messrs. de Bergue and Company I was a species of partner; there was no Mr. de Bergue at that time.

12,947. You were more your own master at first than you were latterly?—Yes.

12,948. There is one matter which perhaps you can explain to us. Am I right in saying that the original intention was to have all the piers built of brick?—Yes, with the exception of some small piers on the north side, in the curve, but all the others were to be of brick.

12,949. And accordingly something like a dozen or better of the piers from the south end were built entirely of brick?—Fifteen.

12,950. Were these all erected under the contract of Messrs. de Bergue and Company?—Yes.

12,951. In a general way the piers were to be under Messrs. de Bergue and Company's contract, brick piers?—Yes, with the exception I have stated.

12,952. Which was not very extensive?—No it was not.

12,953. And after Messrs. Hopkins, Gilkes, and Company got the contract the material for the greater part of the bridge was determined to be of iron?—Yes, that, however, was a change which was resolved upon before Messrs. Hopkins, Gilkes, and Company took up the contract.

12,954. I am coming to that. It is the fact that I am putting it to you?—Yes.

12,955. When was that change resolved upon?—During the latter part of Messrs. de Bergue's contract.

12,956. Was that change resolved upon under your advice, or in consultation with you?—In consultation with me.

12,957. Why was the alteration made?—Because the foundations as really encountered were not as the contract plans would lead one to believe; rock was shown on these drawings where there was none.

12,958. These contract plans were plans prepared by whom?—They were plans prepared by Sir Thomas Bouch.

12,959. (The Commissioner.) I understand that the alteration was made because at a certain distance out the rock went away?—The rock began to dip.

12,960. The rock went away to be replaced by what?—Yes.

12,961. (Mr. Trayner.) And in places which were shown as having an accessible rock foundation you found what, instead?—In some places at that depth we found sand, at others gravel; where what was shown rock, we found generally gravel, slightly varying, sometimes sand.

12,962. Was the inaccuracy in the plan the only reason which led to the change in the material of construction?—The only reason, as far as I am aware.

12,963. How far did the line of rock vary in fact from the line shown by Sir Thomas Bouch, or did you make any soundings or borings in order to ascertain?—Yes, many. I made one sounding 157 feet deep, and did not encounter the rock.

12,964. At a place where the plan indicated that you had rock?—Yes.

12,965. At the line given on the plan?—Yes.

12,966. Over what extent of the line of the bridge did this inaccuracy extend?—From pier No. 14, sheet 3, on the south side, Northward, to the beginning of the single column part, to the beginning of the curve, about span 60 or 61.

12,967. (The Commissioner.) Give the number of the pier?—Pier 60 or 61.

12,968. (Mr. Trayner.) I want to put this beyond any doubt, in case I am misapprehending you. The line shown on the plan in the curves, indicating an accessible rock foundation from pier 15 to pier 61, was erroneous?—Yes.

12,969. At some place one sounding you mentioned you made to the extent of at least 160 feet?—Yes, 157 feet.

12,970. (The Commissioner.) Where was that?
Mr. Truayer. Was that the greatest sounding you had ever heard?—Yes.

Mr. Truayer. I suppose you made soundings or borings at other places?—Yes.

Mr. Truayer. Will you tell me in any other places what distance you bored to ascertain the rock?—We bored fairly through the gravel layer in most cases to ascertain the depth of the gravel layer, and the top of that gravel layer we would nearly take the place of that which was indicated as "rock."

Mr. Truayer. In your other borings than the one you have specified what depth did you go down?—I think about 30 feet.

Mr. Truayer. We bored to ascertain the rock?—We bored many more than that.

Mr. Truayer. And not finding the rock as indicated, you then resolved upon a different mode of construction; is that so?—It occurred to me that a different mode of construction was necessary. I could not resolve upon it, of course.

Mr. Truayer. You consulted with some others, or in consultation with others it was arranged to alter the construction. Who were the others with whom you consulted?—Sir Thomas Bouch, of course, to whom consultation with others it was arranged to alter the construction. Who were the others with whom you consulted?—There may have been others present at some of the meetings, and there may have been others present at some of the meetings, but I cannot say exactly.

Mr. Truayer. Did that inaccuracy in the drawings lead to any other change in the construction than the change from brick piers to cast-iron columns?—Yes; it led, in the first place, to an enlargement of the foundations, and in the second place, to a lightening of the top part of the piers in order to allow the foundation to bear the weight.

Mr. Truayer. Do you mean by the "top part" the whole of the structure upon the brickwork or the stonework?—I had my eye upon the pier principally.

Mr. Truayer. Just let me understand what you mean by the pier?—By "the pier" I mean everything from the bottom to the underside of the girder.

Mr. Truayer. To what extent were the foundations enlarged?—Still I speak to any particular class of pier, because there are many.

Mr. Truayer. Take the high girders?—The original plan of the high girders was that the foundation should consist of two cylindrical piers, each 15 feet 6 inches in diameter at the base, joined at low water by means of a web wall in brickwork, having a coping at high water 2 feet 6 inches thick.

Mr. Truayer. (The Commissioner.) A coping of stone, you mean?—Yes; and further continuing brickwork to the top. The wall continuing to the very top.

Mr. Truayer. The two pillars being connected by a web from top to bottom?—Like an opera glass.

Mr. Truayer. With the bridge of the opera glass extending from top to bottom?—Yes.

Mr. Truayer. (Mr. Truayer.) Just go on to explain the change that was then determined on. That, I understand, was the original design; what was resolved on then in consequence of your discovery of the nature of the bottom?—In consequence of the discovery of the nature of the bottom, the piers which were originally intended for the larger spans were to be used as the foundations for the smaller ones, and in their stead for the larger spans two new ones were intended to be put, one circular and one oval. These were to be joined at low water; and they were to be brought 5 feet above high water, there being a cast-iron base plate over the whole, and then eight columns coming at the top.

The columns were to be placed in two rectangular clusters.

Mr. Truayer. (Col. Yolland.) Your on one side?—Yes; the two columns here (pointing to the middle of the pier) were placed exactly like those two.

Mr. Truayer. (The Commissioner.) Instead of a single one on the outside there would be two?—Yes; one here and one there, the same width as that (pointing to the model).

Mr. Truayer. (Mr. Barlow.) There were two groups of four columns instead of two groups of three?—Yes.

Mr. Truayer. (Mr. Truayer.) Just to exhaust that. That was not carried out?—No, it was not.

Mr. Truayer. Why?—Further difficulties in the sinking of the smaller piers showed us that there was a great risk in carrying out this plan of sinking two caissons for each pier, and that it would be necessary to simplify the operation by substituting one caisson still larger for the two which we before.

Mr. Truayer. Then the one caisson that you did use, I take it, was not broad enough to permit of your erecting upon it eight columns is that so?—(The Commissioner.) Perhaps we might ask him what was the reason of the change in the pillars.

(The Witness.) That is a question I cannot answer. I was instructed to make six instead of eight.

Mr. Truayer. (Col. Yolland.) What cannot you answer?—What led to the change from eight to six columns. (Mr. Webster.) He says, "I was instructed."

Mr. Truayer. (Mr. Truayer.) And your instructions as to that change came from whom?—Sir Thomas Bouch.

Mr. Truayer. Without any reason being assigned for the change?—Yes.

Mr. Truayer. What was the size of the two caissons that you intended to sink?—I think one of the two was 20 feet in diameter, and the other was an oval one, having 22 feet in the direction of the major axis, and 15 feet 6 inches, I believe, in the minor axis.

Mr. Truayer. But I am not sure that I asked you at that point I will ask you this: Would there have been room at all upon these piers to have put the eight pillars?—Upon those piers as intended to be made at that time, do you mean?

Mr. Truayer. No; as they were made?—Upon this pier (pointing to the model), no. Upon the base, yes. (Mr. Webster.) Upon the caisson there would have been room, but upon the pier on the top of the caisson there would not have been room.

Mr. Truayer. Upon the caisson there would have been room, but upon the pier as raised upon the caisson there would not have been room?—No.

Mr. Truayer. (Mr. Truayer.) The pier was designed for the particular arrangement of the columns to be put upon it. (The Commissioner.) No doubt. On the caisson the eight piers might have been raised.

The Witness. Yes.

Mr. Truayer. But not on the pier?—No.

Mr. Truayer. (The Commissioner.) Mr. Barlow wants to know what the dimensions were of the caisson?—Thirty-one feet diameter; it was circular.

Mr. Truayer. (Mr. Truayer.) That was the one caisson which was subsequently substituted for the intended two?—Yes.

Mr. Truayer. (The Commissioner.) Will you tell us what was the size of what you call the brick pier?—The size of the brick pier was 27 feet 6 inches—may be wrong in the inches—long, and 15 feet 6 inches bread.

Mr. Truayer. (Mr. Truayer.) Was that the pier which you intended to erect?—No; these are the dimensions of this pier.

Mr. Truayer. (The Commissioner.) The actual pier. What I understood was this, that you proposed originally to have made the pier of the size of the caisson?—Hardly that. There were two caissons first proposed.

Mr. Webster. There were two caissons first proposed, a circular one and an oval one; then there was one caisson of 21 feet adopted; and then he received instructions to build a certain pier, but he never not
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say that it was ever proposed to erect eight pillars upon it.

13,011. (The Commissioner.) But there would have been room for them?—Yes; but the shape of this pier had been altered, which at the same time had increased its weight.

13,012. (Mr. Traeyon.) Could you have built a pier upon the large caisson which was already sunk in the river bed sufficient to bear the eight columns?—The bearing power of the substrata there is very much a matter of conjecture, and the purpose being to keep the pier as light as possible, I would myself have tried to do it in such a way as to make it lighter in order to fully answer the object, namely, to put as little weight per foot of bearing surface as possible.

13,013. (Mr. Bidder.) I understood you to say that the caisson was sufficient for the eight columns?—That caisson was never contemplated to go together with the eight columns; the adoption of the cylindrical set of columns at the same time led to the adoption of this hexagonal shaped brick pier.

13,014. (The Commissioner.) What I understand you to say is, that it is very doubtful in your mind whether or not the bottom on which the caisson rested would have borne a pier of the same size above it; that is, whether you understand you to say?—It would be a doubt in my mind whether that caisson should have been loaded with more weight than it was.

13,015. (Mr. Barlow.) Would one column additional at each end have made much difference in weight?—A column at each end would have made hardly any difference, but the fact that the brickwork would have been differently shaped would make a difference. There is barely room now for another column. You could not place another column without enlarging the brickwork at the same time.

13,016. (Mr. Traeyon.) Why was it suggested, do you know, that there should be eight columns in each pier when you abandoned the idea of building the piers of brick entirely?—It was an arrangement which recommended itself to us as being rational.

13,017. (The Commissioner.) For the support of the superstructure?—Yes.

13,018. As it appeared to be a rational arrangement for the support of the structure that you knew was to be placed upon it, why did you not carry it out?—First of all, I can at once say that I had no choice except by going away altogether.

13,019. I quite understand that; but can you give us any information as to why it was not carried out?—If one plan is rational, it does not follow that there was not another rational one.

13,020. I do not say it does. I am asking you whether you can explain to me why Mr. Thomas Bouch, having first arranged that there should be eight columns in the pier, came ultimately to the resolution to drop out two of those columns?—No, I cannot.

(The Commissioner.) I thought he had answered that question. Let us see that we quite understand it. I thought his answer was quite clear. He said that when they found that the foundation was so insecure they did not like to put an additional amount of brickwork upon the caisson, because they did not think the foundation would bear it, and consequently if they could put no additional amount of brickwork there they could not put the eight columns, and therefore they put only six columns.

13,022. (Mr. Traeyon.) I think the witness is distinguishing between what is his opinion and what is within his knowledge as to what Sir Thomas Bouch's intention or grounds for the change were. (To the witness.) Is that so?—Yes; that is so.

13,023. (The Commissioner.) That is your opinion?—Yes; that is my opinion.

13,024. (Mr. Traeyon.) Why Sir Thomas Bouch altered the eight columns to six columns you do not know, but you give as a reasonable explanation for the change, that to have put in the eight columns would have necessitated a heavier amount of brickwork, which you think the caisson would scarcely have borne?—Yes.

13,025. (Col. Yolland.) What was to have been the base of the eight columns?—The base of the eight columns would have consisted of two caissons.

13,026. Of what dimensions?—One circular caisson 20 feet in diameter on the one side, and an oval caisson of 22 feet in the long axis and 15 feet in the other, and those were to be joined at low water.

13,027. Why was one proposed to be made round and the other oval?—The reason of that was that a good deal of material which had been ordered and made for one purpose did not come in when the plans had to be altered in consequence of the boring turning out differently from what we had reason to expect; and, secondly, they were so arranged as to serve the purpose of a possible doubling of the line in the future.

13,028. (Mr. Traeyon.) Was there any other change in the construction of the bridge adopted in consequence of what you discovered about the bottom?—The length of the spans was altered.

13,029. In how many cases, and where?—In the case of that part of the bridge which spans the navigable part of the river.

13,030. (The Commissioner.) The high girders?—The high girders, and also in some of the adjacent girders, as far as a change was yet possible.

13,031. (Mr. Traeyon.) By that time you had built up a certain number of piers upon the south, and you had also been working southward from the north?—Yes.

13,032. To what extent were the spans lengthened?—The large spans were intended to be 215 feet long.

13,033. Originally?—Yes, and they were altered to 245 feet.

13,034. Anything else?—The 130 feet spans were altered to 145 or 146 feet. Those were all the alterations in the lengths of the spans.

13,035. Was there any other alteration in the style of the bridge?—None but what was the consequence of these changes.

13,036. Did that affect in any way the construction of the girders that were placed over the piers?—Not in principle; it made them, of course, longer.

13,037. Did it affect the actual construction, apart from the question of principle—did it, in point of fact, alter the design?—The dimensions had to be different in consequence.

13,038. Were the dimensions made greater?—Yes.

13,039. (The Commissioner.) The structure was made stronger?—Yes.

13,040. (Mr. Traeyon.) So that there was more side surface in the girders as actually constructed than originally was intended?—No.

13,041. Are you quite sure of that?—Unless you go into decimals of feet.

13,042. In the first place, was the height greater?—The height was the same.

13,043. Exactly the same?—Yes, because in the original spans there were eight bays, while in the girders as fixed upon there are nine, the height being the same, the proportion of the height and length being different, so that the only greater surface, leaving out of account the greater thickness of the plates making up the girder, the only greater surface which is offered by this girder is in consequence of its being longer. Proportionately to the length it is the same.

13,044. To what extent were the plates of the girders thickened?—I suppose they were thickened in the proportion of the greater strain which they had to carry.

13,045. They had a certain specified thickness for the original design and they had a different thickness as executed. What is the difference between the two?—I really could not tell.

13,046. (The Commissioner.) It would vary on each part of the bridge?—It would vary on each part of the bridge.

(Mr. Traeyon.) Was it a material thickening.

(Mr. Bidder.) When you say thickening do you mean thickening in a direction transversely to the bridge, or the other way?
13,047. (Mr. Trayner.) I mean transversely to the bridge. (To the witness.) Can you tell me, do I not mean in the matter of surface such as would be opposed to wind pressure, but, whether in the actual thickness of each bar itself, the plate was materially thickened as constructed?—I should think it would be about in the proportion of eight to nine generally speaking.

13,048. To make this quite clear, I understand you to say, that the flat surface opposed to lateral pressure was not increased?—No, not per foot.

13,049. Are these the material alterations that were made in the construction of the bridge as differing from the original design, in consequence of what you discovered about the bottom of the river?—Yes.

13,050. Did Sir Thomas Bouch offer any explanation to you with regard to the error which was discovered in his drawings?—Do you refer to the borings?

13,051. You found that his drawings was wrong, did he offer any explanation to you in reference to how that had occurred?—He may have done so in ordinary conversation.

13,052. Do you recollect what he said, if he said anything?—I recollect having spoken with him about it, and he expressing great disappointment at the deception by the builders, they having reported rock, where really there was perhaps a boulder, or something like that.

13,053. You were the resident engineer, were you in point of fact constantly there?—Since I was with Messrs. Hopkins, Gilkes, and Company, yes.

13,054. And were Messrs. Camphuis and Beattie your assistants?—Yes.

13,055. At the same time?—At the same time.

13,056. And throughout the greater part of Messrs. Hopkins, Gilkes, and Company's contract?—Yes.

13,057. Mr. Camphuis the whole time, and Mr. Beattie very nearly the whole time?—He left some time before the works were completed.

13,058. With them there, did you take any personal supervision of the manufacture going on at Wormit Foundry?—Yes.

13,059. Much?—In the beginning more than latterly.

13,060. Could you make that a little more definite, and say over what period latterly your personal supervision was less constant?—My personal supervision in the beginning was almost constant till I saw that the work was being done well.

13,061. And over what period did that constant supervision extend?—I should think for a couple of months, but that I cannot say with certainty.

13,062. The columns that were used in the erection of the bridge were to a large extent cast at Wormit, were they not?—Just so.

13,063. Were there many cast anywhere else, or were they all cast at Wormit?—Not all.

13,064. Where were the others cast—at Middlebrough?—Some were cast in Manchester.

13,065. (Mr. Budden.) Was that in de Bergue's time?—Yes; in de Bergue's time.

13,066. (The Commissioner.) For the high girders, where were they cast?—For the high girders, they were all cast at Wormit Foundry.

13,067. (Mr. Trayner.) Were any of those columns for the high girders cast in the course of two months when you were giving your own personal supervision more actively?—No.

13,068. Then the supervision of those castings was more immediately that of Messrs. Camphuis and Beattie?—Mr. Beattie. Mr. Camphuis occupied a slightly different position from Mr. Beattie.

13,069. Did you do anything personally in the way of testing any of the columns that were cast for the high girders, either to ascertain their strength or the accuracy of the casting?—I never ascertained the strength of the columns. I ascertained, whenever I had an opportunity, the accuracy of the casting.

13,070. (The Commissioner.) You mean occasionally?—Without making it a special point to go through every one of them.

13,071. (Mr. Trayner.) Will you just tell me what course you took to ascertain the accuracy of the castings?—Looking at them—inspecting them; in fact, looking at them carefully.

13,072. You mean an external survey of them?—Yes, an external examination.

13,073. Can you give me any idea how often this opportunity was afforded you?—That opportunity was afforded me very often indeed.

13,074. Did you take advantage of it very often?—I took advantage of it very often.

13,075. Did you see any column indicating the existence of a coal-shut?—Yes.

13,076. How often?—Very seldom; not often.

13,077. Did you see a dozen?—No.

13,078. Did you pass these columns?—No.

13,079. They were broken up, were they?—Every column which I found the least defective, or which was reported to me as defective, was broken up.

13,080. Did you see any columns that had blow holes in them?—Yes.

13,081. Did you pass any such columns?—No, never.

13,082. Did any columns pass under your observation that had blow holes filled with Beaumont egg?—I have never seen Beaumont egg as far as I know; I cannot tell that.

13,083. Can you tell me this; were there any columns that passed your observation that had blow holes in them filled with anything like cement or putty?—Yes.

13,084. What did you do with those?—Broke them up.

13,085. With your knowledge no column went to the bridge that was not, so far as you could tell from external survey, perfect?—Yes, and very positive instructions were given to prevent anything of that kind.

13,086. To whom?—First to the managers immediately in charge, and to their assistants.

13,087. Do you mean Messrs. Camphuis and Beattie?—Yes.

13,088. (Mr. Webster.) Will you give us the names?—Mr. Camphuis and Mr. Beattie. Mr. Beattie at first and then to the foreman in charge of the foundry.

13,089. (Mr. Trayner.) Did you give those instructions to the foreman, or did you direct them to be given through your assistants?—I often gave them, if the assistant was present I would tell him to do so, but if he were not present I would speak to the foreman. I recollect on one occasion particularly, having found a column in which a small hole had been filled up with a foreign substance, being in company with Mr. Gilkes, and the foreman was called and got a severe scolding for not having prevented this. The column was broken up, and the man received most positive instructions there and then to break up himself, without further authority, any columns which in his opinion, were not perfect, and to report to the manager of the foundry or to myself any which he thought were good enough, though they had some slight defect. He brought some under my notice in that manner, which I invariably ordered to be broken up.

13,090. The columns were to be of what thickness?—The columns were to be of one inch thickness of metal.

13,091. Of course of equal thickness all round?—Yes, I suppose so, there was nothing specified.

13,092. An inch column means a column that is an inch thick in the whole circumference of it?—Yes, certainly.

13,093. I will show you specimens Nos. 1, 2, and 3 (handing them to the witness). Assume that those
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were parts of one column, are not of equal thickness?—I do not know whether they are parts of one column. You ask me whether they are of equal thickness?

13,094. I ask you to assume that they were parts of one column; are they of equal thickness?—No, they are not.

13,095. Assume those three specimens are taken from the same column, that column was plainly not according to what you had wished or ordered to be made?—No.

13,096. If you had known of such a column as that going down to the high girders, would you have passed it?—Certainly not.

13,097. (Mr. Barlow.) Why not?—Because I was bent on making first class work only, in all respects equal to the instructions which were given me.

13,098. (Mr. Trayner.) Would you have considered such a column as that proper column to put into that construction knowing the pressure that was to be put upon it?—I would have had no objection as an engineer to put it in. The reason why I would not have put it in is, as I have stated, that I wanted everything to be exactly as I was told it should be; but I would have had no objection as an engineer to put this column in the bridge.

13,101. Tell me what is the thinnest part there, and the thickest of the three bits?—There is one part of five-eighths of an inch here; that is the thinnest I can find: there is one part barely an inch.

13,100. Is there nothing over an inch?—I cannot find any.

13,101. If you had these pieces on opposite sides of the column and extending for some length in the thickness, would you as an engineer have approved of such a column as that going into the high girders?—As an engineer I would have had no objection to it.

13,102. You think then that the column was strong enough at the thinnest part?—The column was strong enough considering the large margin that an engineer—let us ask me as an engineer—must allow in structures of this kind.

13,103. Would the whole structure have been strong enough if the columns had been only five-eighths of an inch?—It would still have been strong enough, it should have been strong enough though there would have been less margin.

13,104. What margin is there in five-eighths of an inch?—In cast iron there should be a margin of at least six or seven times.

13,105. You have not quite followed what I want—if the column was strong enough to bear the superstructure with five-eighths of an inch thickness, was there anything under that which would have been strong enough for the purpose?—If one inch metal is properly designed, if it is really what it should be, then the thing actually would be strong enough would be about the sixth of an inch.

13,106. It was designed an inch thick?—It was designed an inch thick.

13,107. And how much of that was pure margin?—Five-sixths.

13,108. (Mr. Commissioner.) Do I understand you to say that these columns would have borne the superstructure if they were made of iron a sixth of an inch thick?—They should have borne all the strain which ever could have come upon them.

13,109. Is your answer that columns a sixth of an inch thick would have been sufficient to bear the superstructure they were intended to bear?—With the proviso that one inch was the proper dimension in the first place to make these columns of. If one inch was right, then one-sixth of an inch would have borne the strain in.

13,110. It ought to be six times as much you mean?—Yes, perhaps more, but at least a sixth for cast iron.

13,111. (Mr. Trayner.) I understand you to say that that is the general rule by which engineers go in estimating what strength they will use for a certain pressure?—Yes, most engineers give a greater allowance.

18,112. They give five-sixths of margin?—Yes, and some give much more than that.

13,113. And that, of course, assumes that the article as manufactured is without flaw?—No, that is to allow for flaws which could not have been prevented even with the greatest care.

13,114. Did you find the iron which was melted at Wornit, and used in the casting of these columns to be of good quality?—The tests which I made of it showed it to be of very good quality.

13,115. Did you notice, or were you informed by any of your assistants, that it had a very unusual quantity of scum?—No, I was not informed of that.

13,116. Did you know that fact?—I should like first to know what is the usual quantity.

13,117. (Mr. Trayner.) If the fact existed you did not know it?—Did you know that there was an unusual quantity of scum?—I cannot distinguish between an unusual quantity of scum and a usual quantity of scum.

13,118. Would it be correct to say that it had so much scum, that you could scum it almost entirely away without getting rid of the dross and scoria?—The scum is nothing in itself, I think.

13,119. Will you answer the question?—I do not know any iron that would, like the white of an egg, beat altogether into scum.

13,120. All iron in a fluid state throws off a certain amount of scum?—Yes.

13,121. And in iron of high quality is that scum less in quantity than in iron of inferior quality?—I think so. I am not a practical iron man.

13,122. As a civil engineer you must have seen a good deal of iron?—Yes.

13,123. Would the extent or quantity of scum indicate in any way the quality of the iron?—I dare say it might, but I am not prepared to say for certain.

13,124. The foreman you mean was Fergus Ferguson?—And Strachan. The only thing brought under my notice in connexion with the iron, as far as I can recollect, was that Mr. Beattie reported that the iron which we got from Middlesbrough was rather difficult in the lathe—it did not allow the work to proceed so well as he would like. I reported this to the firm, who immediately attended to it, and sent iron to soften the mixture.

13,125. (The Commissioner.) From Middlesbrough?—There was some Scotch iron too sent.

13,126. (Mr. Trayner.) You mean scrap?—No; this was independent of scrap.

13,127. Some Scotch pigs?—Yes.

13,128. Where were they sent from?—I do not recollect.

13,129. In what quantity were they sent?—A ship load.

13,130. Are you guessing, or do you recollect?—I recollect.

13,131. How many tons?—It would be perhaps 100 tons.

13,132. Do you know where they came from?—No.

13,133. Did not you know the makers?—I do not recollect the makers, and I do not know whether I ever knew the makers. I had implicit trust in the firm at Middlesbrough supplying such things without troubling myself about it. There was also some No. 1 Middlesbrough iron sent to them.

13,134. Did you see those 100 tons that came from the Scotch makers?—Very likely I saw it; but I did not look at it.

13,135. Are you aware, as a matter of fact, not from information given you, but from your own know-
lodges, that there were about 100 tons of Scotch pig sent in to the Worrall foundry:—The invoices would show that.

13,136. It is only from information that was given to you. Did you see the iron?—Certainly I must have seen it, but I did not look at it.

13,137. You mean you did not examine it?—I cannot say that, sir.

13,138. You saw about 100 tons, you say?—No, I did not see it. I never saw this iron.

13,139. That is what I want to get at. You were informed that it was sent, but you never saw it?—Of course.

13,140. You mentioned Scotch scrap; how much Scotch scrap was there all the time you were there?—There were a good many hundred tons, but I cannot say from memory how much there was. There was, however, an easy way to get at the reply to your question by referring to the valuation which took place at the transfer of the contract from Messrs. Brough and Company to Messrs. Hopkins, Gilks, and Company.

13,141. I will just show you that valuation, and you will kindly tell me how much scrap there was. This is the valuation (handing it to the witness). This is an abstract of the valuation?—I see scrap cast iron 213 tons 18 cwt.

13,142. Look at one of the preceding pages, you will find that that scrap was produced by cylinders and other things broken up?—Yes.

13,143. What iron was that, that Scotch scrap? That was Scotch scrap, it came from castings which had been made in the Falkirk Works.

13,144. Broken-up cylinders?—Yes.

13,145. Which had been cast at Falkirk?—Yes.

13,146. Apart from that 213 tons, was there, to your knowledge, any Scotch scrap at the Worrall foundry?—Yes.

13,147. How much, and where did it come from, and when?—It came from the same source, but at the time this contract was taken over it was not yet decided whether it should be broken up, and therefore it is not included in this cast iron produced from broken-up cylinders.

13,148. At the time that valuation was taken, was it still in the form of cylinders?—Yes.

13,149. But it was afterwards broken up you say?—Yes.

13,150. You know that?—Yes.

13,151. How much of it, in addition to the 213 tons, would there be of scrap after those additional cylinders were broken up?—I could not tell you from memory.

13,152. Would it be half as much again; would there be 50 tons?—Yes, decidedly. I see 88 cast-iron segments for conical rings, some of these were broken up.

13,153. You cannot put a figure upon the scrap iron beyond the 100 tons?—No; if I had known that I was to be called upon here, I might have brought notes with me which I have not in my possession now. I must draw largely on my memory.

13,154. Was the iron that was used for the castings at Worrall, so far as you know, sluggish?—No, not as far as I know.

13,155. Were you ever informed by either of your assistants, or by the foreman at the works, that it was so?—No. The only complaint I had about the iron was the one which I have stated.

13,156. Was it ever suggested to you that the iron which was being used for the castings should be of a different mixture to that which was being used?—Yes.

13,157. By whom?—By Mr. Beattie. That is the very thing which I have mentioned.

13,158. What was the purpose for which that mixture which he suggested was to be made?—To make it more fit to be turned and drilled.

13,159. To make it softer?—Yes.

13,160. Mr. Beattie was asked at question 9583, "But it was used as scrap for mixing with Cleveland " pigs?" and he says, "No, it was regarded as pure Cleveland iron." (Q.) And there was added to that one-third of scrap?—Afterwards one-third of the original scrap used in every column. (Q.) You would have preferred, you say, to have had one-third of Cleveland, and one-third of Scotch scrap, and one-third of Scotch scrap?—Yes. (Q.) Why?—Because I think they would form a better flux. Then he is asked, "To whom did you make the suggestion?"—To Mr. Grothe. Is that correct?—I do not recollect that.

13,161. He says he made a suggestion to you that the iron should be of a mixture of one-third Cleveland, one-third Scotch pigs, and one-third scrap, in order that there should be a better flux?—I do not recollect that.

13,162. You do not remember that?—No, certainly not.

13,163. Then I asked him this question: "Was there any reason assigned for your suggestion, which seems a reasonable one, not being followed?" He said, "Yes, I believe my opinion as to the mixture was not agreed with by the contractors." You have no recollection of receiving the suggestion, and, consequently, you have no recollection of having talked of it with the contractors?—He would have been sure of my approval, because I think he is a very clever practical man, and I would certainly have gone along with him, if he had made a complaint of that kind.

13,164. Your recollection of the matter differs from Mr. Beattie's—at least you do not recollect anything of that kind having taken place?—No; the only thing was the complaint about the metal, to which I have referred, and which was attended to immediately.

13,165. Did you know that the lugs on the columns for the high girders were being partially burnt on where they came out imperfect castings?—No.

13,166. Would you have approved of that?—No. (Mr. Bidder.) My learned friend hardly puts these questions quite fairly. He asks, "Were you aware that the lugs were being burnt on?" The question should be, "To your knowledge were the lugs burnt on?" He assumes the fact to be so.

13,167. (Mr. Webster.) And it assumes it upon my evidence given in Mr. Grothe's absence, and, of course, Mr. Grothe may or may not admit the fact. I would ask my learned friend, Mr. Trarner, not to put to Mr. Grothe as facts that which may after all not be in accordance with Mr. Grothe's recollection?

13,168. (Mr. Trarner.) I will do that. I was falling into error from having gone over this point before. (To the witness): Were you aware that any lugs were partially burnt on to any of the columns for the high girders?—No.

13,169. (The Commissioner.) Or to any of the columns at all?—Yes.

13,170. (Mr. Trarner.) In the first place I will keep to the high girders. You were not aware of any lugs being burnt on there?—No.

13,171. (Mr. Webster.) Will you ask him whether in fact they were burnt on.

13,170. (Mr. Trarner.) As an engineer, would you have approved of that proceeding if you had known it to be going on?—As an engineer, I would not have objected to the proceeding after I had seen the experiments performed which I saw performed.

13,171. What experiments did you perform or see performed?—I came upon the foreman doing something with a column which I, as a man who lacks practical foundry experience, to a very great extent, did not understand. I did not understand what he was doing. I inquired what he was doing, and he told me that he was burning on a broken lug. This column was a lifting column, which would not put in the work temporarily, though a great strain would come upon it during the time; and I said that I did not approve of a makeshift of any kind; but he was so strong on the point that a perfectly sound thing could be made of it, that I allowed him to go on, in order to benefit by the experience of learning something out of it. This was the burning on of the lug. I had
never seen one burn on, and at first sight, being opposed to making a fire, I said this would not do; but he tried to argue and said it could be done. I allowed him to do it, and I stood by and saw it, and certainly in the way in which he did it there was reasonable assumption to suppose that the new metal and the old united perfectly and became one whole. Then after the colowp was ready, I tried the strength of the burnt-on lug, and I convinced myself that as an engine, I could allow lugs to be burnt on; but as a contractor's agent I refused to give sanction to do it in any part of the permanent structure, not because I was afraid of the consequences, but because I wanted to impress once more strongly upon the foreman our wish to produce only first-class work, without the shadow of a doubt about it. I authorised him, however, to resort to this in the case of the lifting columns.

13,172. Did you forbid it to be done in the case of any columns other than lifting columns?—Yes I did, but I afterwards, for a special reason, did permit it to be done in the case of some 12-inch columns which formed part of the smaller piers.

13,173. And was it only with reference to these 12-inch columns that you authorised it to be done, with reference to the columns that were going into the permanent structure?—Yes.

13,174. As to the tie-bars, what were they made of?—Of malleable iron.

13,175. Were they ever tested by you?—No.

13,176. Did they come from Middlesbrough?—They came from Middlesbrough.

13,177. Made, and ready to go into the structure?—Yes.

13,178. Did you see any testing of these bars by Sir Thomas Bouch, or anyone representing the railway company?—No, I never saw any testing.

13,179. Personally, did you test any of the iron that was used in the structure?—No, it all came in such a form; that any testing upon any part would have been rather a serious matter: it came ready. It would have been a neglect of duty on my part if I had tested bars which had to form part of the permanent structure. I might, perhaps, have weakened them in the testing.

13,180. Am I right in saying that all the iron in the piers, except the columns, was malleable iron?—Yes.

13,181. Did you see the laying of the stone courses? Very frequently.

13,182. They were joined with cement?—Yes.

13,183. Did you notice whether any of the joinings were left too open, or whether they fitted exactly?—Do you mean whether there was a space between two adjacent stones?

13,184. A space between two adjacent stones in which there was an undue amount of cement?—No, all the spaces between the stones were filled with cement.

13,185. There was a layer of cement below the stones, and they were jointed also with cement?—Yes, the space between them was perfectly filled with cement.

13,186. Did you think the spaces between the stones, that is to say the joints or the spaces between the surfaces of the stones, which were filled with cement were of proper dimensions, or did you think they were unduly large?—They were not unduly large. I would rather in such a case have a wide joint than a narrow one, for the reason that in the wide one you can better make the liquid cement run. The cement was invasive cement. In the narrow joints there might be open spaces left here and there.

13,187. In your opinion, the joints were what they should be?—Yes.

13,188. Did you do anything to test whether the cement was fulfilling its purpose of holding the stones firmly together?—No.

13,189. Have you seen the bridge since it has come down?—Yes.

13,190. Some of the stone courses have been separated?—Yes.

13,191. Have you observed that in some places the stones have entirely separated from the cement?—Yes, I have. Whether it was taken off by hand or in the fall I cannot tell, but I saw in some places that the cement was away from the stones, evidently picked out.

13,192. Assuming that in the fall of the structure the upper course came away without any cement adhering to it, or carrying away the whole cake of cement without leaving any on the course below, how would you account for that?—I would account for it by the fact that the adhesion of the surface of the cement to the surface of the stones was not so great as the cohesion of the particles of cement among themselves.

13,193. Is that a matter of possibility upon which you had calculated; did you ever think that in using cement, that it was likely the stone courses, one or other of them, would separate from the cement between them?—I did not think any such thing likely to occur.

13,194. Is not the purpose of cement to keep the two surfaces of the stones together?—As an engineer I would not like to say it was a very good way of doing it especially with smooth stones such as these were.

13,195. (The Commissioner.) You object to the stones being smooth?—With the strong cement which we used (we used the cement exceedingly strong) I would rather have preferred small stones and many joints than large stones and few joints.

13,196. As you used them?—As we used them.

13,197. (Mr. Trayner.) How was the surface of the stone?—It was dressed.

13,198. Was it sawn or chisel-dressed?—Partly sawn and partly chisel-dressed.

13,199. Which preponderated?—The sawn.

13,200. That would not grip so well as a chisel-dressed surface?—No, it is smoother, not much though.

13,201. You prefer the chisel-dressed to the sawn?—I do not care which it is.

13,202. The one is as good as the other in your opinion?—Yes.

13,203. (The Commissioner.) I understood you to say that you did think, from what you have seen of the stones, that they were too smooth-faced?—Even if chisel-dressed I would have considered them too smooth-faced. I do not think there is much difference between chisel-dressed, if neatly done, and sawed; but the rougher they are the better. Rubble would be better in fact.

13,204. From Middlesbrough?—Yes.

13,205. Do you know who was the maker?—No.

13,206. Did you notice whether the holes in the lug and the plate, or the two holes in each side of the lug, corresponded in every case? The lug held the tie-bar; did not pass in between it?—Yes.

13,207. And a bolt went through the lug and through the plate?—Yes.

13,208. Did you notice whether the holes in the lug and the plate, or the two holes in each side of the lug, corresponded in every case?—Yes, as far as I have seen them, they did. The hole between the plate and the lug had to correspond, because it would give in the centre if it did not before the gib and the coppers were put in.

13,209. Are you aware of any hole in the lugs having been broken out larger than its original casing, to admit of the coincidence of the bolt passing through?—I am not aware of any.

13,210. Would you have approved of it if you had known of its being done?—No. You are speaking as I understand of the tie-bars.

13,211. Yes?—No. I am not aware of any.

13,212. Each column had a flange at each end?—Yes.
18,218. These flanges were dressed in the lathe?—
Yes.
(Mr. Webster.) Will you put to him again what you suggested about that hole, because it is an important matter?
(Mr. Bidder.) As I understand it, here is the bolt hole in the lug, and here are a couple of plates. If you are going to put a pin in, these three must correspond (holding up three pieces of paper with a hole in each).
(The Commissioner.) But one may be a little larger than the other. What Mr. Trayner is putting is this: suppose these holes were made and they did not come exactly opposite the other two; that is to say, supposing one was a little out of place, they would cut the other one so as to allow the bolt to pass through.
(Mr. Bidder.) I understood Mr. Trayner to suggest that the hole in the one did not exactly correspond with the hole in the other; then the answer of Mr. Grothe is this, that inasmuch as this is simply held by a pin through the other, when you tighten it up it tightens till it does correspond. When putting the bolt in you simply alter its position till it corresponds—it is no question of cutting.
18,219. (Mr. Bidder.) I will put the question in this way: supposing there are two holes that are to contain a bolt an inch and one-eighth on each side of the lug, and there is a plate to be slipped in between these two with an equal hole through which the bolt has to go, my question is, whether you know of any instances in which the holes in the lugs did not correspond with each other so as to admit of the bolt going straight through?—No, I do not know of any instance of that kind.
18,220. Where the one hole to some extent overlapped the other?—No, I do not know of a single instance.
18,221. If such a thing did occur, would you have approved of a chisel or other instrument being used to enlarge the hole, that was not coincident, beyond the original size?—I would not; but it would depend very much upon the size of the defect what remedy I would apply. If it were only a question of insignificant amount I should have no objection.
18,222. (The Commissioner.) It would depend upon the extent?—Yes, upon the circumstances.
18,223. The position in which it was?—Yes: if the column could be taken out and the defect remedied in any other way, I would prefer it, but if it were in a position where it could not be removed I might approve of a remedy of that kind, but I have never seen any.
18,224. (Mr. Trayner.) Were there also two holes in the channel iron at the end next the lug?—Yes.
18,225. What was placed between the channel iron?—A lug.
18,226. And were those all bolted together by one bolt?—By two bolts.
18,227. Were you aware of any case in which the holes in the channel iron and the lug did not correspond?—I was not aware of any such case till I visited the ruins of the bridge last week.
18,228. When you were at the ruins of the bridge did you see that such a thing existed?—I did.
18,229. In many cases, or in few?—I did not see many cases; I only saw a few cases.
18,230. (The Commissioner.) You did not know of any before?—I did not know of any before.
18,231. (Mr. Trayner.) Did you discover, on your inspection, whether any of the holes had been enlarged beyond their original size?—Yes, there were holes which had been enlarged from their original size.
18,232. Could you form an opinion, from the appearance of the work, how the holes had been enlarged?—The holes seemed to have been enlarged with a cold chisel.
18,233. Was that a thing which you would have approved of?—If I had known of it, I never would have approved of it.
18,234. (The Commissioner.) But you did not know of it?—No.
18,235. (Mr. Trayner.) Where were those defects?—Some were apparent in channel bars lying on the broken piers, and in some lying on shore in Worman Bay and at the former landing jetty.
18,236. They had been from the fallen part of the work?—Yes. I was very anxious to find whether in any case the corresponding holes in two channel bars attached to one lug were all four enlarged; but I never found a case where one set of channel bars had more than either one or, at the utmost, two holes out of the four enlarged. I was particular in looking at these holes, because there being two bolt holes and a double abut there, and in the tie-bar only one, I felt that as long as two holes out of the four were right, there could not be a weak point there more than in the construction of the bracing bar itself.
18,237. (Mr. Bayliss.) Did you consider that there were too many bolts used?—I think one would have been sufficient.
18,238. (Mr. Trayner.) Did the two bolts at the junction of each channel iron with the lug not tend to make the structure more rigid, and therefore stronger?—Not appreciably; the distance between the bolts is so short that I do not think that it would enter into calculation for stiffening at all.
18,239. What is your objection to the enlargement of the holes, then?—My objection is the same as I would have to any other work different from that which I was instructed to carry out.
18,240. Do you think that it was simply bad work; had it no effect whatsoever upon the stability of the bridge?—If the four holes had all corresponded, for instance, in the same bar, it would, no doubt, to some extent, have affected the stability of the bridge, but not to a great extent, because the two bolts, having the channel bars against the lugs tightly screwed up, would give a very great friction against the lug itself.
18,241. Should you regard these channel irons and tie-bars as essential to the strength and safety of the structure?—Yes.
18,242. Did not its safety and strength depend largely upon those?—Largely. I might say the safety and strength depended upon every part being in harmony.
18,243. But were not those very serious elements in the strength-affording part of the structure?—I have not made a calculation to convince myself what part they actively performed in the support of the structure.
18,244. Can you say whether they were essential to the safety and strength of the structure?—Decidedly.
18,245. Anything that tended to weaken them, or to shake them would therefore tend to weaken the structure?—It would.
18,246. Do you think that what you saw had any tendency to weaken the structure?—No, I do not.
18,247. If what you saw in a few instances had existed in many instances, would that have tended to weaken the structure?—In how many instances, would you say?
18,248. Twice as many as you saw?—I do not know exactly how many I saw.
18,249. Cannot you tell me how many you saw?—No.
18,250. Can you not tell me approximately?—I should think I saw five instances altogether; four or five.
18,251. (Mr. Bidder.) Do you know which pier they were from?—No.
18,252. (Mr. Trayner.) They were all from the fallen pier?—Yes; they were—either on the fallen pier, or on the parts recovered, those which I saw, and I looked for them.
18,253. In that model which is before you, you see certain cross-bars or girders; were those intended to be left in the bridge?—No.
18,254. They were used for the purpose of lifting the columns?—Yes, only for that purpose.
All those I suppose were removed?—Yes, they were all removed.

13,251. Were any of the columns that you call lifting columns, left permanently in any part of the bridge?—No, nor one, they extended to the top.

13,252. That way you went to try to lift the girders, and ultimately they were taken away?—Yes.

13,253. Whose business was it to have checked the enlargement of these holes, I mean at the time it was done?—At the time it was done the foreman of the gang in charge of the erection of the pier.

13,254. Which of your representatives should have been made aware of that?—Mr. Delpratt.

13,255. Where is he?—Mr. Delpratt is in Spain.

13,256. With the Tharsis Company?—Yes.

13,257. Under you?—Under me. There were instances brought under my notice by Mr. Delpratt in which these channel bars did not fit in exactly, on account of the men having made a mistake in not putting the right ones in the right places. These piers taper, and while the channel bars in this direction (pointing to the model) are all of the same length, they are not so in the other directions, and each taper differently, because the height is different; while the distance at the top and at the bottom of the structure is the same; therefore the taper varies, and so a slight mistake was easily possible. Whenever such a mistake was brought to my notice, and it was in several cases, I ordered the channel bar to be turned right about, and I ordered the two holes which were in the wrong place to be riveted, to be filled up, and make holes diagonal to the old ones bored, after having taken an accurate template between the distances, and those were the means that in all cases should have been employed, and which could have easily been employed. If the man had simply reported that such a hole did not fit, it would have been made right. It was difficult to see that the men used what was done for the purpose; I required constant attention to see that they did not put a bar in the wrong place, or drop one and take another that ought to have gone somewhere else. In a large work like this where there were 600 or 700 men employed, and with all the materials floating on barges, it was impossible to keep so strict an eye on everything personally as it would be in the same sort of work on the shore.

13,258. (Mr. Barton.) As to these horizontal girders, they were fixed temporarily to the column by means of a feather cast on the column?—Yes.

13,259. When you discontinued the use of those girders, what was done with the feather?—It was left on, not broken off. Our first plan was to cast that on a separate piece, and bolt it on to the column, but we found it so difficult to dispose of the bolts in a judicious manner that we gave up the idea, and we cast a heavy bracket on the column itself.

13,260. Which was left?—Yes.

13,261. (Mr. Trayer.) On some of the columns there was a spigot and faucet.—Yes.

13,262. For what purpose?—To give facility for correct erection.

13,263. So that the columns might be kept in a perpendicular position?—Yes.

13,264. (The Commissioner.) As a guide?—Yes.

13,265. (Mr. Trayer.) Was that adopted in all of them?—In all of them except those resting immediately upon the base-plates.

13,266. (The Commissioner.) Do you mean in the 16-inch columns and the 18-inch columns also?—Yes.

13,267. (Mr. Trayer.) The bottom column had not a faucet on it?—No, not the bottom column.

13,268. How was the second one?—That had a faucet on it.

13,269. (Mr. Webster.) The bottom column had no spigot on it, you mean?

13,270. Are you aware that some of the columns that fell and some of the columns that are standing, have not that spigot and faucet?—I can not aware of it.

13,271. If that is the fact, it is a distortion from what was intended?—Yes.

13,272. With regard to the flanges these two flanges were turned in a lathe, so as to have a perfect bearing?—Yes.

13,273. Throughout the whole surface of each flange upon each other?—No, not throughout the whole surface.

13,274. Throughout how much of it?—A recess was cast in the flange in the first place I should have to refer to the detailed drawings to explain it.

13,275. (Mr. Webster.) Sheet No. 32 is the nearest to what you want, I think?—Only this drawing does not show the annular recess. I see it sketched on here, though but with pencil.

13,276. (Mr. Trayer.) An annular recess in the way of the bolt hole?—Yes.

13,277. You see the drawing in the cover; it would be in the way of the bolt hole there?—Yes.

13,278. Where that line is?—That line would be the line of this similar recess.

13,279. (Col. Veitch.) Was that at the bottom of all the columns?—Yes.

13,280. Including those in the base plate?—Yes, including them.

13,281. (Mr. Trayer.) Can you tell me how far from the edge of the flange the recess commenced?—I believe it is an inch and a half. I would require to look at the drawings to tell you with perfect accuracy.

13,282. What was the breadth of the flange itself?—The breadth of the flange outside the column was 4 inches or 4½ inches.

13,283. I am taking it on the face of the flange?—It would be 5 inches from the inside; there was altogether 5 inches prepared there.

13,284. How much of that 5 inches was in recess?—I think 2 inches, or 2½ inches.

13,285. Leaving the margin on each side of it?—Yes.

13,286. What was the purpose of that recess?—The purpose was to make a better bearing surface.

13,287. Would not it have been better to have faced the whole surface equally so as to have brought the two flanges to bear upon each other throughout the whole extent of their respective surfaces?—I would not see any advantage in that.

13,288. Did the existence of that channel or recess render it all the more necessary that the columns should be directly perpendicular, the one above the other?—I do not see that it had any bearing whatever upon the structure.

13,289. It made no difference with regard to the column from what would have been the case if the recess had not been there?—From not a single point of view do I see that it makes any difference.

13,290. (Mr. Trayer.) Those are all the questions which occur to me to put to Mr. Gröthe.

(The Commissioner, to Mr. Webster.) Would you prefer that we should adjourn now for a little time, or would you like to examine Mr. Gröthe now?

(Mr. Webster.) I do not wish to put to Mr. Gröthe questions which, in the ordinary course, I should have put in cross-examination to Mr. Law. Perhaps you will allow me to call Mr. Gröthe afterwards with reference to any questions that may arise.

(The Commissioner.) Certainly.

(Mr. Webster.) When evidence is being given in chief, and we have our view with regard to certain matters, it would not be right to unfold that view in putting questions to Mr. Gröthe.

(Mr. Bidder.) The same thing has been passing through my mind, and I would suggest—that if on the Court re-assembling, Mr. Law happened to be ready, we should proceed with his examination.

(Mr. Webster.) If not, probably we might ask some
general questions of Mr. Gröthe, and then reserve the other points.

The Court adjourned for the usual period.

After a short adjournment, Mr. Trayner stated that he had one or two more questions to put to the witness.

13,290. (Mr. Trayner.) You explained that the foundation was altered from its original design, and that consequently upon that the spans were increased; why did the alteration in the design of the foundation lead to an extension of the span?—Because there must be a certain proportion between the money spent on the superstructure and the money spent on piers to produce the cheapest bridge; and it was found that by making the spans as they actually have been made, a cheaper bridge could be produced (without of course sacrificing anything) than if the spans had remained as they were before. A more costly pier was substituted for one which was cheaper before, and therefore making fewer piers and lengthening the spans would re-establish that proportion in which the cost is a minimum.

13,291. The new foundation that was substituted was larger and more costly than the preceding one?—Yes.

13,292. And the spans, I suppose, were lengthened in order to reduce the number of more costly foundations?—Yes, without sacrificing anything.

13,293. Were you there when the bridge was finished?—Until the bridge was finished practically, I was there till the end of November 1877; I was there, in fact, until the trains had been running over it for two months.

13,294. The trains that had run across it were ballast trains?—Yes.

13,295. No passenger trains had run across it when you left?—No passenger trains.

13,296. You saw the bridge, and you were thoroughly acquainted with all its parts at the time you left?—Yes.

13,297. And you have since seen what remains of the bridge since its fall?—Yes.

13,298. Kindly give me your view as to what occasioned the catastrophe?—A strong wind on the evening when the accident happened.

13,299. Was that the sole cause?—That alone.

13,300. Is that your opinion now?—Yes.

13,301. Has that always been your opinion?—It has always been my opinion. I do not see how it could be otherwise; it is very simple.

13,302. Have you ever entertained a different opinion upon that?—No.

13,303. Nor expressed a different opinion?—No.

13,304. What wind-pressure was the bridge calculated to resist?—I have that only from hearsay.

13,305. But from whom?—I have heard several people talk about it.

13,306. Have you heard it from Sir Thomas?—No, I have not.

13,307. Did you not hear from Sir Thomas and others what the wind-pressure was to be?—No.

13,308. Or, what the calculations were upon which the bridge was erected?—There may have been a talk about that, but I have never had intimation which was given to any person that the bridge was calculated to stand such a wind-pressure.

13,309. Did Sir Thomas Bouch ever say anything to you either about his calculations or the result of his calculations as to the wind-pressure which his bridge was to stand?—Sir Thomas never did.

13,310. Have you an opinion as to what pressure the bridge was calculated to resist?—Was calculated to resist, or could resist?

13,311. Could resist?

13,312. (Mr. Bidder.) Have you worked it out?—No, I have not worked it out in detail.

13,313. (Mr. Trayner.) Have you any opinion upon that subject?—(Mr. Bidder.) If he has not worked it out, it is hardly fair to ask the question.

(The Commissioner.) Mr. Bidder does not want to have a loose opinion, I understand; and the opinion of Mr. Gröthe (who is a gentleman of very large experience, and who is evidently, from the way in which he has given his evidence, a man of very great ability) will only be valuable so far as he has directed his mind to the subject.

(Mr. Bidder.) As I understand, he says that he has not made calculations to ascertain what the bridge would stand. I take it that no engineer would pretend to be able, without making the necessary calculations, to pledge himself to one figure or another. If he had made any calculation, I should agree at once that it would be very improper to hear his opinion. But if the question is a question, perhaps, to ask Mr. Gröthe himself whether he thinks he is in a position to form an accurate judgment as to what the bridge would have stood in the way of wind-pressure.

(The Commissioner.) I understand the question to be whether Mr. Gröthe considers that he is in a position as a civil engineer, and having been instrumental in raising this structure, whether he is in a position to give us any opinion as to what amount of wind-pressure this bridge would bear, you being a civil engineer, and having been instrumental in raising this structure?—I do not know whether I am right in giving the reply as I do now. I have not made the calculations, because I have not had time since my coming to this country; I have been too busily engaged in making observations of the bridge itself, to make actual calculations, but I have come to a very distinct opinion upon the basis on which that calculation should be made from actual observation of the piers, as I saw them at Dundee, and from a consideration of the structure as I know it.

(Mr. Trayner.) The opinion formed upon that basis is what?

(Mr. Bidder.) I beg your pardon, he has not come to an opinion as to the result, but as to the basis upon which the calculation should be made.

13,314. (Mr. Trayner, to the witness.) Applying your basis, just build up the superstructure and tell us what your opinion is?—I have not the superstructure, and I do not hold it as a result, but, as I said, the superstructure consists of sets of continuous girders. There was great attention paid to making the continuity of those girders perfect for that purpose, whenever two girders had both arrived at the top, the end of one of them was lifted up and the top boom was brought near to the top boom of the other. The extent to which that end was lifted was from five to six inches according to the position of the span in the set, and the actual figure was obtained from Sir Thomas Bouch fixing the amount to which these had to be lifted. Cover plates were then fitted on to the two structures, as yet separate, and accurately marked where both came into these plates. They were then taken on shore, and the holes were drilled in, and then they were flosted out again and fixed on the ends of the two separate girders with service bolts here and there, just to hold them in their position, and then they were rivetted up, the service bolts being finally taken out and replaced by other bolts, and it was not till this had been performed that the girder was to be considered. It was then taken in a horizontal way, being a civil engineer, and having been principally instrumental in raising this structure, whether he is in a position to give us any opinion as to what amount of wind-pressure this bridge would bear, you being a civil engineer, and having been instrumental in raising this structure?—I do not know whether I am right in giving the reply as I do now. I have not made the calculations, because I have not had time since my coming to this country; I have been too busily engaged in making observations of the bridge itself, to make actual calculations, but I have come to a very distinct opinion upon the basis on which that calculation should be made from actual observation of the piers, as I saw them at Dundee, and from a consideration of the structure as I know it.

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(Mr. Trayner.) The opinion formed upon that basis is what?

(Mr. Bidder.) I beg your pardon, he has not come to an opinion as to the result, but as to the basis upon which the calculation should be made.
13,315. (Mr. Barlow.) That is at the expansion joints?—At the expansion joints. The pressure on the end of the expansion joints, which is already very much less, in consequence of this initial strain trying to pull out the end of that girder out, though it may not quite succeed in doing so, is increased by great pressure between the span and the end of the other one. That would still further reduce the pressure upon the pier which carries the expansion bearing; so that in considering the holding down weight of any pier, which forms a resistance against the upsetting force of the wind. To find the most unfavourable case it would now be my opinion to take the average weight taken by each pier without the same time, considering the question of continuity. But it is necessary to establish a difference in the holding down pressure upon the piers which are at an expansion bearing and those which are intermediate; the pressure being very much less at the expansion bearing and greater at others; otherwise there is less resistance against that overturning force of the wind.

Now the position of the train, as I saw it on the drawing, and as I saw it in the structure which they brought to shore in Dundee, indicates that when the accident happened the train must have been upon the span almost off the beam, but still on the span yet, before the end span. And, therefore (because it could not be exactly in the position in which it is found now or else, the whole of the carriages would have been telescoped, which is not the case), the train came only gradually to a standstill as it fell down. Therefore there was no little pressure upon pier No. 33, while there was no great pressure upon pier No. 32.

13,316. (The Commissioner.) No. 33 being the expansion joint?—Yes. In calculating therefore the resistance of any pier against an overturning on its base, it will: hardly do to take the average weight derived from dividing the whole weight through the number of spans and adding the number of passengers, and everything: but the case must be considered separately for the two piers; and especially I think that if that calculation is carried out (I cannot give the figures just now, and merely suggest it as a thing of interest, because I understand that any information will be accepted that I am able to give), it will be necessary to see what actual holding-down weight there was against an overturning on the base in pier No. 33. Pier No. 32 was in a favourable condition; because, although it had the train on it and it had to stand the blow of the wind against the train, it had so much more weight, that I believe (though I am not certain) that that pier was in a most favourable position, notwithstanding having the train on part of it, than the next one which had not the train but had only the free end of the girder, but which girder was not exerting a sufficient downward pressure to resist the blowing over. The observation which greatly confirms me in the opinion that the calculation will turn out in the direction which I believe is the positions of the base plates, stones, and columns on pier Nos. 32 and 37. On all the piers that I have seen, with the exception of I think 39, the evidence of the base-stands yet is very slight, and I should say that everything points to what I have been called a simple mending, something falling from the top and in its fall crushing everything below it, without accepting for all the piers a turning over, as I have heard it described, upon the base or upon a point higher up, wherever it may be. The whole thing seems to have been a smash, with the exception of those pier 33 and 37 and to some extent in 39, which I can account for; but which also can go together for the smash. But in pier 33 there is decided evidence that the bedstones on which the base-plates were fixed have been withdrawn from their position, and that they have been turned over on the side of the stones towards the east. So that this being the most dangerous pier at the time, having the least weight upon it, undoubtly I expect there to be turned over as a solid structure upon its stones and no matter what that pier had been made of, if it had been made of stone from top to bottom it would just as well have turned over on the stones, lifted the stones over and fallen into the water, and as this end of the girder fell it would have smashed the next pier. I must say that I never had any doubt in my mind, while building the bridge, that if one of these spans came down those would come down. The only remarkable thing is that this fall has not occasioned the coming down of the parts north and south of it, and I can only attribute it to the fact that there was a weak point there in the girder. The weight of this end-span upon the small span adjoining it being but small, it was only enough to turn and damaging the base plate (as we saw from the drawings by Mr. Luce yesterday) and falling outside. While it did so it wrecked parts off the connections between the two girders, which fell down upon the channel bars and bracings, and, acquiring velocity, every time, knocked greater at the bearing, I have not seen a single bar broke off there, but all the lugs are broken off evidently by the weight falling upon the bars which held them, and tearing off the brace.

13,317. (Mr. Trayner.) Would you tell me now what in your opinion was the pressure of wind which that bridge could have been upon?—I cannot say.

13,318. As an engineer, the resident engineer in building the bridge, and an engineer who has examined the remains of the bridge, have you no opinion as to what pressure of wind the bridge would yield to? and what wind-pressure that bridge, as constructed by you, would have resisted?—I could only give a positive answer after making a careful calculation, which I have not done.

13,319. You decline to offer any opinion just now?—I cannot honestly give any opinion just now.

13,320. And therefore, until you make the calculations, you decline to express an opinion?—Yes.

13,321. In your opinion, at what point did the bridge give way?—In my opinion, the pier.

13,322. That is the fifth of the fallen piers?—Yes.

13,323. Has the whole of the superstructure fallen over to the east?—Yes, the whole of it.

13,324. There are still some columns lying upon the stone-work of that pier?—Yes.

13,325. How have they fallen, eastward or westward?—They have all fallen eastward as far as I know. Perhaps I may be allowed to make one more observation with regard to this. I should imagine that the overturning on any particular point of the base would be a thing of very short duration, that the moment the pier actually came to any extent out of the perpendicular line and the columns were inclined, the whole thing would become supported by the weight that there would be a downfall. It would not at all follow, far from it would follow, that the pier was not overturned when the end of the span was found quite near it. It cannot turn over like a pin and deposit it there, it must crush during the fall; and, in fact, the place at which it is found would give you an idea to calculate upon what point of the fall the actual collapse took place, I believe in that way that most of the columns would fall east. That would not in the least exclude there being a double up, and an occasional one being turned over in the smash to the other side? On the contrary, I have found it exceedingly difficult to distinguish between the causes and the effects of the accident.

13,326. No. 52 pier, if I recollect aright, is overthrown to the bottom?—It is broken off to the bottom.

13,327. And you think that is the point at which the bridge gave?—No. No. 32.

13,328. Do you know, in fact, at what distance from the line of the bridge the girder was found?—I have seen this lithograph.

13,329. The girder is nearer the line of the bridge?—At 33 than it is at 32?—Yes.

13,330. If the point of turning over was at 33, would you not have expected the girder to have fallen further out at that point rather than at the point 32, where it was more of a crush?—No, I would not.
Mr. Webster. He said the point of giving way, but not the point of turning over.
Mr. Trimmer. You think it was pier 53 at which the bridge first gave?—Yes.
13,382. And you are of opinion that the wind blew it over?—Yes.
13,383. The whole of the pier fell, we see, down to its base?—Yes.
13,384. Have you any opinion as to how it went over, whether on the base, or whether it was the pressure upon the girders at the top of it that carried it over?—No, I think the foundation-stones gave; I mean the stones under the bed-plates. They lifted.
13,385. Those courses of masonry above the brickwork?—Yes.
13,386. So that in your opinion the whole column went over from its base?—Yes.
13,387. If it fell over in that way from the base of the column, would not that have a tendency to throw the top of the girder further out from the line of the bridge than the next pier, which was not thrown over, but crushed?—No, it would not not. In questions of this kind the things are so rapid that it requires a stretch of imagination to put the events as they happened sufficiently far distant to realise it; but still there is an interval of time between every operation that takes place, so that the first thing would be the movement of that end of the girder (pointing to the model). When this girder you can twirl, the girder is not made so rigid if you held it on this end, and held it on that end, and wrung it, you could not give it a motion; so that the going off on that end will at first produce wrenching of the girders. It is a small interval of time before it is broken, but still it is an interval. That thing falls, the pier is taken away from underneath it. What happens? The girder again, I am representing now what happened during the fall.
13,388. This pier according to theory gave way at the base; in that case the whole structure at this pier would topple over?—Yes.
13,389. Within a short, but still an appreciable distance of time before the other one was effects?—Yes.
13,390. Would not the falling from its base have the effect of throwing out that point of the girder further from the line of the bridge than that point of the girder which was more a crush than a blow?—I say it is because I have not done yet. That pier gave over, and before it is very far over it breaks the column underneath it, and falls poniopulcianly down. I said that one might out of this place construe to some extent how far the thing went over before it actually broke. But this is not actually broken yet. If that end of the girder is deprived of its support it will sag, and immediately the end will go down and will strain the top plate; that strains the connection with the next girder permanently, and will even exert its influence upon this one (pointing to the model), straining both these permanently, and instead of having one level set of four or five girders, you will then have a set of girders almost parabolical in shape, and if that strain in the bottom of the river, it must (pointing to the model) be nearer there than to the intermediate pier, and in every instance you will find that at the expansion bearings, the girder lies nearer to the pier than in the case of the others.
13,391. Do you think these bases were sufficiently broad for the columns above it?—The facts are there to prove that they were not large enough, otherwise it would not have been blown over. Either the wind had to be less or the base larger. Of course that is my version of it.
13,392. (The Commissioner.) You say that the fact that the bridge has gone over shows that the base was not large enough?—To resist that power of the wind.
13,393. (Mr. Trimmer.) I suppose you are not in a position to say yet, what power or pressure of wind these bases were large enough to resist?—No, I am not.
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Mr. A. Ordeek. Would you make the calculations and let us have your opinion upon this question?—I am afraid I shall have to send them from Spain in that case, but anybody can make them.
13,394. We would rather see you after they are in our hands?—Any engineer can make these calculations, if you will get your engineer, Mr. Law, to let him recite his calculation upon this subject.
13,395. (Mr. Balfour.) How long would they take to make?—I am slow at these things. I should take a long time about them.
Examined by Mr. Biddulph. 13,396. I understand that you, having seen the ruins of the bridge, and having heard what happened, your opinion tends to the belief that the bridge was blown over by the force of the wind?—Yes.
13,397. Because, as I understood you also to say, you could, in fact, see no other cause to which to attribute what happened?—No.
13,398. And you are driven to that conclusion for want of any other?—Yes.
13,399. I also, if I rightly follow you, understand, that in your opinion, the first pier to give way was No. 53?—Yes.
13,400. That being the pier supporting the last member of one group of continuous girders?—Yes.
13,401. Those girders, you stated in your examination—in-chief just now, were very carefully formed into one continuous girder?—Yes.
13,402. To make it quite clear, is there the slightest ground for suggesting that that was done in a way that prevented their having any stability or continuity, namely by putting in service bolts, until after you had lowered the girder, and then riveting it afterwards?—Nothing of the kind—it was most carefully done.
13,403. There is no ground whatever for any suggestion that the connecting plate.
(The Commissioner.) He has himself said that there were service bolts put in first, which were withdrawn. (Mr. Biddulph.) But the suggestion is that the service bolts were put in whilst the girder was above its proper position, and that the girder was then allowed to drop into its proper position, and that after that the service bolts were taken out and others substituted?—I have seen Mr. Law’s report, and I have heard him make the statement here, and I have seen that he refers to some evidence given by a man named Oram, or some-thing like that. That evidence I have read, and it does not refer in the least to the present case. Oram was never employed on this part of the bridge—he was employed on the part more to the south side.
13,404. But what I am most concerned to get perfectly clear is the fact that nothing of that kind happened in the case of any of these high girders?—That is so.
13,405. The last member of each group of girders so connected together as to form a continuous girder would be what you call a cantilever, I think?—Yes, it would be a cantilever in theory, though in practice supported at the other end.
13,406. It would be a cantilever, both horizontally and vertically?—It would.
13,407. Therefore would not the last member of the group have the assistance of the rest of the group, and of the piers supporting the rest of the group in resisting any lateral pressure?—The answer is, they had enough to do for themselves. This pier had the train on it and it could not assist the others to any appreciable extent, because it had a great strain upon it, though it may not have been quite so much as upon the others; and these girders, though they are made continuous in that direction, are less of a girder in this direction (pointing to the model). They have, for instance, not the same distribution. You see that all the bracing bars in the top are the same, while the lattice bars here (pointing to the model), which keep the two members apart, are of different dimensions.
13,360. You explained to us, I think, how the pressure in the pier would be unequal, the centre pier having, I think you said, greater pressure upon them, and the terminal piers bearing less. — Yes.

13,361. That is owing to the continuity of the girders? — Yes.

13,362. Would not that also, to a certain extent, be true with regard to the lateral pressure upon the whole of the group of girders? — If you have put in the initial pressure before you put them together, but after that, not. These girders have their initial strain put in, but in your case you would have omitted to make the junctions properly. —

13,363. You said, in answer to a question a short time ago, that the spans were altered in their length in order to preserve a certain economical proportion between the piers and the cost of the girders. You do not mean by that that they are altered in any way that impairs the efficiency of the bridge? — Not in the least, but in a proper economy.

13,364. As I understand, what you mean is this: given a certain length to be covered by a bridge, you would put a greater number of piers with very short spans, in which case you might have a very cheap girder indeed, or you might have a very small number of piers with very long and very expensive girders? — Yes, when the superstructure costs as much as the pier, that is the cheapest.

13,365. You did not mean to suggest that it was ever intended by you to alter the efficiency of the bridge to cost? — No.

13,366. With regard to the alteration to six columns, you said that you are not aware of what the reasons were which induced Sir Thomas Booth to adopt that alteration; but as a matter of fact a wider base was secured thereby, was it not, that would have been otherwise secured? — It is a fact that for the same weight of pier the best shape is this hexagonal one. With the same weight of pier you secure most advantages by adopting this shape.

13,367. And given that the weight of pier is limited in consequence of a consideration of the foundations, the form adopted is that which gives you the best and greatest advantage? — That form, given that the foundations must be lightened as much as possible, is the most advantageous.

13,368. And, as I think I understood you to say, it gave a width of base which, in your judgment as an engineer, before the accident happened, was sufficient? — If it did certainly.

13,369. Perfectly sufficient, having regard to the height and position of the bridge? — Yes.

13,370. That was your own independent judgment? — Yes, or I would never have undertaken the supervision of the work.

13,371. And that judgment, as I understand, is only altered now because owing to what has happened, you feel driven to the conclusion that the base was not sufficient to enable the bridge to resist the wind that occurred on that occasion? — That the wind was too strong for the base.

13,372. Then is the only reason why your judgment has been altered with respect to the sufficiency of that base? — That is the only reason.

13,373. I want to have that clearly upon the noses. Your own independent judgment, as an engineer, up to the time of the disaster, and at the time of construction, was that the width of the base was perfectly sufficient? — Perfectly.

13,374. The bridge has come down under the circumstances we know of; but you can see no other cause to which to attribute the accident but the wind; you, therefore, feel driven to the conclusion that it was the pressure of the wind that did it, and therefore you are driven to the inference that the base which you believed sufficient was not sufficient. That is the chain of reasoning which has passed through your mind? — Yes, perfectly.

13,375. You were asked a good many questions with reference to the foundation not turning out rock; they were shown in rock upon the plans, as you know? — Yes.

13,376. You are aware that those plans embodied a report made by professional borers who had been engaged to bore right across the site of the bridge? — Yes.

13,377. Subsequently when you proceeded with the construction of the bridge, it was found that those reports of the borers were erroneous as you approached the centre of the river? — Yes.

13,378. And that where they had represented rock it turned out that there was nothing but hard gravel and silt below? — Yes, perhaps, boulders and clay, and gravel and sand.

13,379. I suppose then you discovered it was, essentially for Sir Thomas Booth to alter his plans, having regard to the altered circumstances? — Absolutely necessary.

13,380. And in your judgment was the alteration that was carried out as regards the foundation, one that commenced itself to your mind? — A very judicious alteration.

13,381. And I believe, as the result has shown, it is one that has given a perfectly sufficient foundation? — Yes.

13,382. With regard to the ironwork generally, I do not want to trench on the case of my learned friend, Mr. Webster, but I will ask you this: To the best of your knowledge and belief, is there any ground whatever for suggesting that this bridge was constructed with inferior materials and of inferior workmanship? — No, not at all. The reverse.

13,383. Do you think it would be possible, in any work of the magnitude of this bridge, that it should be carried out from first to last without a single imperfect piece of work creeping into it? — Certainly not; those who would say so would find it difficult on trying to do it.

13,384. Were all precautions taken that could be taken; in your judgment, to protect you against the introduction of inferior work? — All reasonable precautions were taken.

13,385. And, as I understand, wherever faulty work (whether it be faulty cylinder or faulty work of any kind) was detected, it was uniformly rejected by you? — Immediately; I never allowed one single piece to go in that bridge as to which I did not feel perfectly sure that it was good and right. That refers not only to materials which I had occasion from time to time to purchase myself, but it also refers to anything which was sent by others.

13,386. Did you and your assistants depend for that purpose simply upon the reports of those under you, or did you keep watch yourselves to detect defects? — We watched ourselves.

13,387. You were asked one question by my learned friend, Mr. Travers, as to whether you ever ascertained and tested the strength of the columns, and you said you never did. Would it have been possible for you to have tested the strength of the columns? — I do not know exactly what test they could have been subjected to that would have found its counterpart in the actual conditions under which they were to be used. It was not pressure that would have done them any good. In fact I have never seen a single defect in any column, which would have been detected by pressure. I do not see what test or combination of tests I could have imposed upon any of the columns (supposing that it had been my duty to see that) to ascertain whether they were fit to form part of the structure; but I am too uncertain about the part which they really had to fail.

13,388. You told us that you had visited the site of the bridge since the accident and you have seen the broken fragments upon the pier, and also the broken portions which have been landed at Wormit, and, as I understand, you have had pointed out to you and you have searched out and found for yourself, certain in-
MINUTES OF EVIDENCE.

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Mr. A. Groche.

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13.336. Having seen, and carefully examined the ruins of the bridge, have you seen any defective workmanship which, in your judgment, would tend to any approach of the bridge to the sunken state, the accident that has occurred?—No, not at all.

13.330. With reference to the question of burnt-on lugs, I have only one question to ask you, because I should like to get it clear. As a matter of fact, were any of these burnt-on lugs in the pier which supported the bridge?—Yes.

13.334. There is another matter put to you which I should like to clear up. My learned friend, Mr. Taymou, asked you whether you had seen the instances where the masonry had lifted, and where the cement had parted and come away with one stone and left the others, does that indicate in any sense to your mind itself what the fault was?—I don’t know; I am not familiar with it.

13.332. In fact there must have been a weakest place in the structure of the masonry somewhere, if I suppose?—I dare say there is everywhere.

13.338. And there is no doubt that that was the weakest point in the line of that structure?—Yes; I have heard evidence that stones split up on account of the holding-down bolt having been screwed up, always yielding until at last it came to a point where it held and exerted such a pressure on the sides of the stone until it burst. That is a mere assumption, because this particular bolt with six washers on it was not screwed up, and yielded while it was in the cement great which held it in the hole. But the way in which those bolts were placed was such that it could easily happen, and in, points of fact did happen, that the bolt was too high, sticking up higher than others, and some were lower than others. The course was thus: the stones were first baded and fixed, then the bolts were placed in them which had been left in the template being used to secure their proper position relatively to each other. While one man held this bolt, and was supposed to hold it on the bottom of the hole, the other man poured in the cement grout which was to unite it to the stone itself until it was full; and then they would leave it, and perhaps that pier would not be touched for three or for weeks. Then, when the next operation began, everything being done in turn and according to a regular programme made two years before the completion of the bridge, when the time came for the base-plates to be put on they would be slipped over those bolts and then the nut put on. Now, this man would take his bolt a little, and shift it, while the second man was pouring in the grout, of course that would project slightly, and the rational and proper remedy would be to insert packing pieces, because it was not possible to make the screw go further down there, and then he could not have got the tools to turn for that (pointing to the model), so that the proper remedy, which could in no wise injure the stability of the structure, was to put those packing pieces or washers on, and finally the nut on the top. That is the real history of this bolt, and not that it has been pulled up in the screwing. As to the splitting of the stone, I have seen, during my inspection, many split stones, and I have accounted for by some of the debris falling upon it, of course some come from a considerable height, and breaking it, but I have seen the point disturbed in nearly every instance more or less. That may be due partly to the wrenching action and partly to the overturning, as on pier 33, but, at any rate, I think that this whole series of courses are nearly all more or less disturbed, these points being the points of adhesion between the cement and the stone, on account of the stone being really too smooth. All these stones were properly wedged, and sometimes we were saved the trouble of wedging them by the sea washing over them, but there was no imperfect washer; the man had only to purse bracket over the side of the pier and wash them over, and therefore there was no indiscernible whatever to make bad work, but justice was done to it under particular supervision. Yet it did not adhere, because it has given way, and I want to connect this with the so-called splitting of the stones. The splitting of the stones could only have taken place through a wrench, action from this conical bolt, which had, its width, past below, the narrow part standing up, the lower part being surrounded by pure cement, and the uneven edge of the stone forming a thorough connection. If that were pulled there would be a wrench action, and if that were sufficient the stone would split. This bolt; was balled in order to take a better hold; it was not a usual wrench bolt. The internal edge of the bolts was something formidable, and it was wedged besides; and I am sure that to move that bolt there would be as much force required as to break it, and that in such as the connection between the stone itself and the stone below was not so strong as it had been brickwork, for instance, the stone would lift ten times. In the first place, the bolt was not up; and not that there was a proper action relatively to the bolt, because it was in a stone that could possibly have been split by the action of the holding-down bolts.

13.339. In point of fact, the washers that you found in the case of some of those holding-down bolts were rather no indiscernible of the bolts having come off. Not in the least; in fact, this is the real explanation of it.

13.335. And you know that as a matter of fact, from your knowledge; it is not mere theory?—I know it as a matter of fact.

13.336. I understand that you speak from your own memory and knowledge; that as it was, that they were put in and left to harden for two weeks, and that when they came to screw them down it was found that they had been put in too high up, or something of that kind?—Yes; and some of them, on the other hand, were put rather low down, and no washer could be got in there.

13.337. Mr. Beattie gave some evidence on a matter which I think has been referred to by Mr. Law. It is at page 232 of the printed evidence, Question 9554.

"Were the holes in the flanges of all the columns of different sizes bored, or were any cast in your time?—I believe there were about a sufficient number of 18-inch columns for about four or five of the large piers during my time. Q. They had the holes cast?—Yes. Q. And not bored?—No. Q. Why were the holes of the 18-inch columns not bored like the holes of the other columns?—In the first place we had no convenience to do it—no machine. Q. Could you not have made them bored?—I don’t think so, because there had been a contractor I could have done so. Q. Was it not thought material?—No, it was not thought material. I may say that I had a discussion, or rather a conversation, with my immediate chief upon the subject. Q. What was his name?—Mr. Groche; and I believe he had a consultation with the engineer of the bridge, but I will not be sure about it. Q. The matter, however, was considered?—Yes, it was in some way or other, and I was authorised to go on casting the piers. Q. In your judgment were the holes that were so cast sufficient for the purpose for which they were intended?—If they were made true, Q. Were such as were made under your supervision made true?—I don’t think so, and I have seen any untrue. Q. Whom did you mean by the engineer of the bridge. I understood it was Sir Thomas Bouch." I want you to tell us what your recollection and knowledge are with reference to that matter?—The question might perhaps have been instead of "Were the holes of the 18-inch columns not bored?" "Why were those in the 18-inch columns bored?" The holes when made true would be as good cast as bored; and the simple fact that there was a machine handy to bore those in the 18-inch columns led us, or led rather the Middlebrough firm, to send this machine over and utilise it; not because the work in the other cases would not have been good and reliable, but because it led to a saving.

13.338. In point of fact, were the holes of the 18-inch columns made as good a job as those of the
15-inch columns?—Yes, there was a play in each of them.

13,399. Was there any inferiority in your judgment for practical purposes in the holes of the 15-inch columns?—No; there was not.

13,400. (The Commissioner.) I understand you to say that the cast holes would be as good as the bored holes?—Yes, if properly made.

13,401. (Mr. Bidder.) Were they properly finished in the case of the 15-inch columns on the Tay Bridge?

13,402. (Mr. Trayner.) Are you speaking from your own knowledge and recollection in that matter?

—Yes, entirely.

13,403. From personal examination of the columns?

—From personal examination. I do not set of course recollect having seen every hole.

13,404. (Mr. Bidder.) I ask you whether your recollection enables you to say whether that was a special order of Sir Thomas Bouch's or not?—Not at all. I never asked Sir Thomas Bouch for an order on the subject.

13,405. (Mr. Webster.) I may say, sir, that I do not propose to examine Mr. Gröbe at present upon matters which I may have to put to Mr. Law. I am not going over the ground which Mr. Bidder has gone over.

Examined by Mr. Webster.

13,406. You have been asked some questions about the castings and the iron, as I understand for a considerable time you used to see the foundry constantly?

—Yes.

13,407. And afterwards, as you told Mr. Trayner, less frequently?—Yes.

13,408. You have already said that anything like a defective iron, such as has been produced to-day, being passed, never came under your notice?—No.

13,409. Did you ever, during the whole time of your being there, hear any suggestion made by any of the moulders or people in the work that the iron was not proper or would not work properly?—No. I did not, except the case which I mentioned of my attention being drawn to certain planing, but none other.

13,410. Was it ever hinted to you, directly or indirectly, that improper iron was being used?—Never.

13,411. Or that it would not flux properly or anything of that kind?—Never.

13,412. Do you believe, in fact, that such was the condition of the iron which was being used?—As I said, never came under your notice.

13,413. Is it not possible to have a split those stones by (pointing to the photograph).—Yes.

13,414. (Mr. Trayner.) Very fairly suggested to you to-day, about the nuts?—Not even the putting on of the nuts.

13,415. Of that kind?—Never.

13,416. Until you came to this one which is No. 9?

—Yes, that is 97.

13,417. The next point which has been referred to, in the suggestion of the splitting of these stones. You have told Mr. Bidder already that you have seen the stones that are split?—Yes.

13,418. Did anything happen during the construction of the bridge which could have split the stones in the way suggested, except the putting on of the nuts?—Not even the putting on of the nuts.

13,419. Did anything happen which could have split the stones in the way suggested, except the putting on of the nuts?—No.

13,420. (Mr. Webster.) You remember a particular bolt being referred to with, I think, five or six washers?—Yes.

13,421. Have you, or have you not, any recollection of that bolt standing up when it was originally fixed?—Yes, I have always known that bolt since it was in its place.

13,422. And it is a matter that you have a distinct recollection of from the time the bridge was constructed?

—Yes.

13,423. Now about spigots and facets; you have told Mr. Trayner that, to the best of your belief, except at the bottom of the bottom column, there were spigots and facets in every single joint?—Yes.
13,438. Do you attach any serious importance to the existence of these spigots and faucets with regard to the holding stability of the bridge?—I do not.
13,439. The only stability which they would give would be against a side blow, a direct horizontal blow; but not for any other thing. In fact, they are merely convenient to assist in one column being put right upon the other. If the column joint was put upon each other without any bolts, and simply with spigots, you may judge for yourself how much you would trust to that column.
13,440. But as regards stability in connexion with the superstructure would you rely at all upon the spigot?—Not the least.
13,441. You have seen the bridge since it has fallen?
13,442. Do you find in any single case any indication of a breach or of a defect in consequence of the want of a spigot in any of the upper parts?—No.
13,443. We know that the bottom joint, that is to say the bottom of the bottom column, there was no spigot and faucet?—No.
13,444. Did you observe carefully the condition of the bottoms of many of the bottom columns and the base-plates after they had fallen over?—Yes.
13,445. Do you find that there was any giving or yielding at the bottom of the column as between that and the base-plate in any instance?—There has been a yielding there (pointing to the model), that is to say, in most cases the base-plate is standing and the column is off.
13,446. (The Commissioner.) That is to say the bolts have been given?—Yes.
13,447. (Col. Yolland.) And the flanges?—In some cases the flanges; but it is so difficult to say whether anything has been broken off or knocked off.
13,448. (Mr. Webster.) Do you find in some instances that the column has fallen with the base plates still attached to it?—Yes.
13,449. In pier No. 9 I think there are two or three instances of it?—Yes; in fact it is in those cases where I would expect the turning over—in no other case where I would expect the smash.
13,450. In the cases where you would expect what has been called a turning over, or the greatest strain upon the column, do you find that the lower joint, where the spigot was wanting, has held?—Yes, it has held and pulled the stone out.
13,451. With reference to the bottom joint, have you in any part of the structure as fallen, seen any indication of damage occasioned by the absence of the spigot at the bottom of the bottom column?—No.
13,452. With reference to the question of facing up, you explained at some length to the Court and Mr. Trusler to-day about the little channel that there is in the face of the flanges. Would you just turn to 31; what part of the 5 inches was turned?—I think it is somewhere between 2 and 2½ inches.
13,453. Is it the inside or the outside?—It is a channel.
13,454. But what part of the 5 inches was faced?
—An outer 2 inches or 1½ inch and an inner 1¼ inch. Between an inch and an inch and a half, very likely.
13,455. A suggestion has been made that the undersides of these flanges ought also to have been turned or faced: does that model correctly represent the flanges as they were made in the bridge?—No. These flanges (pointing to the model), in fact, any turned flange there, would necessitate the giving up of the brackets, which are the principal strength of the flange.
13,456. Upon the underside of each flange where the nuts come, as it stood in the bridge and the top side of the corresponding flange, there are brackets proceeding from the body of the column?—Yes.
13,457. Would it have been possible to have turned those faces?—Certainly not with the brackets on.
13,458. Were the joints between the various columns a matter to which you directed your attention?—Yes, certainly.
13,459. Were those joints properly made?—Those joints were properly made, the turned ones, as true as turning will do it; but there was one joint that was not turned, that was the bottom one in the base plate. The column joint was turned, but the base-plate joint was not, for this reason. You see every one of these columns were framed, as I said, before they all have a different rake, because the distance at the top is the same in all cases, and the distance at the bottom is the same, and the height not being the same, the inclination must be different. Every one has a different rake, and if this (pointing to the model) had had to be turned, it would have been a matter almost of impossibility to get the desired rake in the lathe, you would have to fix it in a different plane; and then it was a thing which could not be calculated.
13,460. (The Commissioner.) It would be so minute that it could not be calculated?—Yes.
13,461. (Mr. Webster.) With reference to the joint at the bottom, it is the fact that the top of the base plate was not turned; but how was the surface prepared for the receipt of the turned surface of the flange?—The surface was prepared by putting the base upon a level part upon a kind of foundation, and putting the spirit level upon the top and seeing how much it deviated from the desired inch, chiseling it down to allow the straight edge to follow gradually till the desired line was obtained in one direction.
13,462. Then the same was done in another and perhaps crosswise, and finally in that manner we would get some six or eight points fixed which lay in the plane which we required. Then it was chipped off, and finally to secure proper finish a round wooden disc was rubbed with red lead and rubbed on the top of this base-plate or traced, and wherever the indications on the plate after being turned over again showed that they were points which were too high it was filed smooth.
13,463. You know the kind of work that had to be done to get the face of each of those to the proper tilt?—Yes.
13,464. Would it have been possible to have turned those base-plates prior to their being put down, to make a satisfactory job of it?—I think not.
13,465. In your judgment were those joints properly made?—They were properly made; it would have been cheaper for us if it had been possible to have turned them properly.
13,466. It would have been cheaper for you to have adopted one pattern if you could have done so. This involves more labour and more supervision?—This involves more labour and more supervision, and you have better control over the result.
13,467. I think you also have a recollection of one particular joint over which the cement had run out?—Yes.
13,468. Will you explain to the Commissioners what it was that existed there?—I have seen a base plate which is still standing (I cannot say without my notes from which pier, but I can give it afterwards), which shows that cement had run in from the inside of the column when it was grouted, and I attribute that to the fact that although the bearing on the outer part was good, the inner part had been cut off in part too far.
13,469. Do you remember that joint during the time before you left the bridge, or not?—No, I do not.
13,470. Is there any sign of weakness or giving way, or of anything having happened to that?—Nothing.
13,471. Whatever the circumstances may be, has it
had the slightest effect upon the falling of the bridge?

—It has had nothing to do with it.

13,472. (Mr. Barlow.) I have not heard yet how the concrete got into the columns, and when it was put in. The concrete was put into the centre columns after the whole structure was erected.

13,473. (Mr. Webster.) That is the 15-inch columns.

13,474. From top to bottom? —From top to bottom.

13,475. (Mr. Barlow.) Was it poured in at the top?

—It was poured in at the top. This had to be filled in between the so-called "L" girders or miter girders were fixed on, but that was not the case with the centre columns, because they protruded. I think the proportion was one of cement to five of sand, the same proportion, I think, in which we made all our concrete. In concrete we used one of cement, one of sand, and three of stones; and, if I do not mistake, it was the same proportion; but, as in all other concreting work, it was our invariable practice to load the barges with sand and cement in the proportion in which they had to be used, so that there was no danger of the men using more of the one or the other. I have had occasion sometimes to see while I was there that it was not all used up and then sent away, in fact, if they did not use more than the stipulated quantity of cement. In fact, if you look at our accounts, you will find that we used, during the time of the construction of the bridge, more cement than in the proportion of one to one. The cement and sand were mixed upon the columns, but they had to be hoisted in the bucket, and water had to be pulled up from below, and then it was let drop from the proper height, on about 90 feet, till it gradually got filled.

13,476. Would not that bring a considerable pressure on the columns internally? —Yes, in the first instance, if it had been filled right up without stopping; but when we had to mix it and to hoist it up, the water had to be pulled up from below, and then it was let drop from the proper height, on about 90 feet, till it gradually got filled.

13,477. How long would it take to fill? —I should think it would take at least three days to fill each column, but I could ascertain that.

13,478. Did you find any of it escape at the joints?

—No, never in any case.

13,479. (Mr. Webster.) Now, about the cement; did you test the cement? —I was very often present when it was tested.

13,480. Was it of good quality? —All the cement that was used was of very good quality.

13,481. Would you mind coming down and looking further what you said as to what you have not done at the works?—No, it came to you. Was it any part of your duty to test it at the works? —No, it was not with the exception of cement.

13,482. (Mr. Webster.) You spoke to-day of two bolts in the channel iron which Mr. Trasyner asked you a question about. I will ask you to be good enough to explain a little further what you said as to what you have not discovered.

—Yes.

13,490. Through how many holes does each of these bolts go? —Each of these bolts goes through three holes.

13,491. Two channel iron? —Two channel iron and a lug.

13,492. You said just now that there was an extra margin of strength there with reference to the suggested enlargement of the holes; did you find any case in which the four holes in any two channel iron had all been enlarged? —No, I did not.

13,493. Will you just explain to me what it was that you said to Mr. Trasyner just now, that in order to reduce the strength at the point where those brackets or bolts go through you would require to have all those four holes cut out, compared with one hole of the tie-bar? —To weaken the hold of the channel iron upon the column to a greater extent than the holding bar upon the column, it would have been necessary that more than two of those holes should have been elongated. Even an elongated hole would not render that hole entirely useless, but in order to reduce it very much it would require to have two or four elongated. If either this hole and one on the opposite side, or the two holes on one side, are perfect, and the others imperfect, then there is still sufficient margin to allow one to say that there was as much strength there as here (pointing to the model).

13,494. That is to say, if from the accident of construction (if I may use that expression), you have got a margin of gripping power in the two bolts through the channel irons, greatly in excess of the one bolt through the tie? —Yes, to which, in this case, the grip can be added.

13,495. Would there also be any resistance due to the gap between the surfaces? —Very great resistance indeed.

13,496. You have said that you would not have allowed, if you had seen it, the riming out or cutting out of any hole itself? —I would not.

13,497. As far as you could judge of the work, as you saw it, were the joints properly made, independently of the question of riming out? —Yes, independently of the question of riming out.

13,498. You were there two months after the bridge was opened and trains running over it? —Not after the bridge was opened, but after ballast trains were running.

13,499. Were you there at the time of the Board of Trade inspection? —No.

13,500. It occurred after you left? —Yes.

13,501. You have seen these ruins (if I may use the expression) and you have given your theory to-day of the way in which the bridge fell down. I must put to you distinctly a question which Mr. Bidder put, but I desire to put it again, and I wish you to answer it carefully. Is there any single point in the workmanship of this bridge which, in your judgment, can be pointed out as causing, or contributing to the disaster of the bridge? —There is not a single point which could have caused the disaster.

13,502. (The Commissioner.) I do not understand that answer. —There is not a single point which I have seen which could cause the bridge to fall down in conjunction with other points. Mr. Bidder put a question about it.

13,503. Do you mean that there is not one single cause? —No. Perhaps I do not understand the question myself.

13,504. (Mr. Webster.) Is there any defect which you have heard suggested which, in your opinion, caused the coming down of the bridge from a construction point of view? —No. You mean, would I
consider that the downfall of the bridge was due to the workmen.  

13,506. (The Commissioner.) Do you mean imperfect workmanship or imperfect design?—Workmanship.  

13,506. (Mr. Webster.) That is to say, the materials or the execution of the work?—Yes.  

13,601. Is there any defect in those respects, which, in your opinion, caused the disaster?—No, there is not.  

13,508. (Mr. Balfour.) That you mean that as regards the workmanship and the materials there is nothing that you can see in it that will account for the fall of the bridge?—Nothing.  

13,509. (Mr. Webster.) Mr. Trayner, I am sure, unintentionally threw doubt upon the quantity of the stone courses of the pier had been split?—In several cases stones were broken.  

13,524. But how many of them had been broken through the bolt?—I have not seen any.  

13,525. Look at that photograph (showing a photograph to the witness), pier No. 9. Do you see that that stone has been broken at the bolt?—Yes, perfectly; it is just the thing I would account for by anything falling.  

13,526. Did you see that when you were inspecting the ruins of the bridge?—No, I did not look at that. I was on the pier, but very likely looking from the top it escaped my attention.  

13,527. Look at the very same pier, and the opposite side of it, the next figure, you see that there is another stone broken away at the bolt?—No, I do not see it. Here I see a stone lying and another stone on the top of it.  

13,528. Do you see that the stone is broken away just where the bolt is?—I do not see yet that the stone is broken off there.  

13,529. You see that, and that is one?—Yes, I see that.  

13,530. And you see that, and that is another?—No, I am not sure. That bolt hole, I believe, is just at the joint.  

13,531. I do not suppose you drove bolts through the joints of the stones, did you?—There is no objection to that.  

13,532. Is it a fact, or is it not, that you drove your bolts through the stone itself, or through the interstice between two stones?—This looks to me to be driven through the joint.  

13,533. Is that a right thing to do?—Why not?  

13,534. Do not ask me questions.—My question is merely a reply, or otherwise I would not put it to you. It is not an improper thing to do to drive the bolt at the joint.  

13,535. What was to hold it there if you put the bolt between the joints of the stones—the cement?—Yes; but you see the stones were bonded together—they were lying in bond. I am not saying that it is through the joint, because I would have to consult the photograph further; but it looks to me as being through the joint here.  

13,536. Does it not from the picture appear that the bolt is standing now against a broken surface of stone?—I cannot tell from looking at the photograph whether that is so or not. It is very difficult.  

13,537. Can you tell me if, according to your knowledge, there was a single bolt driven into the masonry work between the courses of stone in the joints of the stones?—I do not recollect, but I have with me in London the drawings showing how they were actually put, and I am quite ready to hand them in.  

13,538. But at this moment you can tell me whether as an engineer, bolting down such a superstructure as one of those columns, you would think it a safe thing to send the bolt into the cement that joined two stones together?—If the joint is good certainly.  

13,539. Would it not have a tendency to separate the joints of the two stones?—No, I do not think it would have a tendency to do that; but looking at the joints as they really were here, easily separating the stone from the cement, I do not think it would be good. If the joints were good, it would make no difference.  

13,540. Do you think that driving a bolt through between two stones that you purposed to have in close cohesion—
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(Mr. Webster.) Do not say "driving a bolt through;" it is placing a bolt in, not driving it through.

13,541. (Mr. Traynor.) Since Mr. Webster likes "placing the bolt in," would that have the effect of separating those stones in a way that you had not intended? and did not wish?—No; it would not separate the stones.

13,542. (The Commissioner.) Might we put it in this way—have you told us that there would be knowledge of the position between the cement and the stone, and less resistance than in the stone itself?—Yes.

13,543. Consequently if you put the bolt between two stones you simply get the resisting force of the cement, and you therefore get it in the position of least resistance?—That is so. Looking at the joint, I would not do it. Perhaps it is not done; it is only my impression looking at the stone.

13,544. Either it is broken, or it is at a joint?—Yes, but I admit that it is broken.

13,545. (Mr. Traynor.) And you admit further that you did not see it on your inspection?—I did not.

13,546. You had the stones placed before these bolts were put in place?—Yes.

13,547. How did you proceed to get the bolt in, how did you make the aperture for the bolt?—That hole was drilled into it.

13,548. Then if it was put into a joint, the whole was drilled between the stones on each side of it and the other parts?—I was not speaking of a joint just now.

13,549. It is a very simple matter. If in both positions the hole for the bolt was drilled between the joints, it would take out a part of the stone on each side and the cement between the stones at that place?—No.

13,550. (Mr. Webster.) In the hole where the drill went down?—Yes.

13,551. (Mr. Traynor.) If you put in this bolt through the joints, you remove the cement entirely from the place where the bolt is to go?—If the cement was in there, yes; but if I drilled the hole before the cement was in I would not remove any cement.

13,552. If it was not there you could not take it away?—No.

13,553. Did you drill the holes in this masonry work before the cement was put in, and before the stones were joined, or afterwards?—Before.

13,554. So that if you drilled a hole in this joint, you would take away the cement?—I would not take away the cement. What you have been saying has never refreshed my memory upon the point. There were no holes in the joints.

13,555. That is another instance, then, where a stone has broken away?—That is another instance where a stone has broken away.

13,556. At pier 12, do you see another stone which has been broken away through the bolt hole?—Which course?

13,557. The bottom course, the second course of masonry work?—I am not sure of that. My photograph is not clear enough.

13,558. I will show it you; do you see that bolt through the photograph (pointing to the photograph)? is that so?—Next door to it there is another bolt.

13,559. No; it is not; that is a bit of the cement away. You are just as able to judge of the photograph as I am; is that a bolt or not?—I cannot say.

13,560. Are you prepared to say that it is not a bolt?—No.

13,561. What is it if it is not a bolt?—It is something else.

13,562. That is only second-rate wit. What is it?—But, really, can I answer that question?

13,563. Looking to the position in which that which I call a bolt is placed, is not that a place where you would naturally expect to find a bolt?—Of course the bolts were in the corners.

13,564. Do you not think that that is more likely to be a bolt than anything else?—That is a difficult question to answer.

13,565. Assuming that it is a bolt, you did not see it?—Assuming that it is a bolt, I did not see it.

13,566. You said you did not see any stones broken away at the bolts on your inspection?—It did not strike me. I saw many stones broken. In fact, this theory of the splitting up, I believe, is so unscientific that it had never struck my mind at that time; otherwise I might have looked at it. May I explain that pier No. 9 has the bottom stone missing, and lies in such a position that any column falling on it would necessarily hit the corner of this stone and break it off into the water without splitting it up previously. It is a very unnatural thing.

13,567. You think that at that pier 9 both the stones I have shown you broken off by the bolts might be accounted for by something falling upon them?—I think so.

13,568. Can you give the same explanation about pier 12, which I called your attention to, assuming it to be a bolt?—Here I would at once account for it by something falling on it, because I am perfectly persuaded that the cohesion of the stone itself was much greater than the adhesion to the stone below it, and that therefore it would first come off before it broke; at the same time it might be broken by a sudden snap, something suddenly knocking against it, without the stone having as it were, time to upset. All that I have seen here in the way of broken stones can be perfectly accounted for, in my opinion, by the smash of falling.

13,569. By the smash or by the transverse wrench?—The transverse wrench, being a slower motion, does not seem to have done it.

13,570. You said that no lig had been burst on any of the columns which were in the high girders; can you say that positively, or do you merely say that, so far as you know, such a thing did not happen?—All that I have said is that, so far as I know, it did not happen.

13,571. It may have happened, but you do not know it?—I positively do not know about it, certainly.

13,572. There was no indication on the part of the men to slack their work, you said?—No, there was not.

13,573. Was there not a little hurry in the work at the end of it?—No. Much work was done at the end, but that was foreseen a considerable time before the bridge was finished.

13,574. How long before the bridge was finished?—I think two years almost. I have been with me in London a programme drawn out in a tabular form which on the face of it shows when it was made, and in which all the operations are foreseen until the completion of the bridge, and in that programme I find that the last operation was to take place, I believe, in the week ending August the 22nd, or September the 1st, while in reality it was done on September the 22nd.

13,575. How many men had you on the job at the end of it?—I think we had 700 more or thereabouts.

13,576. That was an increase of how many beyond the usual staff?—The increase had been going on steadily, and was always in proportion to the work that was in hand at the time. We had more in hand at some times than others.

13,577. Had you 700 men for the last eight months?—I think so.

13,578. And for the preceding eight months how many had you?—I cannot give the figures; even the 700 may be a few more.

13,579. For the last eight months you had on a larger staff than you had had for some time before?—Necessarily.

13,580. Can you give me any idea, without being very particular, of the increase of your staff within the last eight months?—In figures I should think there would be place for some 50 or 60 or 100 more men.

13,581. Within the last eight months I think you performed an amount of work that, to use your own words, "seemed almost incredible to a mind accustomed to it."—Yes.

13,582. Had you foreseen, two years before, that in eight months you would require to float out six and
13,583. That is the falling of two of the high girders; how long did that delay your work beyond what had been expected?—It did not delay it; it only forced me to adopt a slightly different course, to adopt a different programme.

13,584. It must have delayed it somewhat, because the fallen girders had to be removed, and new ones had to be built?—Exactly; but while that was being done much of the work did not stand still.

13,585. But if the girders had not fallen, so as to necessitate the building of new ones, you would have been less hurried in your work towards the end?—We cannot be said to have been hurried on that account, because it was simply working at other places where those girders were being manufactured.

13,586. Yes, so that the fact of the fallen girders threatened seriously to interfere with the expectation of having the bridge finished for the passage of a train by September; is that the fact?—Yes, it threatened; that is to say, people thought it would.

13,587. Did you think it?—No; the first day after the accident happened I assured everybody that it would be ready in the same time, and that it would not delay us.

13,588. In the course of that eight months how many of the columns were cast?—I cannot tell you now.

13,589. But you can give me an idea?—Not many.

13,590. How many hundreds, or how many tens, or how many units?—I should have to look that up.

13,591. Give me an idea?—I must first have one before I can give it you.

13,592. Cannot you find it from the recollection which has furnished so much?—I can guess.

13,593. How far can you guess? You have given a good deal, you know?—I only guess when I have data to go upon, which are wanting in this case.

13,594. You will not even guess here?—No, I will not.

13,595. Had you to work night and day during the last eight months?—No; we worked in some parts at night where it was tide work, such as floating out piers.

13,596. "The contractors did the best to counteract those evil influences, that is to say, the falling of the girders, by putting extra pressure on their workshops, by working day and night at the bridge works by the aid of powerful electric lights, and by engaging a greater number of men"; is that so?—Yes, that is so.

13,597. Then you did work night and day during the last eight months?—We unloaded vessels by night, we floated caissons and piers by night because the day tides did not always suit.

13,598. (The Commissioner.) Did you cast columns by night?—No, we never worked the foundry by night work.

13,599. (Mr. Trimmer.) Was there not a night shift in any part of the foundry?—In the turning shop there was a night shift.

13,600. Did the last eight months in this respect differ in any way from the mode of operation during the time that had preceded those eight months?—Yes, we had not the electric light before that.

13,601. But did you work at night as much prior to that eight months as you did during that eight months?—No, we did not do as much work at night I think.

13,602. In short you represent here, and I understand it to be the case, that during that eight months you did put on extra pressure?—In which sense do you mean extra pressure?

13,603. In the sense in which you used the words in this article?—In the sense in which I used the words in that you have said

13,604. You were pressing both your workshops, you were working night and day at the bridge work, and had powerful electric lights, and a greater number of men in order to enable you to complete the work by September?—Yes, that night work as I have already stated should not been taken in the sense of night work which on account of its being at night was imperfectly done. It was as efficiently done, because it was a kind of work which could be done at night.

13,605. You alone have suggested that the work done at night was inefficient?—No, I have not.

13,606. During that last eight months you were working extra tides in order to get the work done. Is that so?—Of course I have nothing to do but to answer your questions, but at the same time I am an independent witness, and I should be very sorry to leave the Court with a wrong impression as to what I have said. I understood that you yourself wanted me to give the impression that we had neglected the work on account of the extra pressure during the eight months; and I take this opportunity to emphatically deny it.

13,607. Nobody has made the charge, but still you are quite right to deny it, if you think it is worth while. Is the spigot and faucet which, according to the original design was intended to be, and according to your view, was on each of the columns, not of more importance than merely to keep the columns in position?—Only in the case of a side blow could it be of any importance.

13,608. In the event of a side blow it would be of importance?—It would.

13,609. How would it be of importance in that respect?—Because it would assist the bolts in preventing the columns from shifting bodily sideways.

13,610. Then you regarded it as material against lateral pressure?—No, not lateral pressure. I would not employ that term because it would confound it with wind pressure. I said a side blow.

13,611. What side blow did you anticipate that the bridge or the pier of the bridge would be subjected to, against which the spigot and faucet would be available?—None.

13,612. You said that it would add to the strength of the columns in the event of a side blow; did you anticipate that the pier would be subjected to any side blow against which you were providing with a spigot and faucet?—No, I did not.

13,613. Did you take care to see that the spigot and faucet were in point of fact existing on all the columns, except the low one?—Yes, it formed part of the inspection.

13,614. But, so far as you inspected it, you found them on all?—Of course there would be some columns without them and others with them.

13,615. The low columns were not to have them at all?—No; and therefore by merely looking at the columns you could not say, "The spigot is wanting here." All you could say is, "There is no spigot."

13,616. But when the columns were placed, did you inspect them, and see whether or not each column except the lower tier had the spigot and faucet?—No, I could not have done that.

13,617. Therefore you cannot say whether, as a matter of fact, after the columns were all in position, the spigot and faucet was upon every column?—No, I cannot say that.

13,618. With regard to the flanges, are you sure that the circular recess was not in any case more than two inches?—No, I am not sure of that; my dimensions are entirely given from memory.

13,619. Have you seen one of those that is at present in London, or several of them?—No, I have not seen any here.

13,620. Do you know of any of those flanges, which had circular channels, of the breadth or width of three inches and three-quarters?—No, I did not measure them.

13,621. If such a thing exists, was it within your knowledge, at the time, that they were being turned, with a recess so broad as that?—No, not that they were being turned with a recess so broad as that; but there might be some which had that width of recess
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Three inches and a quarter would leave an inch and three-quarters of bearing metal all round.

13,629. (The Commissioner.) I think you admit that there was not proper adhesion between the stone and the cement, owing to the face of the stone being smooth?—Yes.

31,640. (Mr. Webster.) You said, I think, that with your present knowledge you would have had smaller stones and more joint?—Yes, or rougher stones, and more joints.

13,611. (The Commissioner.) You recollect the construction perfectly well; at pier 31 there was a fixed bearing; at pier 30 there was a roller bearing; at pier 29 there was a roller bearing; at pier 28 there was an expansion bearing; at pier 32 there was a roller bearing; at pier 33 there was an expansion bearing; at pier 34 there was a roller bearing; at pier 35 there was a fixed bearing; at pier 36 there was a roller bearing; at pier 37 there was an expansion bearing; at pier 38 there was a roller bearing; at pier 39 there was a fixed bearing; at pier 40 there was a roller bearing; and at pier 41 there was an expansion bearing. Now at the place where there was an expansion bearing there would be no connection at all with the lower pier?—No, it would be only resting upon it, rolling upon it, in fact.

13,642. At the roller bearing there would be the flanges of the rollers which would prevent lateral motion?—That would be the case with the expansion bearing too. There would be two sets of rollers, each set of rollers pertaining to its own girder. In a small set I believe there were only three rollers for each side.

13,643. But in the others there were five?—Yes.

13,644. And the fixed bearing would be fixed in the top of the pier?—Yes.

13,645. You will observe that at every place where there is a fixed bearing the girder is thrown out farther. At 31 it is thrown out 42 feet 6 inches; at 35 it is thrown out 51 feet; and at 33 it is thrown out 44 feet 4 inches. We therefore find that each of these connected girders, where the fixed bearing is, is thrown further out of place than it is at any other point; is not that so?—Yes.

13,646. Supposing that the whole of the girder was thrown forward from the breaking of the pier at the bottom, you can well understand, can you not, why the place where the fixed bearing was would be thrown out rather further than the place where the expansion joint was?—It would slip off there.

13,647. But that would rather militate against your theory that the expansion joint went first, and that that brought the thing down. If the whole connected girder came down, then you would naturally expect, would you not, that where the fixed joint was, it would be thrown out further?—Yes.

13,648. And that might very well account for the girders being farther out at those particular points than at those where the roller-bearings and the expansion joints were?—Yes.

13,649. There the girders would very soon lose the support?—Yes.

The witness withdrew.

Adjourned till to-morrow at half-past 10 o'clock.
Examine by the Commissioner.

13,550. I understand you to say that you have no connection whatever either with Sir Thomas Bouch or with the contractors at the present time.—None. I am an engineer of large experience, and you had the control of this work from the commencement to the end?—Yes.

13,552. You told us that there was an alteration in the design owing to an error in the soundings?—Yes.

13,553. I presume that Sir Thomas Bouch consulted you about that?—He did, generally.

13,554. And did you approve of the alterations?—Yes, in the main.

13,555. Originally, all the piers were to be of brick?—Yes.

13,556. Why were they not constructed of brick afterwards, when you had put the caissons down; was it because the foundations would not bear the weight?—The foundations would not have borne the weight of the brick.

13,557. But the brickwork would have been stronger?—I believe the brickwork would have been stronger.

13,558. When you first made an alteration, you contemplated for the high girders two piers—one circular, 20 feet in diameter, and the other oval, 22 feet long by 15 feet broad?—That is correct.

13,559. That was done in contemplation of a second line being laid at some time or other?—That particular arrangement of the two piers was partly owing to that and partly to the fact that those oval caissons were in existence, but were not to be used for the parts of the work for which they were originally contemplated.

13,560. You also contemplated that there should be two sets of four columns each?—Yes.

13,561. The two external ones, I presume, of the same diameter as the internal ones?—Of the same diameter.

13,562. With a girder, I suppose, intermediate between them?—Yes, with the girder between them in the middle between the two.

13,563. As they are now?—As they are now.

13,564. That was altered afterwards to one large caisson 30 feet in diameter, was it not?—31 feet in diameter.

13,565. Why was that alteration made?—Because the sinking of these two caissons of different shape so noised each other, and in the current with the strong tide, offered great difficulties. We found that these difficulties had not been great as long as we were in a clay bottom, but they became very great when we got into a sandy bottom in sinking the smaller piers.

13,566. That was the cause of it?—Yes.

13,567. When you had laid your caissons down you had, as I understand, ample space on the top of that for building up brickwork to support your eight columns?—Yes.

13,568. Why did you not do that?—I did not do it because I received a drawing which showed how I had to do it.

13,569. That is to say, you did not do it because you were told not to do it?—Yes, I have that drawing with me.

13,570. You are not at all responsible for the design?—No, I am not.

13,571. But the result of your building your hexagonal pier on the caisson when there was room enough to build a pier which would have contained the eight columns, necessarily led to an alteration in the form of the pier, so that you only got six instead of eight columns, is that so?—Yes.

13,572. You have told us that the girder passes intermittently between the outer column and the two inner ones?—Yes.

13,573. Consequently, I suppose, as a mathematical proposition, the outer column would bear the same weight that the two inner ones would?—It would.

13,574. Have you calculated what quantity of metal there is in the 18-inch column; it is easily done, multiply the radius by 3.1459. If you take my calculation, 3.1459 by 174 would give you nearly 55 inches?—For the outer column.

(Mr. Bidder.) I make it 564.

(The Commissioner.) You must not take it to the external radius, but to the centre.

(Mr. Bidder.) Quite so.

13,575. (The Commissioner.) That would make it 55 inches as nearly as possible. The 15-inch columns each of them would be 45 inches as nearly as possible, taking it to the centre of the iron?—Yes.

13,576. Then the quantity of metal in the two inner columns gives us a total support of 91 inches?—Yes, double what one would be.

13,577. Ninety-six inches against 55 inches?—Yes.

13,578. But moreover the external 18-inch column has to support the wind pressure, or a great part of it, has it not?—It has.

13,579. Consequently, where there is wind pressure, the external column has to do much more work than the two internal columns?—Yes.

13,580. Would you call that a good arrangement of design?—I would not call it a good arrangement of design, but it might be said perhaps that the outer column was the one which was considered sufficient in strength, and that the inner ones were made of one-inch thickness, because it would not have been convenient to decrease that dimension to a fraction of an inch, so that really the outer column might represent a sufficient strength with 55 inches, and in the 90 there would be a surplus.

13,581. You mean to say this, I suppose, that according to your view (which I am not contesting for a moment) the outer column would be quite sufficient for the purpose, and that the inner columns were too strong for the purpose?—Made so for convenience sake.

13,582. At any rate we may come to this, that the outer column which had to bear the greater strain, not only the strain of the train and the weight of the girders and superstructure, but also the wind pressure, had a total capacity of resistance considerably less than that of the two internal ones?—Yes.

13,583. You said yesterday, in answer to Mr. Trayner, that "There must be a certain proportion between the money spent on the superstructure and the money spent on the piers, to produce the cheapest bridge, and it was found that by making the spans as they actually have been made, a cheaper bridge could be produced without of course sacrificing anything, than if the spans had remained as they were before."

(Mr. Bidder.) That is quite so.

13,584. A more costly pier was substituted for one which was cheaper before, and therefore making fewer piers, and lengthened spans, would re-establish that proportion in which the cost is a minimum; and in another answer you amplify that rather. Mr. Bidder says, "You said in answer to a question a short time ago that the spans were altered in their length in order to preserve a certain economical proportion between the piers and the cost of the girders."

Then he says, "You do not mean by that that they
"were altered in any way that impaired the efficiency of the bridge?" Your answer is, "Not in the least, but a proper economy." Now I want clearly to understand what you mean by that, for I confess that I am at a loss. You have told us that these piers were built in order that they should be lighter?—Yes.

13,684. You have told us also to-day that they are not so strong as brick piers would have been. You have also told us that the spans were increased from 215 to 245 feet. Do you mean to tell us this, that a span of 245 feet would require a lighter and weaker pier to support it than a span of 215 feet?—Theoretically it would require a heavier pier to support it, but in practice I think not.

13,685. You think then, that increasing the span 30 feet you could make your pier lighter and weaker?—Not lighter certainly.

13,686. But you did make it lighter?—For the 216 feet span the class of pier was entirely different. 13,687. But a stronger one?—Yes; a stronger one—those same brick piers would have supported the span if it had been 245 feet. The same pier should have been used if the spans had been only 215 feet.

13,688. Where is the equilibrium?—I do not quite see the equilibrium. To bring out the most economical bridge.

13,689. Do you mean to bring the costs within the contract price?—No; this had nothing to do with the contract price. The contractors were paid by unit, not in a lump sum.

13,690. By the weight?—By the weight and the quantities.

13,691. I think you told us that the strength of the booms was not materially increased when the span was increased in length. The weight of the spans was in the proportion of the square of the length.

13,692. They were increased in strength?—Yes.

13,693. Then there was a considerably greater weight for the piers to bear?—In the proportion of 64 to 81, as 8 is to 10.

13,694. But the spans were very much heavier when they were 245 feet, not only for length, but also for strength?—Yes.

13,695. Consequently those piers ought not to have been lighter or weaker than would have been sufficient to have borne the span when it was 215 feet?—The calculation, I think, could hardly have been made from data supplied by the 215 feet span, because the class of pier was entirely different. If the same description of pier had been used for the 215 feet span as was afterwards used for the 245 feet span, the piers would certainly have had to be increased in strength, but that was not so. There were two new things—new piers and new girders.

13,696. Then what do you mean by saying this—"As I understand what you mean is this," says Mr. Bidder, "nobody can understand it better than Mr. Bidder does. Given a certain length to be covered by the bridge, you might put a great number of piers with very short spans, in which case you might have a very cheap girder indeed, or you might have a very small number of piers with very long and very expensive girders." Is that so?—Yes, but neither of the bridges would be an economical one. All other circumstances being equal, given a certain length, which has to be spanned by girders resting upon piers, then the greatest economy in the plan, or in construction, is obtained when the superstructure costs as much as the piers. If, for instance, the spans were taken in certain limits, say a little smaller or a little larger, then the number of piers would become either more or less. Of course the number of piers depends upon the number of spans. If the number of spans were increased or decreased, the number of piers would decrease or increase. In diminishing the number of piers the weight, and therefore the price of each span, would increase as the square of the square of the length of the span. At the same time you would have a less number of spans, so that the real increase of proportion would not be the square of one span, but the direct proportion of one span. On the other hand, by lengthening the spans you get a fewer number of piers.

13,697. Tending to economy?—Yes, but if a calculation is made either in the abstract or from an actual case, you will find that by increasing the lengths of the spans a couple of feet or several feet, or by decreasing them, you get in each case an increase in the total cost. If you either increase the number of spans, or decrease the number of spans, from what it would be if the superstructure cost as much as the piers you get in both cases an increase in cost.

13,698. What bearing has that upon the point I am putting to you?—I think in that case that if you increase these large spans by 30 feet you diminish the strength of the supporting piers?—Hardly. The pier was afterwards designed for that span.

13,699. But you say it was a weaker pier than you would have had for a shorter span?—But not a weaker pier than was considered strong enough for the work.

13,700. But it was weaker than it was originally intended?—Yes, it was weaker than was originally intended.

(Mr. TAYLOR.) Would you pardon me for calling your attention, Sir, to this. Mr. Grøthe has been speaking of the spans as having been increased from 215 to 245 feet; the specification makes the spans 200 feet.

(The Commissioner.) That I am quite aware of. The contract was for 200 originally, but he spoke of them as being 215.

(Mr. TAYLOR.) Yes.

(Mr. Bidder.) I think the explanation of the difference is, that Mr. TAYLOR, if he will look at the contract, will find that it is 200 clear to the water line.

The piers project to some extent—the spans are 215 feet—from centre to centre is 215 feet.

(Mr. BIDDER.) One is the length of the girder, and the other is the length of the span.

13,701. (The Commissioner.) That is so, I dare say. (To the witness.) Now I must ask you some questions about workmanship, for which you are to a certain extent responsible?—Yes.

13,702. You are not responsible for that work which came finished from Middlesbrough, but you are responsible for that which was made at Worrin?—Yes.

13,703. I think you told us that when you heard that a lug was being cast on a column, you examined it carefully because it was a new thing to you, and you wished, not having much experience in foundry-work, to get knowledge wherever you could; was that not so?—Yes.

13,704. I think you told us that you had not very much experience in foundry-work?—I had not.

13,705. Mr. Camphius had not either?—He had not either.

13,706. For the last ten or eleven months of the work Mr. Camphius had sole charge of the foundry, had he not?—Such charge as I described yesterday, being more of an administrative kind than a technical kind.

13,707. Then who had charge of it?—The foreman.

13,708. Fergus Ferguson?—Yes.

13,709. A workman?—Foreman. He was more than a workman.

13,710. But without supervision by any superior authority?—He was subject to constant supervision.

13,711. By whom?—By myself, for instance, and by Mr. Camphius.

13,712. As far as he administered it properly?—He had at the same time to report upon any irregularities that he saw going on, or had any knowledge of.

13,713. But at the same time, as far as I can see, the responsibility for the works during the last ten or eleven months rested chiefly with Fergus Ferguson?—Chiefly.

13,714. You having comparatively small practical knowledge of the subject, and Mr. Camphius having
comparatively small practical knowledge of the subject?—That is so.

13,715. You told us that you had found on one occasion a column with a quantity of foreign matter filled in a defect?—Yes.

13,716. And that you were extremely angry with the person who did it?—Yes.

13,717. Was that Fergus Ferguson?—Yes.

13,718. Then Fergus Ferguson you found did sometimes fill up columns with foreign matter?—He was responsible for it, but he disclaimed all knowledge of it now.

13,719. He would not know it?—He said he did not know of it.

13,720. Then it is quite clear that all the columns did not pass even under his supervision?—They must have done so.

13,721. They ought to have done?—But it may have escaped him, because it was not very easy to find that part out.

13,722. Was it not during the last 10 or 11 months that the columns of the high girders were cast?—During the last 10 or 11 months of the work not very many were cast.

13,723. The last ones?—About 80 were cast after the accident; about 80 columns were cast during the last eight months.

13,724. Only about 80?—About 80; they were cast, however, in two months.

13,725. And was it during those two months that you discovered this?—No, before that.

13,726. The columns you have told us, both the 13-inch and the 15-inch columns, were to be one inch thick?—Yes.

13,727. Were you aware that Fergus Ferguson had taken upon himself to cast them one inch and three-eighths; he is asked, "Just tell me, if you please, what thickness you generally cast?—Between an inch and an eighth, and an inch and a quarter." Were you aware that those columns which you had ordered to be cast of one inch, he took upon himself to cast to one inch and three-eighths?—He did not take it upon himself; I instructed him to do it.

13,728. In the next question he is asked this, "For what purpose did you put any metal in the mould of any specified thickness?—I just took it upon my own responsibility to do so. I thought it better to give an extra thickness than have them the other way." Therefore he told us that he took it upon his own responsibility—Ferguson's words would be exactly my words, because I took it upon my responsibility for the very reason he gives.

13,729. Fergus Ferguson told us that he took it upon his own responsibility without communication with anybody else.—He received instructions to that effect.

13,730. You gave him those instructions?—Yes.

13,731. Why did you give him instructions (because we supposed not to tell you that yesterday) to cast them an inch and three-eighths when the arrangement was that they should be an inch thick?—Something passed with regard to these columns which I would ask permission to state in connexion with this matter. I have with me a drawing, dated March 30th, 1876, showing the arrangement of columns for the large piers and the balustrades. This drawing was supplied by Sir Thomas Bouch, and discussed in his presence. There was a different arrangement of diagonal lattice bars between the small columns, from what has actually been executed, there being another strut in between and a more shallow cross. The drawing which is before me gives a side view of the pier, and, therefore, these crosses do not represent the actual angle which the bars would make with each other, but they are the projection of that on a vertical plane. These pencil lines which were drawn here by me (pointing to the drawing) give the real angle looking at it straight on. That is a very flat angle, while these two other pencil lines give the real angle of the bars as they have been made. That alteration was in the presence of Sir Thomas Bouch resolved upon, and then some discussion took place as to the thickness of the metal in the different columns, which was not marked on the drawing, the drawing not being on a sufficiently large scale to allow of it being measured off. I see on this drawing in my own handwriting, that I have put to the thickness of the 15-inch column 1 inch thickness of iron, and to the 14-inch column 1 \(\frac{3}{4}\) inch metal. That was the drawing which at that time we were to act upon, but in consequence of a further conversation some time afterwards, of which I do not recollect the date, a counter order was given, and the 14-inch metal was ordered to be made 1 inch.

13,732. That is the outside column?—The outside one was made one inch.

13,733. The same as the inner one?—Yes. I had no doubt myself that the 1-inch metal would not be sufficient for that column, but as the diameter of this column (pointing to the model) is larger, and as the upward pressure of the metal when it is poured into the mould increases, of course, with the size of the core, without saying anything about it, I told Fergus Ferguson to make them one inch and an eighth, in order to allow for any inequality which I was almost sure would take place, in consequence of the increase of the size of the core.

13,734. May I translate that shortly into this, that owing to some alteration in the tins, you thought it better to increase the strength of the columns?—No, that would not have a direct bearing. I have taken the liberty of taking the tie bars at the same time, because this drawing shows a deviation in that respect, and as it is very likely a drawing that I might have to hand in, I wanted to explain that at the same time.

13,735. But that about the tie bars has nothing to do with this matter?—It has no direct bearing upon this at all.

13,736. (Mr. Balfour.) I would just like to mention that this gentleman has a formula of expression which I think might lead to error. He used the expression to-day which he did yesterday, "I have no doubt that a certain thing would not be sufficient." He puts in a "not," which makes the meaning exactly the opposite of what he intends.

13,737. (Mr. Bidder.) He means that he was satisfied that it was sufficient.

13,738. (Mr. Balfour.) Then the "not" should go out.

13,739. (Mr. Bidder.) I am not sure that his phrase is not strictly accurate.

13,740. (The Commissioner, to the witness.) Putting aside altogether the question of the tie bars, was it in consequence of a recommendation from Sir Thomas Bouch, or an order from Sir Thomas Bouch, that you increased the size of the columns, or gave directions to Fergus Ferguson to increase the thickness of them to one and an eighth?—No.

13,741. Sir Thomas Bouch had nothing to do with it?—No.

13,742. You, as the agent for the contractors, did it?—I did it on my own responsibility.

13,743. The contractors were paid by weight of metal, were they not?—Yes.

13,744. Then the increase in the thickness of the columns increased by so much the payment to the contractors?—It did.

13,745. Therefore it was increasing, in fact, the columns at the expense of the Company and to the advantage of the contractors?—It was.

13,746. Was Sir Thomas Bouch cognizant of it?—I do not think he was.

13,747. You do not think he knew that the thickness was increased?—No.

13,748. And therefore you increased it without any intimation from or any communication with him?—Yes.

13,749. You recollect those two girders falling down?—Yes.

13,750. Bringing the columns down with them?—Yes.

13,751. Did they fall just at the base of the pier, or where did they fall?—They fell very much as they have fallen now.
The Tay Bridge Disaster:

Mr. A. Grant.
28 April 1871.

13,748. About 40 feet out?—I should think they were a little nearer, but very much as they are lying now.

13,749. They were clear of the piers?—Yes.

13,750. But they brought down all the columns?—No at all.

13,751. A great number of those were sent to the workshop afterwards?—Yes.

13,752. And were broken up?—Yes.

13,753. Did you see them?—Yes.

13,754. Did not you see that a great number of them were unequally cast?—No, not a great number.

13,755. Then why were they broken up?—Because they were damaged, they could not have been used in that state.

13,756. Do you say that there were none of them that were unequally cast, were there none of them with cold shuts?—I have not seen any cold shuts, I have seen inequalities in the casting such as I should really expect would take place.

13,757. Not more than you expected?—No.

13,758. You were asked yesterday whether or not the spigot and faucet, or as the men in the North call them, the male and female, would add to the strength of the column, and you said you did not think they would?—I did, but I made the proviso that they would against a horizontal blow.

13,759. Supposing, for instance, there was a ridge at the top, they would be of use, would they not; a lateral wrench this way, they would be of use, would they not?—I think not. I think they would lift out, because the fit of them and the length of them was not so that it would give any stiffening.

13,760. But you must consider what the circle would be. It would catch against the edge, would it not?—I believe it would not.

13,761. It was very slight, was it?—Yes.

13,762. Did not fit very tight?—It had to slip in easy.

13,763. But supposing, for instance, that the bolts in the bolt holes had worked loose, then I suppose the spigot and faucet would have been of some use in keeping the columns straight, would they not?—They would be of use in keeping the column itself in its place.

13,764. So as to prevent any play?—Yes, without, however, enabling it to stand any strain, but simply to keep it in its place.

13,765. The direct continuity of the column being essential to its stability?—If there were no bolts.

13,766. Supposing, for instance, that the one flange slips over the other flange, that would to a certain extent affect the stability of that particular column?—Yes; it would.

13,767. Therefore the spigot and faucet would be useful in that way to prevent that?—Yes.

13,768. You have been once down to the bridge since it has fallen?—Yes.

13,769. And on that day it was blowing a strong north-east wind, and it was raining?—Yes.

13,770. I need not ask you whether you found a difficulty in getting upon the piers?—Not a difficulty in getting on, but some difficulty in getting off again.

13,771. At any rate it was not a pleasant thing altogether?—It was; not a pleasant day for an inspection.

13,772. And yet you discovered, I think, several instances that you have mentioned in which there were defects which you would not have allowed if you had known of them?—Certainly.

13,773. Even in that superficial view that you took, you discovered some defects which you would not have allowed if you had remained in the columns if you had known of them?—That is so.

13,774. (Col. Yolland.) Did you see any instances, when you went on the piers, of fractured lugs?—Almost all the lugs were fractured.

13,775. Were there many cases of fractured tie-bars?—No.

13,776. Did you see any?—I saw a tie-bar broken.

13,777. You saw one?—I saw one.

13,778. Can you tell us at all what was the area of the lug that was fractured at the fracture?—I forgot the figure.

13,779. Was it a single lug or a double lug?—A double lug.

13,780. You saw no single lugs broken?—I do not think so.

13,781. Can you tell us at all what would be the area where the fracture took place?—I would require to get the dimensions of the lug. The fracture was generally through the bolt hole (pointing to the drawing).

13,782. Through the bolt hole?—Yes, in that direction, and some in that (pointing to the drawing).

13,783. Can you tell us at all what the superficial area would be through that fracture?—I can make that out as soon as I have a drawing showing the exact dimensions; and, if you will allow me to hand it in after the adjournment, I will do so.

13,784. Would it not have been a desirable thing that the channel irons, which acted as struts, should have been brought round the columns, with their surfaces in contact with the circular surfaces of the columns themselves, so as to have made them more efficient as struts?—That would have been a good arrangement.

13,785. (The Commissioner.) That would have been an improvement in the design?—Yes.

13,786. You know the specification, of course?—Yes.

13,787. Will you refer to the top of the page which I have marked there (handing a copy of the specification to the witness), under the head of "malleable iron girders," you know that part of the specification?—Yes.

13,788. You see the tensile strain there is 21 tons to the inch?—Yes.

13,789. It says, "the wrought-iron plates, bars, angle, and T-irons used in the construction of the girders for this bridge must be of such strength that one square inch of section shall support a tensile strain of 21 tons without breaking." That clearly applies simply to the girders?—It applies there to the girders, no doubt.

13,790. You know this specification by heart?—I did.

13,791. Is there anything at all in this specification as to what shall be the tensile strain which the tie-bars shall support?—I think, as an opinion, and one that is not a new one, but has existed all along. I might say that no engineer or contractor would for a moment suppose that the 21 tons did not apply to the other ironwork.

13,792. You have no doubt whatever that it applied to all the ironwork?—No.

13,793. I think I understood you to say that these ties were sent from Middlebrough direct, ready to be put up?—Yes.

13,794. But you never saw them tested?—I did not.

13,795. And Sir Thomas Bouch never was there, or employed anybody, so far as you know to test them?—Not so far as I know.

13,796. During the whole time you were there?—No.

13,797. (Mr. Barlow.) The diameter of these caissons was 31 feet, was it not?—Yes.

13,798. Do you know the weight of the pier and its girder?—Not by heart.

13,799. In your opinion, as an engineer, what weight per square foot would it have been safe to put upon those foundations as they were executed?—The opinion which I had at the time, and which is illustrated by this plan which I made when the alteration of the piers was resolved upon, using piers which were originally intended for the large spans for the smaller ones, was that there would be a weight on the foundation per square foot of surface of 2-7 tons.

13,800. That is taking into account the brickwork?
Taking into account everything, taking the whole of the superstructure. 13,801. Taking the whole superstructure into account, you put it at 27 tons per square foot upon this foundation?—That was not on this (pointing to the drawing) that was on those which were first designed. I believe the weight here (pointing to the model) per-square foot came out even less; I think it was somewhat about two tons per square foot.

13,802. Do you consider that those foundations as put in are quite safe to carry two tons per square foot?—I believe so.

13,803. Do you think they would carry three?—They would carry three; I think so.

13,804. Without any danger or doubt?—You get, of course, nearer the margin with three.

13,805. But you think they would carry three?—I would not like to put three on them.

13,806. Were any of the columns of the bridge broken or cracked before you left the work?—No, I never saw one broken or cracked, nor did I hear of one.

13,807. So far as you know, when these columns were put into the bridge they were all without cracks?—Yes, they were all without cracks.

13,808. How do you account for the circumstance that any cracked afterwards?—It is very difficult to say. I suppose it was due to the nature of the cement or sulphate of lime. I have the specificaion here, and on page 6 of the first contract or specification under the heading of Portland cement concrete, concrete, with contraction in the ironwork greater than that of the concrete so as to bring a strain upon the ironwork from that cause?—In a frost the iron would contract on the fixed core, and a tensile strain would be produced in the cast-iron.

13,809. The horizontal bracing being T-iron 6 inches by 6 inches, and the diagonal bracing angle iron 1/2 inch by 3/4 inch?—They are shown as flat bars here, but I know they were angle iron really.

13,810. Do you remember what sort of cross braces were described in that specification?—Yes.

13,811. Do you remember that the angle iron was given up, and flat bars introduced instead of it?—Because I suppose for a tie-bar a flat bar was considered sufficient. I have heard these bars called "ribbons," but of course if each of them is strong enough they would suffice perfectly as ribbons.

13,812. If they were angle iron instead of tie-bars you would have on the one hand the action of a strut, and on the other the action of a tie?—If this bar had been in tension (pointing to the model), that bar would have been able to assist it as a strut.

13,813. Consequently there was a considerable diminution of strength in changing those angle irons of 3/4 inches by 3/4 inches to flat bars 4 inches wide?—I do not know the sections of the two; but I think an angle iron of 3/4 inches by 3/4 inches by 4 inch would be stronger than a 4 inch by 1 inch flat bar.

13,814. Besides which the angle iron would act as a strut as well as a tie?—Yes.

13,815. So that there would be altogether a considerable diminution of strength, with in fact very little diminution in the moment, because the mode of fastening the angle bars did not allow the full section of the angle bar to act as a tie.

13,816. It would act as a strut?—It would always act as a strut, but it would not allow the full section to be taken as the effective section as against tearing sounder, because the mode of fastening them in the logs necessitated the cutting away of part of the angle iron to let it slip in. At the end it was really a flat bar 3/4 inches by 3/4 inches, and that was the effective section as a tie, assisted by the other bar that would act as a strut.

13,817. If any fracture had occurred, say in that upper column upon the outside, what would have been the effect upon the bridge?—If this column broke straight through (pointing to the model), then there would be no particular danger as long as the road was purely vertical, but of course it would considerably weaken the concern if the wind blew in that direction (describing the direction).

13,818. Supposing it were fractured completely through?—If it were fractured completely through a danger would exist even with a direct load, because it would have only the concrete core.

13,819. In what way would it operate if you were to take away, for example, that column?—If this column were taken away this side of the girder (pointing to the model) would not have any support left for it, and there would be a danger for the girder, insomuch as it would be a girder of double the length; it would be two spans united into one.

13,820. It would sag in?—It would sag in.

13,821. Would there be a tendency to break the two small columns on the other side?—I believe it would, certainly.

13,822. In fact it might bring the bridge down?—Yes.

13,823. Would that same effect take place supposing the next column were broken through with such a fracture?—To a slightly less extent, because then you have a slight support in this top column connected with the bracings. You have a cantilever fastened to this head of the column.

13,824. There would be danger there, but not so great?—No.

13,825. And the danger would diminish as you came down?—Yes.

13,826. Nevertheless the breaking of any one of those would be an element of danger?—Yes.

13,827. And the same I suppose on the other side?—Yes.

13,828. In the first contract that was made with Messrs. de Burgue there was a specification of the cross bracing. Do you remember what was described in that first contract or specification with regard to the cross bracing?—The cross bracing in that first contract was very different from this. It however referred to the columns on the north side—on the north side they were only two column piers, instead of four, or five, or six. It is true that there was one raking column to guard against any centrifugal effects, but they were only two column piers only.

13,829. (The Commissioner.) You are talking of the north side?—Yes.

13,830. Mr. Barlow is speaking of the south side?—There were at that time no bracings contemplated for any other piers than those north side piers.

13,831. (Mr. Barlow.) The specification for the bracing refers to the north side?—Yes.

13,832. Do you remember what sort of cross bracings were described in that specification?—Not from the specification; but I happen to have a sketch of them here. Here is a drawing of the cross bracings (producing the same).

13,833. Would that same effect take place supposing the effective section of the angle bar to act as a tie?—Yes.
work to do?—That work was really done after I had left the bridge, but I was a party in suggesting the arrangement as it was finally carried out, so I can speak to it. It was Mr. Reeves who was put in charge of that work. Mr. Reeves was one of my principal assistants, and had been so during the whole line with the exception of a few months in the beginning of the construction, and before that he had been my assistant in works in Russia.

13,841. It was his business to see to that tightening up?—It was his business to see to the tightening up under the superintendence of the company's inspector.

13,842. Who was responsible for setting out the work in proper lines?—Different people.

13,843. The contractors, I see by the specifications, are responsible?—I understood you to mean whether one of my assistants or myself was responsible.

13,844. In the first place the contractors were responsible for it, were they not?—The contractors were responsible.

13,845. Who do you say was put in charge to do that work?—Generally it was put in the hands of another assistant, who is now in India—Mr. Le Brun.

13,846. We have had it in evidence that one or more of these piers was fully 2 feet out of its proper line?—Two facts is rather too much, I think, but there are several piers which are not exactly in line, and it could not be expected, in fact, that the lower piers would have been in line. The difficulties under which those piers had to be lowered and sunk were formidable. For instance, when we had our three piers ready for lowering, there has come on a gale, which has lasted for three days, and we have, had to leave it rocking there, and we had a difficulty in getting away from it with our lives, so that it made it very difficult to sink them exactly in the right place. To sink them very efficient arrangements were made. One assistant stood with a thousand dollars on the most convenient pier, and took from a proper point, either on shore or on another pier as directed, his bearing. On the pier which was to be lowered down to the river bed marks were made, and a system of signals was arranged between the man with the theodolite and those on board the barge. The lowering went on without much regard to position, except care was taken not to go too far away from the line till the pier was near the river bottom, almost touching it, and then particular attention was paid to the line. The distance from the previous pier was obtained by steel ribbons, two of them being fastened to the previous pier and to the barges, and then the distance was obtained by theodolite. Of course, other men were stationed at capstans with four or even eight ropes to place the barges exactly in position, and as soon as the assistant with the theodolite gave the signal that it was all right, the pier was lowered until it had got a hold upon the ground, so that it was done accurately. I do not think there was any instance, even in bad weather, where we got the piers more than three inches out of their real direction.

13,847. Except the two which have been referred to?—That was on this account. Some of these piers were put unintentionally out of direction for a reason which I can perfectly explain. The reason was this. The Tay Bridge was planned, as the law required, to be a single line, but there was always an expectation of at some time or other having to double it. Now the central part of the Tay Bridge is much wider, both as regards piers and superstructure, than the parts at either end, and the question arose, when the line was doubled, how could the straight bridge be maintained, and as the feeling for a double or a single, if there was decided either to keep the axis of the single line straight or to settle upon a straight axis for a double line, which meant of course a deviation of direction for the single line.

13,848. There was an oscillation of mind during the time?—Yes, according as the double line was more or less before the public. When the idea was that there should be a double line most of the large girders were placed in such a direction that the central line of the bridge when it would be ready was straight, each of the two lines slightly opening out as it came to the centre. When that was given up, all we could do was to take a straight line as we could from the last pier ready on the south side, and the last pier ready on the big spans, therefore it is not a straight line, but by a little deviation in the sleepers and a little in the piers, we at last got what we wanted—namely, a line which did not look much out of the straight. That is the explanation of the deviation of direction.

13,849. (Mr. Bidder, through the Court.) The first question I would ask you is with reference to the answer you gave this morning that the caisson as constructed would have carried eight columns. What I want to ask you is, would so wide a base have been obtained with eight columns as with the present six columns?—On the same hexagonal pier, not on the same base a pier could have been constructed which would have given as wide a base.

13,850. (The Commissioner.) That is to say, if upon the caisson you had raised a pier with a wider base, then you could have put the eight columns on it; the eight columns would have had a wider base than the present six columns?—Yes.

13,851. They would have been in the same line as, at present?—Yes, the shape of this pier would have differed.

13,852. I presume the outer columns would still have had the raking in that they have now?—Yes, the same raking.

13,853. Consequently the bases would have been at just the same distance, only they would have been in the same line as the others?—Yes.

13,854. (Mr. Bidder, through the Court.) With reference to an answer you gave that half the weight of the girder goes upon the outer column, will you explain why that is necessary so—will you see whether or not, from the measurement, the girder does not come intermediate between the two outer columns?—It is, as I see here, intended to be in the centre, and therefore I would reasonably suppose, these being single girders, and there not being a continuous platform—the case would be entirely different if it were a continuous platform—as each of these girders is separate the weight in the centre would naturally produce the same downward pressure upon each of them.

13,855. (The Commissioner.) Therefore you do not alter the answer that you gave to me?—No.

13,856. Mr. Barlow wants me to put another question upon that answer. In the ground plan, there would have been plenty of room upon the caisson to have raised a pier which would have carried the two other columns?—Yes, there would have been.

(The Commissioner.) I specially guarded myself against putting any questions to Mr. Grothe about the connexion of the two groups of piers. (Mr. Bidder.) I do not think you quite caught the meaning of what I was pointing to. I had not in my mind at all the question of the connexion of the two triads of piers, but what was in my mind was this, that that girder (pointing to the box girder at the top of the model) rests, as we see, upon the L girder, and that rests upon the heads of the three columns; and whatever the weight was that was put upon that, the ultimate pressure per square inch upon the three columns must be sensibly the same, because if one of the three has got a greater pressure per square inch than the others, it must give more than the others, and so the balance redresses itself. That is what I had in my mind.

(The Commissioner.) Do you mean that it is compressible? (Mr. Bidder.) It must give in some way or other—it is compressible to some extent—a column 80 feet long must give to a sufficient extent to redress the balance of pressure.

13,867. (The Commissioner, to the witness.) You have heard the question?—Yes.
18,858. What answer do you give?—I should not like to count upon that. Perhaps, if I have not understood the question, but it was, as I understand, whether the particular position of this box girder upon the top, this cellular girder, as it is called, upon this girder (pointing to the model) does really produce the condition of which I spoke, namely, of forming a load put in the centre of this girder.

(Mr. Bidder.) No, that is not what I mean:—

(The Commissioner.) What I understand Mr. Bidder to mean is this: Assuming that weight is resting upon the top of those three columns, if any one of them was bearing, as it were, the whole of that weight, whether it would give until the weight was borne by the other two equally.

(Mr. Bidder.) Until the weight approximated to the strain upon the inner column was the same. The moment the strains upon the two columns are the same, the compression must be the same.

(Mr. Bidder.) What is suggested to me is that in a structure of that kind the pressure of a heavy weight must, apart from any question of the lateral action of the wind, go straight down, and that consequently the pressure per square inch of columns must be the same, or sensibly the same. It is suggested to me that, putting aside any question of lateral forces, it must go straight down, unless you take into consideration that the whole thing is going to crumple upon it. It is only talking about the strain under the action of simple vertical force, I am not talking about the thing as a whole. It is suggested that the girder, being perfectly square, is rigid, and not able to open out; we are discussing simple vertical force.

(The Commissioner.) Let me put this question. Suppose, for instance, that you had a three-legged table, and you put a weight on top of that on one leg, would it not give way on that leg?

(Mr. Bidder.) If you put the question to me whether, if you put a weight on one leg of a table the weight upon the three legs of the table is equal, I say, certainly not. But allow me to supplement that illustration. I am only thinking of the special case being considered. The question is, would it not be capable of bearing the weight at its maximum—at its extreme strain.

(The Witness.) Would that make any difference at all in the answers that you gave with regard to the strain that the outer column would bear?

(The Commissioner.) The outer column, I understand, would give till the strain upon the inner column was the same. The case is the same with you. You put a weight on one, whether the strain really is, would it not. But allow me to supplement that illustration. The case is the same with you. You put a weight on one, whether the strain really is, would it not. But allow me to supplement that illustration.

(The Commissioner.) I think you stated not. I think he stated that it would be quite sufficient to bear it.

(Mr. Bidder.) If you will turn to page 7 of Mr. Law's report you will see at the bottom of page 7 that he gives a table of the pressure on the western and eastern rollers with a train on the bridge, and with various pressures of wind, and I want the witness just to consider that. The eastern rollers are the ones in question, and I want Mr. Grothe to take it with a train on the bridge and with the greatest pressure of wind that is shown there, 40 lbs. to the foot, the most adverse circumstances indicated by Mr. Law. You will see, in Mr. Law's report, that the total pressure upon the eastern rollers is represented by 543,535 lbs., and I think you will find that that comes approximately to about 1,245 tons, if I am not mistaken.

If you take Mr. Grothe's view that that is equally divided between the 18-inch column and the two 15-inch columns that would give 122 or 123 tons for the 18-inch column to bear; and taking the sectional area which you named this morning, 65 inches, you will get about 21 tons as the pressure on each column. Last figure in the table, namely, 545,936 lbs., is with an extreme pressure of wind of 40 lbs. to the square foot, which comes to 245 tons to be divided between the two 15-inch columns and the 18-inch column, leaving 122 tons for the 18-inch column to bear, upon the 55 inches of metal 21 tons to the inch. It would be glad if you would ask Mr. Grothe if, in his judgment, that in any way imperils the safety of that column.

(The Witness.) Not the least. I start upon the assumption that this one (pointing to the outer column) was amply strong, and that this (pointing to the inner one) might have been much weaker.

13,863. What would be the number of tons pressure to the inch in compression which you might calculate in such a column, as being what an engineer would consider safe?—Safely four tons, allowing a very wide margin, because it would of course stand much more.

13,864. (The Commissioner.) Considering that this column is perfectly rigid, supposing it to be a rigid steel bar, and the force which was tending to overset it being a force acting on the girder and on the strain in the girder, the greatest pressure would be at the bottom?

13,865. It would be very different from what it was near the top?—Very different, it would be in proportion to the leverage.

13,866. It is a regular steel yard?—Yes.

13,867. Hence, therefore, if there was any great lateral pressure you would expect that it would put near the bottom where there would be the greatest strain?

13,868. Before it would part anywhere else?

Before it would part anywhere else.

(Mr. Bidder.) That becomes a tensile force, a tension on the hoists.

(The Commissioner.) Quite so, not force of compression. I am not thinking of that at all.

13,869. (Mr. Bidder, to the Court.) With regard to the question about the comparative economy of one mode of construction and the other, I think it wants a little clearing up. An iron pier as compared with a brick pier is considerably lighter pier?—Very much lighter.

13,870. At the same time there is an entire change of the material of which the pier is constructed—that is to say, you use iron instead of brick?—Yes.

13,871. As I understand, the iron pier for a certain span, of course, has got to be constructed of a strength having regard to the weight which it has to carry?—Certainly.

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13,872. And that strength, or rather, I should say, proportionately that strength must be increased in proportion to the weight which it has to carry?—Yes, sometimes the weight acts beneficially, however; you could construct it lighter because it had a greater weight to carry.

13,873. Going back to the brick piers in the old design, the brick piers, you said, were sufficiently strong. Is not the case that they were very much more than sufficiently strong?—Hundreds of times, I believe.

13,874. I mean is there any inference that because the iron piers are weaker than the brick piers, therefore they are not sufficiently strong for the required purpose?—No, not at all.

(The Commissioner.) That was not my question.

13,875. (Mr. Bidder.) I know it was not. I know what was in your mind, but sometimes others may draw an inference from the thing as it stood which you did not mean to be drawn and which we who understand it may not draw. (To the witness.) Let me see if I correctly understand your view about the balance of economy; given a mile of viaduct to be constructed, you might say theoretically there are two extreme cases, you might do it in one span, in which case you would only have two piers, or you might do it in 1,760 spans of a yard apron?—Yes.

13,876. The first one would involve a very small comparative cost for piers and a girdar of the most expensive character?—Yes.

13,877. In the second case, in order to get equal strength and efficiency, it would cost nothing for girders, but an immense expense in creating 1,776 pier?—Yes.

13,878. Is this what you meant, that given a standard of safety and efficiency, and taking every intermediate case between spans of a yard, and a span of a mile, and in every case working out the girders and the pier to get precisely the same safety and efficiency, you come to an intermediate point which gives you a minimum of cost?—Yes, that is so.

13,879. (The Commissioner.) I understood him to say so, but as a matter of fact, it did not turn out strong enough to support the bridge, the bridge came down?—The bridge is down.

13,880. (Mr. Bidder, through the Court.) You stated in reference to a plan on which the columns were marked as 1½ inch thick, that there had been a counter order reducing the thickness to an inch. Will you consider whether you are quite clear that there was any such counter order?—I am perfectly clear as to that.

13,881. Was it by letter?—No, it was verbal from Sir Thomas Bouch to me.

13,882. (The Commissioner.) You are quite sure of that?—Yes; first there was an increase, and then afterwards a decrease again. The increase I marked there and then on the drawing.

13,883. And afterwards he told you to put it down to 1 inch?—Yes.

13,884. But did you not follow that out?—No, I did not, because the difficulties of producing a good casting were very great, and I took it upon myself to secure a margin.

13,885. (Mr. Bidder.) You took it upon yourself to allow a good margin so as to secure a good casting?—Yes. The contractor would have been much in favour of the contractors to cast them 1½ inch, because it would have been simply the additional material and nothing more for the workmanship, and therefore it would have been to the advantage of the contractors to cast them 1½ inch thick.

13,886. With regard to the tests of the iron, I think you said you knew nothing about what tests were taken at Middlebrough?—I do not. I have heard occasionally—

(The Commissioner.) You must not tell us what you heard.

13,887. (Mr. Bidder, through the Court.) With reference to the questions put to you by Mr. Barlow as to the cracks that have been described as having been discovered in certain columns, if I recollect rightly they are described as longitudinal cracks.

(The Commissioner.) Vertical cracks.

13,888. (Mr. Bidder.) Vertical cracks. I suppose if the causes that Mr. Barlow indicated created one of those cracks, you would expect it to be longitudinal, would not you?—Certainly.

13,889. Suppose it gave from the swelling of the concrete and from the action of the frost, it would open up longitudinally?—Yes.

13,890. For the work that these columns had to do, would a longitudinal crack materially affect the strength of the column?—I should like to think five minutes about that, or longer if I could.

13,891. (The Commissioner.) In fact you would rather not answer it?—Not just now.

13,892. (Mr. Bidder, through the Court.) Supposing the piers had been constructed throughout like this (exhibiting a sketch to the witness) with an enclosed circle, would not those columns have had very considerable strength for resisting compression, and resisting flexure?—It would have had considerable strength, but it would not if the hole were through—if it were slotted out—it would not be in the same conditions which a full cylinder would.

13,893. In some cases you adopt the trough shape, do you not?—Yes.

13,894. And you get a very strong member by that construction, do not you?—Yes.

13,895. Though not so strong as if you filled up the fourth side?—Extent has to be taken into account; there may be circumstances in which this would be quite an efficient strut to the full extent of the metal for a short length, but it might not be an efficient strut in a long column.

13,896. Take any one of these columns; the two things that a column, as a column, has to do are, are they not, to support vertical pressure and to resist flexure?—In other words, tension and compression.

13,897. Take it for the supporting of vertical pressure; is a column materially weaker with a vertical crack in it?—Shall I go into that question.

13,898. (The Commissioner.) Just as you like. If this column instead of being made of soft cast-iron were made of some more pliable material, say, for instance, lead, and a pressure came on here, then undoubtedly this crack would swell out, it would open up in the sides; whereas if it were in tension there would be no danger, so that it depends on the extent of the crack. If the crack were prevented opening out further with a vertical lead on the top, I believe there would be no danger.

13,899. (The Commissioner.) If prevented by hands you mean?—If prevented by hands from opening out further. If it was not prevented from opening out further, I should be afraid of this giving way and the crack increasing.

13,900. By compression?—Yes. Perhaps the Court will allow me to make a correction of a statement I made yesterday. I do not know that it is of much importance, but I may ask to give the correction. I have found a drawing of the stones as they were actually put down, and from that drawing I see that my statement yesterday, that a bolt might be put in the joint, was not accurate. At the same time, I have found out how the mistake arose. The mode of fastening down the columns on the other brick piers of the standing portion was so far different that inasmuch as the copestone on the top was only very slight in thickness, the bolt went through it to a considerable depth in the brickwork. In that case there are holes through the joint. That is how the mistake arose.

13,901. (The Commissioner.) Was that holding there in the brickwork?—In the brickwork.

13,902. (Mr. Trugman.) Then your answer to question 18,454, in which you said, "What you have been saying has been refreshing my memory on the point, there were no holes in the joints," is correct if you add the words "no holes in the joints of the
"stones"?—Yes. Then I was asked yesterday whether I could give an opinion on the wind force necessary to overturn the bridge. I would not have mentioned this again, but in the earlier part of the inquiry it was mentioned that I had read a paper upon that subject, or had given a lecture upon the subject, in which I expressed the opinion that the bridge was perfectly strong enough to stand 90 lbs. of wind to the square foot. I have a number of newspaper cuttings relating to the Tay Bridge, and I see among them a report of that lecture, which was given on the 4th May, in which was reported the Dundee paper, tolerably accurately, the only mistake being that "tons" were put instead of "pounds." In that lecture, given to a mixed audience, and without notes or manuscript, I sketched upon a black board, for the satisfaction of the audience, the piers, and the girders on them, and dealing with all these 130 feet spans which they existed at that time, for the plane had not been altered, I made a rough calculation that a wind 91 lbs. to the square foot would be required to upset the structure in the small spans.

Further examined by Mr. Trayner.

13,907. Are you now in a condition to describe the experiments made by Mr. Kirkaldy, and to state the result of them?—Yes, so far as those experiments have gone.

13,908. Are they not finished?—No, there are other experiments which the Court desired to have made which are not yet made, but which do not affect the calculations. I have all that are required for the calculations.

13,909. You have everything now that enables you to speak to the questions touched upon in the Appendix to your Report, upon which you have not yet been examined?—Yes.

13,910. Will you state, so far as necessary, what the experiments have been, what the results are, and then bring those results to bear upon your Report?—I will. The first sheet of experiments which Mr. Kirkaldy has transmitted, and which is dated the 21st of April, were upon six bolts (see Appendix, Table A). In directing Mr. Kirkaldy to make those experiments, I specially requested him to take great care to observe the rates of extension, as being very important for enabling calculations to be made as to the resistance of the bolts and the flanges, and he has done so; he tabulates here the extensions of the bolts, commencing with 10,000 lbs. upon the bolt, and going by increments of 2,000 lbs. up to the breaking weight of the bolt, and he gives the total extension. He also gives the total weight with which the bolt broke, and reduces that to the total per square inch, and he then gives the apparent area of the fracture. But I should say that in reducing it to the total per square inch he has taken the section of the bolt, whereas, in every case those screws broke through the thread of the screw, he should have reduced the breaking weight to the area of the section there. Had he done so, those which appeared to be low class iron and that I had different bolts and the flanges, and he has done so: he tabulates here the extensions of the bolts, commencing with 10,000 lbs. upon the bolt, and going by increments of 2,000 lbs. up to the breaking weight of the bolt, and he gives the total extension. He also gives the total weight with which the bolt broke, and reduces that to the total per square inch, and he then gives the apparent area of the fracture. But I should say that in reducing it to the total per square inch he has taken the section of the bolt, whereas, in every case those screws broke through the thread of the screw, he should have reduced the breaking weight to the area of the section there. Had he done so, those which appeared to be low class iron and that I had much greater strength; roughly, if you add half as much again, that expresses what they really did break with; so that instead of being 16 tons to the square inch it would be 24 tons to the square inch.

13,911. (The Commissioner.) You would say therefore, as I understand, that the bolts are of very good iron would you?—I stated that I had never seen nothing to lead me to think that the wrought iron was not of good quality. To facilitate my subsequent calculations I plotted a diagram in which the results of the extensions—the mean extensions—for the whole of the six specimens are laid down, and which then enabled me to determine more accurately what resistance the several bolts in the flanges would offer, according to the difference of their distance from the point at which they were being strained. Yesterday afternoon Mr. Kirkaldy sent up another table of experiments, dated the 22nd of April (see Appendix, Table B) which gave the result of three experiments which he tried upon the tie-bars. I might mention that the experiments on the tie-bars were made by Mr. Kirkaldy; and I do not think any person other than his own people were present; but that the experiments upon the tie-bars were witnessed by the Court, myself, and by a gentleman who represented both the contractors, and Sir Thomas Bouch, or at least Mr. Stewart was present. In the case of the first tie-bar which was experimented on, the bar itself did not break, but the slings gave way; and one sling gave way before the other. The result was that that bar broke with a lower strain than the others, and I thought it only fair and right to exclude that from the results, and to take only the other two; I was led to do that for this reason also, that those other two being of equal length enabled a mean to be taken at once of the rates of extension; whereas, if I had included the other it would have involved a very long calculation, which, having to give the results this morning, I was not able to go into.

13,912. (Mr. Bidder.) Are you quite right that that first tie-bar did not break, but the slings gave way?—Yes, it broke with 24,875 lbs. to the square inch, whereas one of the other bars bore 26,118 lbs. to the square inch, and the third bore 25,618 lbs. to the square inch.

13,913. (Mr. Bidder.) Before you go further will you tell me whether it is the sectional area right through the bore hole upon which that is calculated?—Yes. The way in which Mr. Kirkaldy reduces his experiments is clearly erroneous. I have not stated that at all; I am dealing with the facts he has given me. Mr. Bidder is quite right. In the fourth column the sectional area is stated to be 227—that is, the bar without any deduction for either slot at one end or bolt hole at the other. I had not observed that, but precisely the remark will apply as I made in the other case, that the strength given there is the strength of iron 19-55 tons per square inch, 21-09 per square inch, 19-31 per square inch; but I do not think it is correct to say that those figures till they have been verified.
It would be very desirable that that should be ascertained, namely, whether in the lower series of experiments, in arriving at the breaking strain per square inch, Mr. Kirkaldy took the same sectional area that he did in the former experiments.

Mr. Kirkaldy is a very careful experimenter, and we may take it for granted that he would take every possible care in arriving at his results.

The experiments are made with the view of testing the iron, therefore naturally they would be taken with very great care.

I should think he probably has rightly reduced this though he has not exactly reduced the other two.

If necessary, we will get Mr. Kirkaldy to explain what he did; we need not suppose what he did. Will you proceed with Mr. Kirkaldy's experiments, and their bearing upon your Report?—I also directed Mr. Kirkaldy in the case of the ties to be very careful in measuring the extensions, and be commenced by noting the extension produced by a strain of 10,000 lbs; and he also noticed the increments of extension for each 2,000 lbs. to the breaking strain. I have plotted a precisely similar diagram to the one I referred to before, which shows the rate of extension of the ties.

Will you let me see the diagram for the bolt?—Yes (handing it to Mr. Bidder).

It is very nearly uniform till you get nearly to the strain of about 34,000, and then it rapidly runs up. With regard to the extensions of the tie-bars, these are comparable with the strains upon the bars in the structure, with one exception. The tie-bars were put together with gibbs and cutters from the bridge, precisely as in the structure itself, but in the experiment where the slings were they had a bolt passing through without the thread of the screw; and therefore there was one element of extension which did not exist in this experiment; but the greater facility of crushing, the greater extension which was allowed by crushing, in the first instance is shown by the rate from 10,000 to 12,000, and 12,000 to 14,000, being much more rapid than the subsequent rates of extension; it had then evidently got its bearing, and it extended at a very steady rate. That clearly is an error of observation (pointing to a part of Mr. Kirkaldy's table).

You will observe that the increased inclination of the first two tables shows that the rate of extension was more rapid—there is a hilltop—and, therefore, we can see that that is clearly an error of observation.

There is another error of observation at 2,000, is there not?—No, there is only one error of observation; the other is the increased rate of extension. I have here one of the keys (producing it).

This key was in specimen 1,419, that is, the lower line in these experiments. This key is handed down to the other end of the fence, and four inches in the manner I have assumed it would do with the circumstances.

Is that your gib?—No, the gib was marked in the same way; the gib came against the two sling plates.

Have you the gib?—No.

There would be no difficulty in having it?—No, they are all producible.

What did you say that the final compression of the bars was?—I mean the core?—An eighth of an inch was the extent of the compression which produced that was 56,488 lbs. In order to obtain the assistance which would result from the action of each of the screw bolts in the flanges it was necessary to determine the proportionate extension which each bolt would receive at the moment that the last bolt was being broken. It is evident that the two furthest bolts will break first, and that they will be exerting the full strain due to the fracture of the iron, whereas the other bolts would only be exerting a strain proportionate to or due to the rate of extension to which they were exposed. In order to put the bridge so nearly as possible under fair conditions, and under such conditions as it probably would be under in practice if all the bolts had been very carefully screwed down and had a fair bearing, I have assumed that every bolt had an initial strain upon it of two tons, that is to say, that every bolt had been screwed down by means of a spanner, so that it exerted a force in holding together the flange of two tons for every bolt, that would be equivalent to three tons on the square inch. Then I have taken the actual extension which was found to that strain of two tons, and I have made another diagram in which I have drawn that line parallel to the line which represents the line of the flange. This diagram is drawn full size and has vertical lines corresponding with the positions of the centre lines of the bolts. On the line of the furthest bolt I have set up, on a very exaggerated scale, the extension due to the tie, and so I obtain, by measuring from the lower line, the actual extension to which each of these bolts was exposed at the time of the outer bolts-breaking, and giving credit for an initial strain of two tons. Proceeding upon that principle I then obtained—so the result what would be the ultimate extension of the bolts in a 15-inch column, taking the breaking line, the line on which they would turn, the line called in my Report line A A, I find that the moment of resistance of the other six bolts in the 15-inch column would be 197,710 foot-lbs. The great value of these experiments will now be seen, because assuming the law of the tension ut vis and taking in my calculation at page 13 the 15-inch column gives 44,502 foot-lbs, instead of 166,022 foot-lbs.

Would all the figures on the other side of that page require corresponding corrections?—Yes, the resistance of the bolts was an assumed resistance, assuming that they would bear 21 tons. We have the actual breaking strain now, and it takes the place of my figures entirely.

The bolts broke with about 24 tons instead of 21 tons.

You would add about an eighth to those figures?—I should add a seventh to my figures. I do not make any use of those figures, for I use the actual figures.

If a seventh were added to the figures on page 12 the 306,000 odd would become 350,000 odd and the 248,000 odd would become 283,000 odd, or something of that kind?—Yes, I now obtain the exact force which would be required to tear asunder these flange bolts in the case of both the 15-inch column and the 18-inch column. I look then to see what is the ultimate extension of the furthermost bolt, and then take the strain which would be required to tear asunder these bolts, because that determines the extent to which the columns themselves have been allowed to deviate from the vertical, or its normal position at the moment of the bolt breaking, and I find that that would give a horizontal movement at the top of the columns where they are attached to the ladders of 434 of a foot; about half an inch.

Then the next matter for inquiry was what extent would be produced in the tie-bars by a movement of the columns corresponding with 434 of a foot at its upper extremity. Taking first the bars between the 15-inch columns, I made a calculation which showed that the increased extension in one of those tie-bars would be 43 or of a foot. The horizontal movement would be 0728 of a foot, that is to say, the distance between the upper and lower points of attachment; that which I have designated as "a" in my formula, and that becomes reduced in the case of the panels between the 15-inch columns to an extension on the bar itself of 403 of a foot.
... 13,992. (Mr. Bidder.) A lengthening of the bar?—A lengthening of the bar to that extent. I have in these bars, as in the others, taken an initial strain of two tons on each bar as being produced by the driving home of the keys; and assuming that they remained in the top, the strain, the tie-bar which I have given would add another two tons to the resisting strain of the tie-bar itself; so that the efforts which those bars would make to support the columns at the moment when the outer bolts were breaking would correspond with four tons diminished by the proportion of the horizontal distance to the vertical; it would resolve it to two-thirds, and that for the initial strain would be equivalent to 2,968 lbs. for each tie at its point of application, and if the moment of all the bars is taken for that, multiplying by 14, and multiplying again by 42, which is the mean height at which the effort is exerted, you would get a resistance of stability equivalent to 1,745,184 foot-lbs. With the increased train which the weight of the structure in resisting any effort to overturn the columns of 1,524,016 foot-lbs. The initial stress on the bolts due to a strain of two tons upon each bolt would give a moment of resistance for the whole of about 2,995,076 foot-lbs.

13,999. (Mr. Bidder.) That is on all the columns?—Yes, top and bottom, the bolts would act top and bottom in resisting the effort to overturn. The initial stress on the tie-bars gives a moment of resistance of 3,877,880 foot-lbs., making a total for the initial moment of stability of the pier with the train upon it of 5,661,662 foot-lbs. I have shown that if the wind blew against the structure, the effort to overturn it would be represented by 319,032, multiplied by the force per square foot. That will be found in the last line of page 24 of the Appendix to my Report.

13,930. That is with the train on the bridge?—Dividing therefore the foot-lbs., by that co-efficient, it gives 17'81 as the stress that would put the initial stress upon the bolts and the ties. Up to that point the normal moment of stability of the pier would sustain it. As soon as the wind reached that amount it would then begin to put a strain upon the bolts and the tie-bars beyond the two tons to each, which I have assumed.

13,931. (The Commissioner.) That would be just the point of equilibrium, in fact?—That is so; not the point of equilibrium with regard to its being overturned, but the point of equilibrium between two moments of resistance. Then, proceeding a step further, I come to what would be the respective moments at the instant of fracture of the farthest bolt of the whole structure.

13,932. (Mr. Barlow.) Need you go through the whole detail of the calculation, do you think?—No, only to explain how it is arrived at.

13,933. (Mr. Bidder.) I hope, sir, you will not stop Mr. Law in this, it is very useful.

(The Witness.) It is quite obvious that as the bolts are elongated by a strain and the columns move over, they offer less resistance by virtue of the superincumbent weight. The moment they become inclined they still offer resistance until the centre of pressure has passed beyond the line about which they are turning; but that does not take place at all before the farthest bolts have lost or are losing that. But they do move over to such an extent as very considerably to diminish the moment or resistance that is offered by the structure, by virtue of the weight of the superincumbent structure.

13,934. I think your previous evidence shows that the head of the column would not get over the foot of the base?—It would not get over the foot of the base.

13,966. A 15-inch column, in fact, would carry you just about halfway—I will show you in a moment what the effect is on one or two. The moment of resistance, for instance, on the column No. 1 is reduced from 146,011 to 8,832, a minus quantity being 56 times the force of the wind. The weight taken off...
by virtue of the wind in accordance with the diagram at the end of my Report, Plate No. 5. Making allowance for the diminished resistance by the columns, by virtue of their movement, it brings the momental strength of the structure, resulting from the weight of the superstructure with train upon it, to 896,492 foot-lbs., plus 2,937 times the force of the wind. That is considerable, because while it takes off nearly an equal amount of weight from column No. 1, that it puts on to column No. 4, by virtue of No. 4 inclining against the wind, and therefore having a very considerable horizontal force of resistance, an additional weight put upon that has more effort in resisting overthrow than the same weight put upon column No. 1 has, tending to throw it over. So that whereas in column No. 1 the wind relieves it only from 56 times the force, it puts on to column No. 4, 2,937 times the force of the wind.

13,936. Could we not simplify that by taking a comparatively small factor?—It is eliminated directly. The moment of stability, arising from the strain on the bolts, has now become increased in accordance with our previous figures to 2,625,250 foot-lbs., and the whole of the tie-bars have become increased to 8,149,272 foot-lbs., making a total of the resisting moment of 11,694,638 foot-lbs., plus 2,937 times the force of the wind. This is equal, as before, to 319,052 times the force of the wind; and by a very simple reduction it gives the force of the wind required to overthrow the structure with the train (assuming it to be perfect in its conditions, giving an initial strain of 2 tons upon the bolts and bars, and assuming all the ties to do their duty) as 36'58 lbs.

13,937. On the whole surface of the girder?—And pier. That is really the best result that I can arrive at. It appears to me to be that mode of fracture which would afford the least resistance, and therefore the one upon which the structure would have failed. To show the action of these strains I have made a small diagram in which I have plotted the strains which arise from the weight of the structure in blue, which decreases as the strain comes upon the structure. The resistance of the tie-bars I have shown by yellow, which increases with the wind pressure, which is shown in these vertical columns. The strain resulting from the bolts I have shown by the blue. The increased stability given by the wind I have shown by the red; and it will be seen by this diagram that, as the figures show, the initial moments are sufficient to balance a wind of nearly 18 lbs., that then the strains become increased, and that at about 36 lbs. the bolts yield, when the resistance immediately drops by the height of the blue line, and of course the structure would fail. It is my observation with reference to the force which would be required to overcome the structure considered as a rigid structure.

13,938. (The Commissioner.) Before you leave that, I see you have got the red line indicating stability resulting from wind: is that from pressure of wind on the top?—No, exactly from the cause that I last named, that inasmuch as both the outer columns on the windward side would move inwards, and the effect of the wind is to take weight off the westward column, and put it on the eastward column, where it is most useful; to that extent it adds to the stability. It increases the weight upon that column which is best capable of resisting the effort to be turned over. In comparing my estimate of the wind which would throw the rigid structure over with those of Dr. Pole and Mr. Stewart, I said I did not attach much importance to them because it was an impossible assumption that the bolts should all be taken out, and I did not make allowance for all these little refinements of calculation; but had I done so, the first statement of the wind of 36'39 lbs. would have increased to 36'69 lbs., and that of 32'69 lbs. would have increased to 32'96 lbs. I only wish to observe that, in order that it may not be supposed that it was an error.

13,939. At what page of your Report is that?—At page 28 of my Report. If you take the refinements, which I have now pointed out in my calculations of the wind, it will bring 36'38 lbs. to 36'69 lbs. and 32'69 lbs. would really be 32'95 lbs.

13,940. (Mr. Bidder.) May I assume also that the figure which you gave me a moment ago 36'58 lbs. force of wind to overthrow the bridge and train, takes the place of the 30'84 lbs. on page 29?—Yes, that is on totally different data.

13,941. The figure of 36'58 lbs. should take the place of that 30'84 lbs.?—It should do so.

13,942. (Col. Fotherland.) Is it assumed that there are no weaker parts than the tie-bars?—It assumes that the structure is perfect; it does not take into account the fact that a bolt with a screw nut upon it is bearing against a sharp edge in the lugs. Those were not conditions under which the tie-bars were tried. It assumes that there is no possibility of movement of the flanged column upon the others, and upon another, and upon that I think I would make this observation, because I am afraid I did not make myself understood. From the way in which Mr. Grothe spoke upon that, it is clear that I did not make myself understood. The reason why it is of such immense importance that there should be some sufficient means of preventing one column moving horizontally upon the top of the other, is that at the attachment of every tie-bar you thrust against one and you pull against the other. Therefore, if these columns are able to slip upon the other, these tie-bars become useless. My calculations also assume that there is no play or yielding in the attachment of the struts to the column, and that they have an efficient abutment. I have assumed, in fact, that the struts are perfectly rigid and properly attached, and that there is no imperfection in the connection of the flanges, that all the bolts come up to the quality of those tested, and that the tie-bars also come up to the quality of those tested, and that all of them start with an initial strain of two tons. Of course if the structure by racking had elongated these bars and reduced these powers of resistance, then a very small force would have overthrown it, and the fact that it broke at other points than the lower ones is a proof that certain parts had become so derganged, or that imperfections did exist at those points at the time of the accident. Had everything been perfect it must have gone over upon the lower columns, and no others. If all had been perfect it is a mathematical proposition that it must have done so.

13,943. (Mr. Bidder.) It may be a mathematical proposition, but I am inclined to think that it is an improbable one?—If all these ties and struts were sharp and each one doing its duty, it must have parted on the lower line, and that being the line of least resistance. I say that it is a mathematical axiom that a structure must break upon the line of least resistance, and that is the line of least resistance.

13,944. (Mr. Barlow.) You assume the action of these bolts in the way that you have described; the lowest one is acting upon the base-plate?—It is.

13,945. What is there to hold the base-plate?—Four bolts, the strength of which as shown in the first part of the Appendix to my Report is greater than that of the flange bolts.

13,946. But what holds those?—Those are held by stone, and the giving of that stone would be one of those weak points which would contribute to the fall of the structure, and would enable less than 36 lbs. to overthrow it.

13,947. Your 36 lbs. is on the assumption that the base-plate is held down firmly and immovably?—Yes, and in every case the stone was not disturbed; so that it was evident that after it had yielded to sufficient extent to incline the structure over so that the other points immediately became weaker, although the resistance had been at first sufficient to strain the stone, it broke at another point. You see that also in pie No. 29. The resistance had been sufficient to break these columns at the lowest points; but when they had yielded to a certain extent the angle of the structure was then thrown over, the strain upon it discovered some weaker point above, and it parted there and this came back again partly to its place
...and cities so as to have allowed in; be? Wherever it happened to be, that the expansion joints were, and I mean by that both the terminal expansion joints and the intermediate ones.

And also the roller joints? — No, I am speaking of the expansion joints only. At the expansion joints it is evident that as soon as the bridge began to be overthrown, the girders, which were not united there by cover-plates, but only by the rails, parted, and so enabled themselves to be drawn off the pier and fell partly through them, so that in those cases two things have happened: in every one of those cases the girders have fallen near to the base of the piers, and have had their end posts broken off, and upon the top of them some of the columns running the western side of the girder, showing that they did not fail with the westward girders as a radius, but that having been drawn partly off they were crushed partly through and then drawn off by the turning over of the other piers; and that some of the western part of the structure of the pier fell on to the top of the girder, being dragged down by the expansion joints. I think that the order of falling and the manner of falling is very evident from the position in which the girders were found. It will be observed that at pier No. 35, which if I mistake not has a fixed bearing, the girders having been bent by its attachment at each of the expansion joints, by its falling more perpendicularly there, was not able to deflect to the extent necessary to produce the arc without breaking in the middle. Under pier No. 35 you will see that the girder is broken in half. It has evidently turned upon a radius, fallen over with the piers where it was fixed, and has been partly drawn off and fallen through the piers where the expansion joints were. I think that the position in which the second of the carriages between the tender and the second-class carriage are found, indicates that they left the rails before they had fallen much from the perpendicular, that they were swept by the ebb tide bodily against what had been the vertical side of the structure, and that they subsided upon their wheels. I think that the van even although it must be either the first or the second appearing now to have been found upon its side, must have been carried with its roof against the western side of the girder when the carriage met the water. I think that is demonstrated by the way in which the roof of the carriage has been cut; and I think that the photograph shows that one of the third-class carriages (I think it must be either the first or the second appearing now to have been found upon a radius) was carried up bodily against the upper or western side of the girder, the ends falling through the spaces and the middle being crushed down, and then when it subsided it went back again upon its wheels. The destruction of the structure, as far as I can judge from the photograph, not having seen the carriages themselves, although I have seen the roof of the van, leads me to think that the carriages could not have been in motion when the destruction caused to them was effected, because I think the parts would have been swept away had there been a forward motion.

Then the injury had been inflicted upon them by the fall? — By the fall, I think. I do not know that I have anything more to say with regard to the cause of falling.

An opinion was expressed by Mr. Groth yesterday, in answer to a question as to what had brought the bridge down, and he said he was of opinion that it was wind-pressure alone; after what you have seen of the fallen part of the bridge, do you think that this is in any way a correct view? — No; I of course endorse the view at once that wind-pressure alone (supposing the structure to have been perfectly made, and so designed) to the amount of 37 lbs. to the square foot would have been sufficient. I think that being perfect it fell in consequence of an excess of wind-pressure is evidently not the case, from the fact that it did not fall upon those points which would have been the least lines of resistance had the structure been perfect. The mode in which it fell shows that there must have been weak points in the structure and with the knowledge which I have before me of the way in which certain parts of the structure, which I have described, are made and the knowledge of the fact that the bridge did, within a short time of its
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Opening, work in such a manner as to render it necessary to introduce packing pieces in the ties, shows me that the structure was not in that perfect condition which would enable it to withstand a pressure of wind anything approaching to 97 lbs., which a perfect condition of the structure would have enabled it to withstand.

13,960. Were those defects in the structure, which you have pointed out as factors in the disaster, such as a careful supervision should have detected?—Most certainly. Expressing my own view of the manner in which that structure should have been constructed, I consider that every bolt should have been steady pin, and should have fitted the hole to which it was applied, that every strut should have had a firm shuntment, that the joints of the columns should have been incapable of movement, and that the parts should have been accurately fitted together, storey by storey upon the land, and carefully marked and put together again as if that were a man's business, so that it should have been impossible for a workman to find that holes did not coincide, and then to take a rough tool and drive out the hole in such a manner as to enable him to get the bolt through, but also in such a manner as to render the strut of no efficiency.

13,962. Was the loosening of the cotteries, rendering necessary the application of packing pieces, also a matter which a skilled engineer should have indicated a progressive weakening of the structure?—Yes, of course it showed that the ties, or the struts, or some part of the structure had so far yielded that a strain had been brought upon that tie-bar sufficient to extend it—Mr. Noble, that it should have been impossible for a workman to find that holes did not coincide, and then to take a rough tool and drive out the hole in such a manner as to enable him to get the bolt through, but also in such a manner as to render the strut of no efficiency.

13,964. But does not the fact of the only course adopted by him to remedy it, indicate that there was a want of skill in the supervision of such a structure on which so much depended?—Yes, it indicated a want of mechanical knowledge, and a want of appreciation of the gravity of what was taking place, and of what the consequences of what was taking place might be.

13,965. If an engineer of skill had had those defects, which Mr. Noble was capable of observing, reported to him, or had observed them by personal supervision, could he have proceeded?—Yes, if the application of that skill, to avert the catastrophe?—He certainly would. A person of mechanical skill becoming aware of the defects, would have incurred a heavy responsibility had he not remedied them.

13,966. And they could have been remedied?—They could have been remedied, for instance, if any indication had been seen of a joint opening, nothing would have been easier than drilling a few holes in those flanges and driving steel pins in. It would have been easy to a person of mechanical skill to strengthen the structure so as to have made it secure.

13,967. At all events, if the bridge to the eye of a man sufficiently skilled was in a state threatening its stability, it would have led to the stoppage of the use of the bridge until that had been remedied?—Yes, it would have been very easy to have drilled a hole through the two channel irons partly into the side of the ling, and driven a steel pin in there, which would have made a most efficient strut in any case where there was indication of a movement having taken place. There is no remedy that might have been applied if the structure had been very carefully and critically examined.

13,968. You heard the evidence given, both at Dundee and here, with reference to the castings which took place at the Wormit foundry, have you an opinion as to whether the supervision of those castings was as careful as it should have been?—I have only heard the evidence, but answering as regards the evidence which I heard, it certainly was not. I consider that in such a structure the thickness of the columns should have been determined, every individual column should have been examined, and not passed until it had received upon it the mark of the person who passed it as a guarantee that it had passed under his inspection. In fact, I think that each storey should have been erected, and fitted, and marked before it formed part of a structure of such a character as this.

13,969. More than that, should it have been possible in a structure like this to have passed castings which it was impossible for a workman to find that holes did not coincide, and then to take a rough tool and drive out the hole in such a manner as to enable him to get the bolt through, but also in such a manner as to render the strut of no efficiency.

13,970. But, upon the whole, your opinion is that the supervision of the castings was not what it should have been?—I know, from the evidence that I heard, that means were not taken to ascertain the thickness of the columns, and I see, from the observations which I have made that in many cases they were very unequal.

13,971. There was a matter put this morning to Mr. Grothe with reference to the distribution or equalization of the pressure upon those three columns at the top of the piers. I understood the question to be this: whether, if one of the columns was weaker than the others, the superincumbent pressure would come down in such wise as to equalize the pressure, although one of the columns was weaker than it should have been?—Were you present this morning when the question was put?—Yes, I heard it.

13,972. Will you give me your opinion upon the effect of the three-legged table illustration that was put?—Disregarding altogether, for the moment, the action of the ties—(and I did not bring any allusion to anything) as to equalize the pressure, viewing these as simply three legs of the table, which was the illustration used, if you placed a weight upon the top of that table in such a manner that half of it fell upon one leg and the other half upon the other two legs, if that leg were broken, I might certainly follow it—it certainly would not diminish in any shape or way the strain which followed that leg. I can conceive, as a theoretical question, that if all those tie-bars are quite perfect they may act, that if the one column descended partly they act to throw a portion of the strain of that column upon the others; but that I do not hear referred to. Undoubtedly, if you merely put a beam (because there are two beams it does not alter the case) upon two columns with a weight suspended in the middle, the
settlement of one column would not in any way relieve it from the weight which it previously had to carry; the stress would follow it, and be the same after it had sunk as before.

18,973. So that the effect of it would be that if one log of the three gave, the structure would give?—If one of the columns failed in such a way that it ceased to be able to support the load, necessarily that side of the bridge would have failed, because it would have been left without support whatever.

18,974. (The Commissioner.) Or if the beam was put over two out of the three legs, I suppose those two legs would hear the greater part of the weight?—It depends upon which failed.

18,975. I am not talking of failing at all, but I am talking of the weight of the girder. If the weight of the girder was put over the two inner legs, the outer one would bear hardly any weight?—None whatever.

18,976. Therefore if it is between them, half the weight goes to the two inner ones and half to the outer one?—Yes, if it were so distributed it would be in the reverse ratio of the respective lengths.

18,977. There are some more tests to come from Mr. Kirkby?—Yes, he is going to try the tensile, the transverse, and the compressive strength of the cast iron of the columns, and he is also going to try experiments upon the strength of the lugs by placing some of the columns with the tie-bar at the angle which they made in the structure.

18,978. When shall we have them?—I believe it will be as soon as possible after the tests are over. I have no doubt they did state the fact that they were riveting up the junctions, and that the ballast trains passed while they were doing it; and then they were asked as to the amount of motion. I am referring now to Questions 6821 to 6825.

18,985-6. That is the evidence of William Newcombe?—Yes, the evidence of the two men must be taken together as making a connected statement.

18,987. Then you understood the statements, as to the time when they were finishing the junctions, to refer to the final riveting of the covering plates connecting two girders together?—I did so understand it. I heard it and I do not think any other meaning could be attached to it. He was a riveter, and he was riveting the junctions.

18,988. You said that you had not the advantage of hearing Mr. Groth's evidence yesterday?—I had not.

18,989. (The Commissioner.) Will you look at the answer to Question 6860: "You assisted in putting them on columns"? (that is the girders)?—A. Yes, the evidence of the two men must be taken together as making a connected statement.

18,990. (Mr. Bidder.) Referring to page 461, at Question 15,214 of yesterday, you said that you were going to ask you this question, and I will tell you what the question is before I read the passage. If Mr. Groth's description of what was done is correct would not that entirely modify your view. He says, "The superstructure consists of sets of continuous girders. There was great attention paid to making the continuity of those perfect." I suppose I may assume that you heard the evidence of Mr. Groth yesterday upon this subject?—No, I did not, I was not in the room when Mr. Groth gave his evidence. I heard the evidence referred to here, but I did not hear Mr. Groth give his evidence, nor have I had the opportunity of reading it.

18,991. Your expressed opinion in this paragraph, as I gather, appears upon the face of it, is entirely based upon certain evidence which you refer to?— Entirely.
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Those plates. They were then taken on shore and the holes were drilled in, and then they were floated out again and fixed on the ends of the two separate girders with service bolts here and there just to hold them in their position, and then they were rivetted up, the service bolts being finally taken out and replaced by other rivets. It was not till then that the channel iron was placed back to back with the lug and then lowered down; so that these girding being continuous, they exert an unequal pressure upon the different parts to which they belong, the least pressure being on the end pieces. All that I ask you is whether that is a correct description of the mode in which the operation was carried out, it would not satisfy your mind, as an engineer, of its efficiency?

13,992. Then I think I may pass away from that matter. Now I may pass on to page 7 of your Report, where there is a statement with reference to the overturning of the second-class carriage; but I think the subject is dealt with again in the Appendix to your Report, and it will be more convenient to deal with it there, so I will pass on to page 8.

You say there, "Unfortunately the plates must have been very far from rigid structures, in consequence of the imperfect manner in which the struts and ties were connected with the columns. The struts were to the holes in the channel irons, which were not really flat surfaces, and if you had sur- faces under the same condition, really flat surfaces, and if you had surfaces without inequalities, then the amount of friction would be proportioned to the contiguous surfaces of the iron of the lug and the channel iron, do you mean to suggest that the axiom could not be applied? Having seen these channel iron, I do not hesitate to say that they really give no efficient friction to motion in reference to the lug.

13,993. And that friction would be proportioned to the strain with which the bolts were screwed up?

13,994. Which I think you told us in other cases you assumed as two tons to the bolt?—No, I have assumed a strain of two or three tons upon the flange bolts, but no amount of strain could, or did, bring the channel irons into contact with the lugs over any considerable portion of their surface.

13,995. You say here that they are retained in their positions by the pinching action of the bolts?—Yes.

13,996. You mean that the nut being screwed home pinches the channel iron and the lug together?—Yes. I would observe with regard to anything like two tons being put upon those bolts, that they were in such a position that it was exceedingly difficult to tighten them up at all, and that in some cases I find that they have absolutely had to cut away the upper part of the channel iron to enable them to be turned round at all.

13,997. But whatever the strain put upon those bolts was, whether it was two tons, or any other quantity, the action due to that retaining of the strut in its position with reference to the lug would be due to friction, and would be a definite proportion of the stress upon the bolt?—That would depend upon the nature of the surfaces, and if you had a rounding surface of about one-eighth of an inch in projection, with a very limited area indeed, the strut being also kept partly off by its torsion at the other end, the amount of pinching action would be exceedingly slight; in many cases I could get my rule in between the struts and the lugs.

13,998. Of course, the nature of the surfaces, as we all know, affects the friction; in this case it is the friction of iron upon iron?—Yes.

13,999. Do you mean to suggest that friction varies with the surface in contact or with the pressure?—If you had surfaces under the same condition, really flat surfaces without inequalities, then the amount of friction would depend upon the insistent load and not upon the area of those surfaces within certain limits.

14,000. And of axioms; it is an axiom, is it not, that the friction is proportionate to the pressure, and not to the bearing surfaces?—It is so; but those bearing surfaces are so exceedingly limited that that axiom could not be applied. Where you have two rough unequal surfaces, with absolute inequalities and depressions, and not really plain surfaces, and when you have the opportunity of examining, after they have been bolted together, how far they have been rubbed, you can judge what would be the perfectness of the contract, and the resistance that they would offer. Having seen these channel iron, I do not hesitate to say that they really give no efficient friction to motion in reference to the lug.

14,001. We had better keep to the point, and not go off to the general question. Those surfaces, which were pinched together by the bolt, are brought into contact under certain pressure, and they are both iron surfaces whether they are small, or whether they are large, are they not?—Yes.

14,002. Do you mean to suggest that the axiomatic rule of friction, that friction is proportionate to pressure does not apply when the surface is small in that way?—Certainly, if you get a rounding surface, as this was, you would not get the same amount of resistance which you could have got if those two surfaces had been properly fitted together and then screwed up tight into hard contact.

14,003. You mean to suggest then that with the same stress upon the bolt you get a less friction, if the surfaces in contact are small, than you would get if the surfaces in contact were large?—Under the conditions in which these channel iron were not as a general proposition of smooth bearing surfaces.

14,004. Let me see the channel iron for the moment to take care of itself, and discussing simply that part of the channel iron which is involved in this case, that is to say, a channel iron held to a lug by the pinching action of bolts screwed up so as to squeeze together the contiguous surfaces of the iron of the lug and the iron of the channel iron, do you mean to suggest that the strain upon the bolts being the same, the friction is less if the surface in contact is less?—Yes, with such limited surfaces as you have here, I do.

14,005. And you lay it down, as an engineer, that with the same pressure, under those circumstances, the friction varies with the area of surface in contact?—Yes, because if you had put very great stress upon those bolts, and then endeavoured to move the strut, you would have done it by the abrasion of this ridulously small surface which was not a quarter of an inch in superficial area. You would have avoided it; you could not have obtained the same pinching action as if it had been a fair surface screwed up with the same stress upon the bolts.  

14,006. Your views upon that point are somewhat novel, but still there they are. Now I pass on to the next. Assuming that your views are right in this respect, and putting aside altogether this pinching action, you have pointed out that the bolts are an inch and one eighth bolts in a hole of an inch and a quarter diameter.

14,007. Am I not right that being so, the utmost amount of distortion of structure that will permit will be the difference between those two diameters, that is to say, one eight of an inch in the most adverse circumstances?—Oh no!

14,008. Do you follow what I mean?—Quite. Many of the holes in the channel iron, which were originally
punched with a circular punch, had been elongated by a flange tool into much more than an inch, as I could show you here.

14,009. That is not in the slightest degree an answer to my question; it is entirely going away from the point. I draw your attention to the facts which you stated before, and I will deal afterwards, if you please, with the accidental elongations. Assuming a hole of an inch and a quarter with a bolt of an inch and an eighth under the most adverse circumstances, that is to say, assuming that the bolt was on the wrong side of the hole to take the stress, you get a play of an eighth of an inch, and no more. — Do you not get a play of a quarter of an inch? — I think not.

(The Commissioner.) You get an eighth of an inch to each hole, assuming there to be one hole. That would be a quarter of an inch.

14,010. (Mr. Bidder.) You would get an eighth of an inch at each end; that would be a quarter of an inch under the most adverse circumstances. — You would get an eighth of an inch at each end; that is to say, you would get a quarter of an inch at both ends.

14,011. So that the amount of play, I may say, due to that cause, assuming that there was no other holding, and that the punching action failed or was non-existent, would vary from nothing up to a quarter of an inch, according to what happened to be the relative position of the bolts previously? — Yes.

14,012. Of course I do not want to repeat the questions more than I can help. Let me ask you at once whether the same observation will apply to the same extent in the case of the ties? — It would not apply at all in the case of the ties, because they are tightened up against the hole, wherever they may be.

14,013. My question may not seem to follow consecutively, because I have adopted the order of the Report. If you pass on to the bottom of page 9 there is a statement there which may be of some importance under certain circumstances, and which I have not been able altogether myself to verify; — Considering that the columns are 76 feet in height, that with a wind pressure of only 20 lbs. on the square foot, a pressure of 337 tons would be thrown upon the eastward 18-inch column at the time of the passage of the train, and that a horizontal pressure of 37½ tons is acting against the top of the column, it is easy to conceive what must have been the inevitable consequence of pulling the part of the ties. My question is: how you arrive at the figure of that pressure of 337 tons upon that particular column? — It is from the fact that it is giving credit to the holding down of the flange bolts. If you exercised a force of 20 lbs. of wind pressure at a height of 80 feet multiplied into the width of the girder. You would find in giving credit to the flange bolts in holding down that with the resulting pressure upon the column No. 4 would be that amount of 337 tons. It is not the pressure due simply to the weights upon it; it is as well the compressive strain due to the tensile strain of the bolts on the other side.

14,014. Due to the leverage of that wind acting at the height of 80 feet? — Yes.

14,015. I do not quite follow that, because I think you have shown further on, that the surface is such that every pound of wind is equal to 1½ tons of pressure? — I have not reduced it so. It may be so.

14,016. You give the total surface with the train upon the bridge as 3,760 feet? — But you must take into account the pier.

14,017. But the pier is not large at a height of 80 feet? — No, because there is the reduced centre of pressure, 77 feet.

14,018. Be it so; but that is a total surface of 4,148; that would be a little under 2 tons, 1½ tons? — Yes, the calculation in detail.

14,019. Therefore a pressure of 20 lbs. would be about 37 tons of wind? — Yes, very likely. I had better refer to my figures.

14,020. We could not follow how that figure had been arrived at? — It was arrived at by calculating the moment of the wind which comes out at 8,881,400; that is multiplying 319,052, as you have it there, by 20. I start by a proper moment, as you assume, only it is in pounds. At the bottom of page 24 you will find that the moment is equal to 319,052 multiplied by f. I having multiplied it by 20 get the result of 6,381,400 foot-pounds. Then I have an initial pressure to begin with of 288,458 pounds due to the downward pressure, and then I have the unbalanced pressure which was required to resist it. I took the weights on the other columns by their distance, so as to give their moments, and then I took for the unbalanced moment the resistance of the bolts through their centre of effort; and that gives me 336-62 foot lbs.

14,021. That means tons of moment, then? — No, it does not; it is reduced as tons of vertical pressure. That is the vertical pressure which would be created at that point. It means the pressure which would be brought to bear upon that column by applying a lateral stress of twenty times, 4,143 feet at a height of 77 feet.

14,022. If you told me it was the moment having regard to the height of the wind, I could follow you; but when you tell me it is simply vertical pressure, I am puzzled, because I find, at page 7, that you have given as the pressure or the east rollers with 20 lbs. of wind, and with a train on as being 485,775? — Those are dead weights without the stress occasioned by the horizontal force of the wind. We should examine: the pier to be turned end up, and had to be a cantilever.

14,023. That is, you say, as I understand, the dead weight of 485,775 lbs.? — Which are you referring to?

14,024. At page 7 you have taken into account the effect of the wind pressure, and throwing the weight on to the pillars? — Yes, that refers to diagram No. 5, where no account is taken of the lateral stress.

14,025. That obviously is a much smaller figure, because it is only about 227 tons which would be borne by the same column. — Very much smaller. If you want to get the stress occasioned by the wind, you must multiply 4,143 feet by 77. That does take account of the lateral stress, but it does take account of the unequal distribution of weight upon the west rollers.

14,026. The dead weight, as you call it, under those circumstances, you have shown as 227 tons in round numbers upon the eastern rollers; if we put half of that on to the outside pier, that is 110 tons; now the other 227, you tell me, is the component of the lateral force of the wind; how do you make out that the lateral horizontal force of the wind has a vertical component downwards equal to 20 lbs. upwards? — The vertical stress upon that column to begin with is 288,458 lbs., being the half of what you have at page 7.

14,027. That is 110 tons? — It is 288,458 lbs.

14,028. Unless my copy is different from yours, the pressure on the eastern rollers with the train on and 20 lbs. of wind is 485,775 lbs., and the half of that is 243,000 lbs.? — Yes.

14,029. And that is about 110 tons, I think you will find? — It would be better to keep to pounds, would it not?

14,030. Assuming that you are right in saying that the pressure is divided equally between the 18-inch and the two 15 inches, that would throw 110 tons on the 18 inch column. There can be no question about it if your figures are right? — Certainly.

14,031. Now, then, there is another 227 tons additional vertical pressure, which you tell me is the vertical component of a horizontal force of wind blowing upon the girder? — Yes.

14,032. How can that be? — I have here a structure which has a certain dead weight, no matter from what source, put upon it at this point (pointing to the model.)

14,033. You are not talking about moments? — I am talking of a dead vertical pressure resulting from...
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You have, to begin with, a certain vertical weight through the centre of that column (pointing to the model), which is equal to 289,458 lb. You have then a horizontal force acting at the top of the rollers (or acting at 77 feet taking the whole surface) equal to 4,125 feet per second, multiplied by 20, and that in addition to the weight, which has nothing whatever to do with the stress, has to be borne by a tensile strain upon the eastward column, and a compressive strain upon the westward. Whatever their weight may be, it has nothing to do with the resolution of that strain.

14,045. Consider the circumstances of that eastern column; on the top of it you show on page 7 that there is a downward force which is equal to 110 tons?

14,046. If it were not a rigid structure the tie-bars would have been inadequate; and therefore before that compressive strain could have come upon the column, the structure must have been overthrown.

14,049. That is not at all what you said in the paragraph. You said there was a pressure of 337 tons on the column, and you may imagine, therefore, what will happen if the ties are slack. Now you admit to me the existence of that pressure which you assert in the paragraph can only occur in the event of those ties being strained to a point at which the downward vertical component of each tie is equal to 135 tons; I must not be misunderstood here, because it is perfectly clear to any person who reads what I mean. If the structure is rigid, 337 tons will be brought upon this pier; therefore I say it is evident what must be the consequence of any want of rigidity.

14,050. Where is the statement saying that that is qualified by the rigidity?—The very structure of it. I am going on with my argument. I have pointed out what the strains are upon the structure considered as rigid. I go on to show that it was not rigid, and what the effect of slackness would be. Then I go on to show what strain really would come upon those ties, and have to be transmitted through them, and therefore what would be the effect of any slackness in them.

14,051. If you will but look at what you said in the paragraphs, you have been pointing out that the channel irons are imperfectly connected, that the gibbs and catchers are rough, that the tie-bars are not tightened up in a way that satisfies you, that packing is requisite, that the slackening of the ties removes the condition upon which alone the power of the structure to resist overthrow by lateral pressure depends, and so on; and then you enlarge on what you found in the ruins of pier 22, and the present state of 29 and 31; and then you go on to say, "Considering that the columns are 76 feet in height, that with a wind-pressure of only 20 lbs. on the square foot a pressure of 337 tons will be thrown upon the eastward 18-inch column, it is easy to conceive what will happen if the ties are slack."—Yes. What would happen would be that in the transmission of that strain the whole structure would perish. That is the strain which would be transmitted if the ties were capable. It is the resolved strain resulting from that wind-pressure, and it is just because the ties are not sufficient that you see what the inevitable consequence of the slackness must be.

14,052. At any rate I think I have made that clear. That statement at the bottom of that page is only true on the assumption that the ties have a vertical downward component of 15 tons each?—It is only true as regards the amount which these tie-bars could transmit; but it is true further, in the fact they would be called upon to transmit it, and would probably fail in doing it.

(Mr. Horilon.) How many of these tie-bars would be operating?

(Mr. Bidder.) Fourteen; seven on each side.

14,053. (The Witness.) The whole, necessarily 56. I would make this observation, inasmuch as my calculations show that the 86 lbs. of wind would be required to overthrow that pier; it is perfectly clear that, supposing it had been in a perfect condition, 20 lbs...
would not have done it. Then I say that under those conditions, when the 20 lbs. came against it, 337 tons would have been pressing upon that column.

14,054. And that 337 tons pressure could not be carried without the ties until the ties were exercising a vertical downward pressure of over 15 tons each?—No, that is not so, because with a wind pressure of 36 lbs.—

14,055. We shall never get on if you go away from the point. I am discussing the meaning of a particular statement, that with a wind pressure of 20 lbs. there is a strain of 337 tons, and, if I am not right in understanding that that pressure of 337 tons cannot exist unless the ties are exercising a pressure which gives an average downward component of 15 tons?—The strain which would be produced upon the straight tie bars would be about 1,600 lbs. each, and less upon the others.

14,056. You may lead me away as many times as you like, but I always come back to the same point. This column has a weight upon the top of it; it has got 14 ties loading downwards, and no more ties in connection with it; and whatever downward pressure is put upon that column, additional to the 110 tons, must be by those 14 ties, and nothing else. So far we are agreed upon about ten minutes ago. That being so, does it not inevitably follow that if you have, as you show here, a gross pressure of 337 tons, an average of 15 tons must have been put on per tie. You cannot get out of it, you know?—It might be so if they yielded.

14,057. It must be so. If ever that column is to have 337 tons upon it with 20 lbs. of wind, there must be an average downward vertical component on each tie of 15 tons?—It was precisely because those ties were not adequate to bear that the structure fell.

14,058. Am I not right that it must be so. If that pressure is to exist there must be an average downward vertical component of 15 tons per tie? Yes or no?—What is the weight you make it in tons, the unbalanced weight?—I will go over it again. You have stated that there is a downward vertical pressure, under these circumstances, of 337 tons?—I have not stated that; I have stated that there would be under certain conditions.

14,059. Under the conditions of 20 lbs. of wind?—Yes, if the ties could have transmitted it. That is the whole implication. It is perfectly clear that either the structure is a lattice girder competent to transmit that strain or that; if it is not, it must have failed.

14,060. You may diverge as many times as you like, but I shall come back to precisely the same point if we should here till Doomsday. You have stated that with a wind-pressure of 20 lbs. to 20 feet, a pressure of 387 tons would be thrown upon that column, which you tell me is downward vertical pressure, you have shown at page 5 that the downward vertical pressure on the top of the column, is equal to 110 tons, and there remain 227 tons, which you admit is put on by the ties, and nothing else; and there being 14 ties, I ask you must it not, inevitably be that the ties have put on a downward vertical pressure of 15 tons each upon the average?—They would have been called upon to do it, and in doing it they would have failed.

14,061. Yes, or no?—I say yes, they would have been called upon to do it, and in doing it they would have failed.

14,062. And until that strain has been called for, that pressure could not exist?—It could not. I do not pretend that any columns failed by virtue of their crushing strain; none of them did; I give you an illustration of the utter inadequacy of the ties. That would be the strain if the ties were efficient, but the ties were insufficient, and therefore they failed.

14,063. You also pointed out in your Report the possibility of the ties getting loose, and the fact that certain of them had apparently got loose, and that a piece of packing iron had been put in, and then the tie tightened up again?—Yes.
14,077. I ask you whether any of these holding-down bolts have been uprooted out of their holes by the accident?—Yes, they have, having split the stone; and if you produce the photograph book I can show you.

14,078. Leaving out cases where the stone has been split, is there any instance in which a holding-down bolt has been uprooted out of its hole?—Yes, I can show you on the photograph.

14,079. Will you show me an instance where a holding-down bolt has been drawn out of its hole?—It is at pier 9 (pointing to the photograph).

14,080. That is the westernmost column of pier 9?—No, it is No. 6.

14,081. Do you point to that as being an instance of a holding-down bolt being rooted out of its hole?—Yes.

14,082. Does it not appear that the stone into which it was buried has been split into fragments?—It has been split in half, and the bolt drawn through it. The drawing of a taper bolt through a taper hole split the stone. It was uprooted, and in being uprooted it split the stone that it was drawn through.

14,083. You suggest that the splitting of the stone is the cause of the splitting in the easternmost column of pier 9?—Undoubtedly. There are three or four instances.

14,084. In that case it appears that the stone immediately below the bed-plate is still in contact with the bed-plate, and that there has not been the least separation between the bed-plate and the stone, and that it is the lowest stone below that which has been broken; and fragments having fallen away the end of the bolt is exposed?—Because that is where the stress was. The other part is not conical; it ceases to be conical when it gets into the other stones. It is thrust back about two feet from its place to the west.

14,085. (The Commissioner.) It is not immediately obvious to me; it belonged to the fissure a little to the left of it?—It is as you say. That upper stone sat upon the step that you see there.

14,086. And it drawn away a bit of the cement?—Yes, it split the lower part.

(Mr. Bidder.) You see what I mean, Sir. There is no separation between the upper stone and the bed-plate.

(The Commissioner.) There is a clear separation between the upper stone and the lower stone, but not between the upper stone and the bed-plate. The bolt has been drawn out from the lower stone.

14,087. (Mr. Bidder to the witness.) I forget what you gave us this morning as the ultimate strain, according to your calculations, upon the bolts at the time the thing breaks?—I did not give you the strain upon those bolts.

14,088. You must have got it, I think. You gave us the ultimate tension of the bolts, did you not; it is involved, 1 think, in your calculations? I gave you the ultimate strain of those bolts.

14,089. But, in your calculations of the overturning of the bridge, what was the ultimate strain upon the bolts?—You could not have transmitted more strain than the flange bolts would have given you. It is clear that the resistance there was less than from the flange bolts.

14,090. You stated, I think, with an initial strain of two tons per bolt?—That was not the holding-down bolts; that was the flange bolts as amongst themselves. In the mode that I have assumed that the structure fell, there was no pulling up strain, and most of these photographs bear evidence that these very columns turned upon their bases, and are lying so now.

14,091. You are not in a position to tell me what, according to your calculations, would be the strain actually upon that bolt at the time when, according to your view of it, it split the stone?—It would be impossible to say that. It must have been very great, because it is a very strong stone; it is a sound and very good stone, and it broke a section of five square feet. The section of the stone where broken is four feet by one foot three inches.

14,092. You have calculated the strain upon the flange bolts, have you not?—Yes; but the fulcrum which is pulling against them is also on the base piece.

14,093. You have calculated the strain upon the eight bolts that held down the column to the bed-plate?—Yes.

14,094. Assuming these strains, it is not a very difficult thing to arrive at what must be the corresponding strain upon the four holding-down bolts?—No; there is very little strain on the holding-down bolts under the circumstances which I supposed.

14,095. You believe that the strain on the holding-down bolt at the time of the accident actually split the stone in the second course of masonry?—It has done so, as a matter of fact.

14,096. It could not do so without some strain?—Undoubtedly. That simply showed that there was a weak point there.

14,097. But the weakest point is sufficient if there is any strain put upon it. Will you explain to me how a holding-down bolt could split, if it did split, the stone in the way you suggest without any strain being exerted upon it?—There must have been a very heavy strain indeed upon it.

14,098. A moment ago you told me that there was not any appreciable strain upon the holding-down bolt?—No, I beg pardon. What I say in my hypothesis of the 36 lbs. of wind is that no strain of importance would come upon the base pieces, because they were the turning points. The pier that was overturned bore upon the base piece and severed its connection with it by bursting the bolts bearing upon the fulcrum.

14,099. If I fixed a column on to this book and put strains upon it, giving it a strong tendency to go over so that there is compression here and tension there (describing the same), the same thing must happen: the book below surely; you do not mean that the book below can remain entirely impactive without any tendency to turn?—No, you do not mean that. It might be possible to have that strain upon the outer bolt; you put a lesser strain upon the two opposite bolts; and you do not put any upon that (pointing to the model).

14,100. Upon the outer holding-down bolts would there be, as a matter of fact, in your judgment, a continual strain or not?—As a matter of fact, there must have been an enormous strain.

14,101. On your hypothesis there would be very little strain?—Not very much.

14,102. Then your hypothesis has very little relation to the fact?—My hypothesis is, supposing that every part of the structure was sound.

14,103. On the bolt hypothesis, which you say assumes a perfect and rigid structure—No, I beg your pardon.

14,104. Then what does your hypothesis assume?—That the ties each exerted an initial strain of two tons, and would then bear a strain according to the results obtained by Mr. Kirkaldy.

14,105. On your hypothesis there would have been very little strain upon that windward part—I do not like to assert it generally in that way. It can be calculated out if you wish it. You ask me to give you a general answer. Comparatively, it is small. If you want to know actually what it is, it can be ascertained; because it is only in proportion to its distance from the centre upon which it turns.

14,106. The distance being greater, it would be less?—It would be less, of course.

14,107. Perhaps you will be able to ascertain by Monday morning what it would be?—The other bolts, I think, had about four tons on them ultimately, and perhaps this might have five tons.

14,108. I do not hold you to that particular figure, but it is what would be the strain upon Monday if, on calculation, you find that you have made a mistake? Would five tons pressure produce such an effect as is shown on the photographs?—No, the column is still bolted on to the base piece, and that shows that the column broke not there, but at some higher point, and that it was pushed back two feet after it was carried over (describing it). That shows an inherent defect in some other part of that column.
14.109. On your hypothesis that all the parts of the structure were acting as they ought to act, the pressure on the holding-down bolts would have been comparatively moderate, certainly quite inadequate to produce the results which have been produced in the way you describe?—Yes; the failure in some of the other parts increased the strain there.

14.110. Now would the failure or imperfection of any part of the bridge bring an increased strain upon that bolt?—Very easily, if these ties failed to support, or if anything broke the connexion between the No. 6 column, and the adjoining one, and that was turned over with a leverage, it would have done what it has done; and instead of turning upon the line of bolts, its fulcrum, it has turned upon the joint of the stone as its fulcrum, and wrenched it out. The fulcrum has been further inwards. It appeared that the joint of the stone was weaker than the base plate.

14.111. You must remember that this was one of the windward columns, and not one of the leeward columns. I suppose you will agree with me that if you take away the ties, or one of the ties, the greatest stress is thrown upon the leeward columns?—Take away the ties and they all fall over together.

14.112. That is as it may be: but the ties distribute the stress from the leeward columns towards the windward columns?—That may be so.

14.113. And, pro tanto, they tend to throw an additional stress upon the windward columns?—Yes.

14.114. This being a windward column, if the ties are defective, it ought to have less stress upon it?—The ties which bound it, I said were No. 6 to No. 1; but that did not fail, as a matter of fact, I have assumed that the column would turn over upon the line of bolts, in the base plate. In that column the bolts of the base pieces have hole, and it has turned over at a lower point upon the line of the stone, showing that the resistance offered by that stone was less than the resistance of the bolts. That is all it shows.

14.115. I will read to you what Mr. Albert Grothe says with reference to the manner in which these stones were not as hypothenus you supposed as you supposed them to be.

14.116. What would be the tensile force that would be put upon a bolt in screwing up the nut?—It would depend entirely upon the smoothness of the thread, and the looseness of the nut, and a great variety of causes.

14.117. The looseness of the nut cannot have much to do with it?—It has a very great deal to do with it.

14.118. You have assumed a strain of two tons per nut as being the strain on the flanges?—Yes.

14.119. Is that in your judgment a reasonable assumption?—I think so; I do not think they ever bad so much.

14.120. It is a liberal assumption, is it?—It is a liberal assumption.

14.121. If, in screwing up these holding-down bolts a strain of two tons was put upon them, do you believe that two bolts, after the bolt had been in stone cement for five or six weeks, would be sufficient to draw it up?—Yes, because there might be an imperfection in the cement.

14.122. I agree that if the cement did not adhere to the hole, 20 lbs. might do it; but under ordinary circumstances, the cement having been properly put in and having been properly set, do you believe that a pressure of two tons would suffice to draw it out?—No, I believe it was because of the imperfections.

14.123. The cement not having adhered?—Not having set properly, or not having been properly mixed.

14.124. Was it that which ultimately held it after the cement and the bolt had been drawn up 8 inches?—You must see evidently that, if you draw a head which is 16 inches in length, through a hole 2 feet 6 inches, it is drawn until the resistance is too great to draw it any more; it can cut down the screw, and break the tool and then he could not have got the tools to turn for that (pointing to the model), so that the proper remedy, which could be in none but the sharpness of the tool, was to put the packing pieces or washers on, and finally the nut on the top. That is the real history of this bolt, and not that bolt has been pulled up in the screwing.

Do you say that that is incredible?—It is. That bolt weighed about 50 lbs., and a man merely holding it at the end of his arm to steady it would have found it very difficult to steady it anywhere except on the bottom of the stone. It would certainly show great carelessness, because the holes should have been sounded to see that no dirt was in them, and then the bolts could have been put down to the very bottom.

14.125. I notice that with reference to this particular master, to take it out of the region of hypothesis, Mr. Gröthe was asked by Mr. Webster, at Question 13,334: "Q. You remember being referred to with, I think, five or six washers?—Yes. Q. Have you, or have you not, any recollection of that bolt standing up when it was originally fixed?—Yes, I have always known that bolt since it was in its place. Q. And it is a matter that you have a distinct recollection of from the time the bridge was constructed?" In answer to Mr. Webster's question, he swore as a fact, that he recollects this bolt as standing up in that position from the first, and that it was not pulled down, you are prepared to adhere to your statement that his evidence in his statement in his evidence on the subject is incredible?—I heard his evidence, and what I gathered from it was that he had seen the bolt in that condition after the washers had been put on, and when its altered height was apparent. Previously to that, when it was standing out 3 feet, or nearly so, above the surface, any inequality would have not been observable.

14.126. He has a personal recollection of that bolt standing up when it was originally fixed, and he had known it since it had been in its place, and with that knowledge he swears that the cement had nothing to do with it. Do I correctly understand that you still, upon mere theoretical considerations, believe that that is incredible?—I can hardly believe that such carelessness is credible. My belief is that it is incredible, and that his observation applies to a time after the base plate was fixed with the washer upon it.

14.127. What would be about the tensile force that would be put upon a bolt in screwing up the nut?—It would depend entirely upon the smoothness of the thread, and the looseness of the nut, and a great variety of causes.

14.128. That is quite possible after the accident, but have you found any place where the cement was inferior or of insufficient quality?—No, I have not.

14.129. Is there any indication that the cementing of those bolts had not been properly carried out?—It
could not have been properly carried out if it were done with a bolt 8 inches out of position.

14,130. That is in another respect. Did you find any case where the cementing was not done so as to give a good hold on the stone in the case of these bolts?—Yes, I have found cases in which the cement has come away from the stone entirely, as you see in that case.

14,131. But the stone is gone altogether, I think, in that photograph; is it not?—Yes, but part of the cement remains attached to the bolt. The adhesion between the iron and the cement would be double the adhesion between the cement and the stone. The adhesion between the cement and the stone has been the least, evidently.

14,132. A portion of the cement has remained upon the bolt?—Yes. (The Commissioner.) Is the theory upon this point, Mr. Bidder, that the bolt was not resting upon the bottom of the hole, and was purposely held up eight inches above the bottom of the hole? (Mr. Bidder.) No, Sir, Mr. Grothe said yesterday that the men held them in the holes, and I think he said in some cases something might have got into the hole; sometimes he said the bolt did not reach the ground in the bottom of the hole, because something had got in.

Adjourned till Monday next at 11 o'clock.

FIFTEENTH DAY.

Monday, 26th April 1880.

Mr. Henry Law called again.

Further cross-examined by Mr. Bidder.

14,135. You have just told me in conversation that you have calculated since we last met one figure I put to you, and which you were not able then to give me; that was the strain upon the holding-down bolts at the time when you assumed the structure to be on the point of overturning. I understand you to say that you are now prepared to give that figure, and perhaps it will be convenient now to give it?—The distance of the two holding-down bolts apart is 1 foot 10 inches upon the line of the strain.

14,136. There are four bolts?—Yes; it turned upon two of them and broke the other two.

14,137. (The Commissioner.) You mean the two outside ones?—Yes, it turned upon one pair, and it broke or pulled out the other pair, and the moment which I have calculated as being the moment upon the flange bolts is 88 foot tons. That has to be borne by two bolts; and, therefore, it comes to 44 foot tons upon each of these holding-down bolts, and that divided by 1 1/8—that is 1 foot 10 inches—gives 24 tons as the strain upon that bolt.

14,138. Twenty-four tons upon the bolt itself?—Yes, upon the bolt itself, under the conditions assumed by me that the structure was turning over with the separate columns.

14,139. (Colonel Yolland.) Twenty-four tons to the square inch do you mean?—No, twenty-four tons actually. The strength of the bolt, taking it as of the same quality of iron, as the flange bolts determined by Mr. Kirkaldy’s experiments would be forty tons.

14,140. (Mr. Bidder.) Twenty-four tons on each bolt?—Yes. It will be observed that two of the bolts broke, and two were pulled out of the stone, breaking the stone.

14,141. (Mr. Barlow.) And in other cases the stones remained attached?—In other cases the stones remained attached to the base piece and came away along with it. Whenever was the weakest point went. We cannot say what the strain on those bolts was, but we can say that it would not have exceeded twenty-four tons because the flange bolts would then have given.

14,142. (Mr. Bidder.) I suppose what you have allowed in your Report in the first page of the Appendix still remains true does it not; that the ultimate tensile strength of the holding-down bolts was greater than the ultimate tensile strength of the flange bolts?—Yes, they have the same relative proportions as stated there, but you must add so much more. You must add 1/4th more.

14,143. You have given us a pressure of 24 tons upon a particular bolt, but it is true that the ultimate strength of the holding-down bolt is greater than the ultimate strength of the flange bolt?—Yes, it is in the ratio there stated.

14,144. Now I will take up my cross-examination at the point where I left off on Friday afternoon. I got as far as page 10 of your Report. I want to ask you one or two questions about the last paragraph in that page; you state there, which we know as a fact that certain columns were of unequal thickness of metal, and you say in some cases the metal on one side was only 3/16ths of an inch, and on the opposite side 1/8 inch. I stop there to ask you in how many cases did you find that difference of thickness of 3/16ths on one side, and 1/8 inch on the other?—Only in one.

14,145. Why do you say “in some”?—Which is the paragraph that you are referring to?

14,146. I am referring to the bottom of the page?—I would correct that. I did find 3/16ths in more than one instance—I only found half an inch in one.

14,147. I have never heard of half an inch yet?—I have got specimens in court.

14,148. You speak of 3/16ths, are you referring there to the specimen that was produced to Mr. Grothe?—I do not know whether it was produced to Mr. Grothe—I was not here.

14,149. A specimen was produced to Mr. Grothe, and measured by him, and found to be 3/16ths?—If it was produced here it is a matter of fact.
14,160. (Mr. Vawser.) Some of these specimens were shown to Mr. Campsfts?—Yes. I produced other specimens in court.

14,161. (Mr. Bidder.) In how many does did you find the metal on one side only 4ths?—In two columns.

14,162. I should like to see the 4-inch one?—I have got it here—it is being looked for.

(No answer.) I have not seen 4-inch. These are what I showed to Mr. Campsfts (producing the same).

(Mr. Bidder.) I shall be glad to see the 4-inch one presently.

(The Witness.) The least I found was 4-ths. When I say least of course there were more than two cases in which the hole was nearly through, but the column No. 4 in pier 33 was 4-ths at one point.

14,153. I will take that—have you got it here?—No, it is a base piece that I could not bring. I rather think it is in London; the whole piece.

14,154. This is the first we have heard of half an inch, and the first we have heard of 1 inch?—I have had no desire to magnify the imperfections, and I have not gone to the extreme points. My desire is to state the truth as I found it—to exaggerate nothing, and not to create a bad impression.

14,155. Let me see the 4-ths one?—It is at Mr. Kirkaldy's.

14,156. Let me see the 4-inch one?—It is half an inch externally, but when you deduct the holes it is not 4-ths. I have set the calipers, and there is the and B. The first of the two A is 4-ths, and B is 4-ths. Is it 4-ths or 3-ths?—A 4-ths. I did not refer to it because it did not extend much.

14,157. What extent of it did you see—when you said "dying out upon the piece that was left," you mean that the iron was thickening?—Yes, I measured the thickness of the metal in that column at various points round. I commenced at a point where it was 4-ths.

14,158. What area of 4-ths did you find?—It came to that perhaps for the extent of an inch.

14,159. Do you mean a square inch?—No, I could not tell what it would be in square inches. I could only see it in the circumference round the column, the other part of the column is gone. The other part of the column is 1 inch thick, and at another point 1 inch, the opposite point is 4-ths.

14,160. I want you to take the very worst case of all, a column which on the one side you say is 1 inch thick?—1-4-ths—just over half.

14,161. I want to have it clear whether the cases of 3-ths of an inch or less, are all covered by those two cases?—Yes, that is so.

14,170. But the 4-ths you say is not a column?—It was a piece which was attached to the base-piece, a piece of column immediately above the base-piece.

14,172. Above the flange?—Yes.

(The Commissioner.) Mr. Barlow says he does not quite understand it, and I do not quite understand what is meant. Are there three columns or two columns, or four columns, that the witness is speaking to.

(Mr. Bidder.) Two columns.

14,173. (The Commissioner.) Two columns in which there is a thickness of 4-ths?—Yes, there is only one in which there is only 4-ths.

(Colonel Yolland.) What column is that?

(Mr. Bidder.) In pier No. 33.

(The Witness.) No. 4 in pier 33, and there is another column which is in London, which is No. 6 on pier No. 34, and that ranges from an inch to 4-ths of an inch from top to bottom on one side, and most of the specimens which have been produced in court are from that column.

14,174. (The Commissioner.) There are two columns of 4-ths?—There are two columns in which there is a thickness of 4-ths or less than 4-ths.

14,175. In the 4-ths one of those columns?—Yes.

14,176. (Mr. Bidder.) There are two columns A and B. The first of the two A is 4-ths, and B is 4-ths. Is it 4-ths or 3-ths?—A 4-ths. I did not refer to it because it did not extend much.

14,177. A and B are the two columns which justify this statement in this paragraph?—Yes.

14,178. Now as regards A, which is 4-ths, over what area does that extend?—I cannot tell because the other part of the column is gone.

14,179. You said just now that it is limited, you had some reason for making that statement, I suppose?—Yes, because I saw that it was dying out upon the piece that was left.

14,180. What extent of it did you see—when you said "dying out upon the piece that was left," you mean that the iron was thickening?—Yes, I measured the thickness of the metal in that column at various points round. I commenced at a point where it was 4-ths.

14,181. What area of 4-ths did you find?—It came to that perhaps for the extent of an inch.

14,182. Do you mean a square inch?—No, I could not tell what it would be in square inches. I could only see it in the circumference round the column, the other part of the column is gone. The other part of the column is 1 inch thick, and at another point 1 inch, the opposite point is 4-ths.

14,183. I want you to take the very worst case of all, a column which on the one side you say is 1 inch thick?—1-4-ths—just over half.

14,184. On one side 1-4-ths, and on the weak side for one inch of the circumference it is 1-4-ths of an inch, put that column in a position amongst those columns where it would be exposed to the severest strain, and where it would be in a position that would be the worst for it, have you any reason to believe that that column would fracture under the strains that you have calculated?—No; I do not think it would, nor do I attribute the failure at all to the shape of the columns; it evidently has determined the line of fracture in that particular column. I do not say it led to the failure, but it determined the line of the fracture, because the bolts stood—it did not contribute to the breaking of that column.

14,185. Was that a 15-inch or an 18-inch column?—An 18-inch column, No. 4.

14,186. I said nothing about the insufficiency of the crushing strain; in fact, I showed that the strains were exceedingly small wherever I referred to them.

14,187. Now I will pass on to the paragraph at the top of the page 11 of the Report upon the subject of burnet on lugs, did you find any burnet on lugs in the high girders?—I do not know how I could detect
the structure; I think I said in my evidence-in-chief that I did not detect any burn on lugs, and I did not know how to look for them, the structure has been painted over and over again.

14,187. Have you any reason, as far as your observation goes, for stating that any of the lugs that hold the diagonal tie-bars in the bolt givellers were burnt on?—No. I have no reason for saying that, but I have a reason for saying, at least I see that in some cases the columns are broken away with a very much larger section of metal than the lug would have offered, which would lead me to think there was a weakness in the column there, a crack in the column. The lug has come away bringing out a large piece of column upon it.

14,188. Which would seem to indicate that the lugs held pretty well?—They held very well, and that is where I think the burning on of a lug would be so prejudicial. The evidence was that it tended to produce a crack either in the lug itself, or in the column itself by means of its expansion. There were appearances on the photographs which lead to that conclusion.

14,189. I observe, in passing, that at page fourteen of your Report you give the resistance of the tie-bars and the ultimate strain that they could be calculated to sustain as 15,120 lbs.?—Not the tie-bars—the surface of the key.

14,190. The compound structure, the tie-bars, gib, and cotters, and everything?—The surface of the key which was half an inch by three quarters of an inch.

14,191. Taking the compound arrangement of the tie-bars held in the way that is described with that gib and those cotters, you give as the ultimate strain that they are calculated to sustain 15,120 lbs.?—Yes.

14,192. You now know that that is wrong, do you not?—No, I have no reason to believe that that is wrong at all.

14,193. These very tie-bars, with these very gib and cotters have been experimented on by Mr. Kirkaldy, and they have sustained a strain of 56,000 lbs., have not they?—Yes, and in doing so, the keys were crushed to such an extent as to produce a failure.

14,194. They have sustained 56,000 lbs., and in doing so the key was crushed to the extent of an eighth of an inch?—One key was crushed to the extent of an eighth of an inch; the cotters were similarly crushed. We do not know the extent to which the connexion at the bolt hole would have been crushed; we shall know that in a day or two.

14,195. I should like to keep things clear. The statement in this page 15 is that you calculated the greatest strain the tie would sustain to be 15,120 lbs.?—And in doing so, no reason to retract that now.

14,196. I want to understand the thing and to get it clear, because you know that the tests show that the tie-bars did sustain 56,000 lbs.?—Yes.

14,197. How am I to reconcile that with your statement that you have no reason to believe that they are ultimately calculated to sustain more than 15,000 lbs.?—The key when exposed to this compression, and having yielded to an extent which would have led to the overthrow of the structure, brought the whole strain upon the tie-bars, and the ultimate strength of the tie-bars was then exerted, and was equal to 56,000 lbs.; but these very parts had yielded; the crushing strain had caused them to yield; the iron had not sustained that weight, it had yielded.

14,198. Pardon me, you did not expect, did you, or did any man expect that a tie-bar 12 feet 6 inches long would sustain a strain of 15,000 lbs. without any extension?—I am not speaking of the extension of the tie bar at all, I am speaking of the crushing of the key. This 15,000 refers solely to the crushing of those keys; it is as clear as possible.

14,199. Let me ask you this, do you mean to suggest that the yielding of the gib or the crushing of the gib to the extent of an eighth of an inch would bring the structure down?—Yes.

14,200. That is to say, that the extension of the tie-bar caused by the yielding of the gib an eighth of an inch would bring the structure down?—No; let me state it in my own way; I say that—

14,201. I should like an answer first, and then you can give any amount of explanation you please?—Then my answer is that having answered your inquiry in the negative I will now tell you what I do mean. The strain upon the tie-bar produced a compression upon the key of an eighth of an inch, and nearly an equal compression upon the cotters, that is, nearly a quarter; the tie itself extended; I do not know how much, but I will neglect that. A quarter of an inch upon one of the angular tie would have amounted to more than half an inch upon the head of the column, and that would be increased by the height to such an extent as to render the column incapable of sustaining a strong lateral pressure; it would endanger the whole structure. You cannot say it sustains the pressure when it yields to the extent of an eighth of an inch.

14,202. Then in that sense no tie-bar sustains any strain whatever, because every tie-bar elongates when it is under strain?—I do not say so at all; but if the tie-bar is so insufficiently proportioned that the amount of elongation is capable of endangering the structure, then it is not sufficient. This is what happens here.

14,203. The tie-bars were made, mostly in lengths, of wrought iron, were they not?—Yes.

14,204. Every wrought iron bar when under strain extends more or less, does it not?—Yes.

14,205. It must extend more or less?—Yes.

14,206. It is not put into strain until it is extended?—It is usual to key it up to produce an extension so that there may be a normal strain.

14,207. And consequently it is a mere question of degree as to the extension of the tie as a whole?—Yes; but here you have a weak point which is only capable of bearing 4th of the strength of the tie.

14,208. Is not your mode of calculation this, if I have followed you correctly in your Report and the figures you gave on Friday: You first take the effect of the weights of the structure in standing it?—Yes.

14,209. You then go the root of the column; and you take the moment of resistance of the bolts at the moment when they are strained to fracture, to the overturning of the columns?—At both the top and the bottom.

14,210. You then ascertain, by the help of Mr. Kirkaldy's experiments, what at that moment is the extension of the bolt under the stress that is put upon it?—Yes; without that I was not able to calculate at the moment you last referred to.

14,211. You then geometrically ascertain that extension of the bolt ascertain what would be the lateral consequent motion of the top of the column?—Yes.

14,212. You then geometrically ascertain what elongation that requires in the diagonal tie?—Yes.

14,213. And you then ascertain what stress that elongation of the diagonal tie would produce?—Yes.

14,214. And you bring that stress into your calculations as the force tending to keep the columns straight?—Yes. You have neglected the initial strain, which in every case I have added as well.

14,215. Quite so; it is wrapped up in the whole?—Yes, it has to be added to the extension. But now let me mention one circumstance, which is, that the extensions I have taken do not take into account the extension which would arise from the crushing of the screw against the imperfect holes in the lugs; that we have yet to determine.

14,216. You have not taken that into account?—No.

14,217. Let us see how it would have affected the question. It would have given a little more extension of the bolt?—Not of the bolt; it would not have affected the bolt at all.

14,218. It would have produced a little more yielding at the root of the column?—Yes, a little more.
14,219. A little more yielding at the base of the column; and there would have been a little more lateral motion of the column at the top, and therefore a little more elongation of the tie?—No; it would not have affected the movement at the bottom of the column, and would not have affected the lateral movement at the top. What it would have done would allow the tie to be elongated with a less resistance; that is to say, the amount of elongation it gave would have offered less resistance.

14,220. What screw are you speaking of when you say "crushing of the screw"? The transverse screw that holds the sling-plates to the bottom lugs.

14,221. Putting that one aside, I think I have corrected in your mode of calculation?—Yes.

14,222. And therefore am I right in saying that Mr. Kirkaldy's experiments were upon one of these ties, with gib and cotters just as they would be in the bridge?—With gib and cotters, but not just as they were in the bridge, because the end of the sling-plates was secured by a pin.

14,223. With that exception?—Yes, with that exception.

14,224. And the extensions observed by Mr. Kirkaldy are the extensions produced by the lengthening of the tie-bar and the compression of the gib and the cotters?—That is so.

14,225. Therefore in his observations we have the work of the squashing of the gib, and the extending of the tie-bar summed up?—Summed up to the extent to which it would extend at the moment of fracture of the further bolts of the 18-inch column.

14,226. Under the pressure which he has given in his table, he gives us for every pressure the extension of the tie-bar and the compression of the gib and the cotter?—Yes.

14,227. You have given us, as I followed your figures very carefully on Friday, two views of the case, or rather two cases. You have first taken it upon the basis of the bolts being screwed down to an initial tension of two tons, and of the ties being up to an initial tension of two tons, and you have ascertained to what force the wind must rise before any further strain whatever is brought upon the structure?—Yes.

14,228. And that, I think, if I correctly recollect the figure, you stated was 17'81 lbs.?—Yes.

14,229. You have then proceeded, in the way I described just now, to ascertain the effect of the ultimate tensions of the bolts at the point of breaking, the corresponding elongation, the corresponding tension of the tie; and so have arrived at the ultimate moment of stability of the bridge?—I have.

14,230. And the figure you arrived at by that mode of calculation is that 36 lbs. of wind would be necessary to blow the bridge over with a train upon it?—Yes; and I would say this: My desire is only to give you all the information I can. I was going to tell you what the effect would have been of taking in the third tie.

14,231. I do not want you to do that. If you have any necessary explanation do not let me shut it out; but taking my question as a text for a discourse makes my question very much more definite. The view is, upon your own figures, that, putting aside faults of execution, if there were faults of execution, it would have required 36 lbs. of wind to blow this bridge over on every foot of the structure?—Yes.

14,232. Girders, piers, train, and everything?—Yes.

14,233. Just let me draw your attention to one part of the detail of your calculation; I want to test it. I do not, of course, pretend to be able to follow you in all your calculations, but there is one or two matters that I should like to call your attention to.

14,234. (The Commissioner.) That calculation of 36 lbs. is upon the assumption that everything is perfectly strong?—Yes; it is upon the assumption that all the struts have perfect abutments, and all the flanges are incapable of motion; in fact, I have summed that up, and it is upon the notes.

14,235. (Mr. Burton.) Is it upon the assumption that the base of the column was permanently fastened down?—Yes; after that it would require a greater force than the strain upon the flange-bolts to move it, and therefore I have assumed that it was immovable.

14,236. That wind pressure of 36 lbs. would not be necessary to overthrow it; if it was not permanently fastened down a smaller pressure would do it?—Yes; I have assumed that it was bolted down immovably.

(Mr. Bidder.) That is apart from error in the construction of work, if there are any; I wish to keep the two questions distinct—design and construction. At present I am dealing with the efficiency of the design.

(The Commissioner.) Am I right in saying that the reason why both Mr. Barlow and myself put the question was that many of your questions before had reference rather to the workmanship?

(Mr. Bidder.) That is quite true, Sir.

(The Commissioner.) And it is much as you were not specially responsible for the workmanship; we merely wished to know what your question was.

14,237. I am much obliged to you, Sir; I have been asking questions upon the other points because they follow in order in the Report. (To the witness.) Now, I am going to your calculation, which is upon the assumption that the design is perfectly carried out. If you look at page 504, Question 13,925, you say this: "I look then to see what is the extension of the furthest bolt, because that determines the extent to which the column would have been allowed to deviate from the vertical or its normal position at the moment of the bolt breaking, and I find that that would give a horizontal movement at the top of the columns where they are attached to the L-girders of 6'434 of a foot; about seven-eighths and three quarters. Then the next matter for inquiry was what extension would be produced in the tie-bars by a movement of the columns corresponding with 6'434 of a foot at its upper extremity. Taking first the bars between the fifteen inch columns, I make a calculation which showed that the initial strain upon the structure would be 0'52 of a foot."

That calculation appears to be right, according to my checking. Then you say, "The horizontal movement would be 0'792 of a foot: that is the increased horizontal distance between the upper and lower points of attachment, that which I have designed as d in my formula; and the horizontal distance would be the difference between the two sets of panels between the 16-inch columns, to an extension on the bar itself of 0'52 of a foot". Then I say, "A lengthening of the bar?—A lengthening of the bar to that extent. I have in these bars, as in the others, taken an initial strain of two tons on each bar, as being produced by the driving home of the keys; and assuming that they remained in that condition, the strain due to the extension of the tie-bar, which I have given, would add another two tons to the resisting strain of the tie-bar itself, so that the effort which those bars would make to support the columns at the moment when the outer bolts were breaking would correspond with four tons. The trouble is, the horizontal distance to the vertical, it would resolve it to two-thirds, and that for the initial strain would be equivalent to 2,968 lbs. for each tie at its point of application; and if the moment of all the bars is taken for that, multiplying that by fourteen, and multiplying again by forty-two, which is the mean height at which the effort is exerted, you would get a resistance of stability equivalent to 1,745,084 foot-lbs. for the structure before any lateral strain was put upon it, the normal resistance due to the keying up of the ties; and if you double that it would represent the resistance of stability which those same ties would offer when a lateral strain is on the point of breaking the tie-bar itself, and then you give the figures, I believe quite correctly, 3,490,368 foot-lbs."

So that if I follow that calculation rightly, it is this: extension of tie-bar geometrically following the movement of the column,
E. April 11, 1880. that two of four tons, and then you multiply other bar of which you do not know the tension, you must take the tension of the other bar proportionate to its length, must you not?—Yes; that is exactly what I say.

14,255. I am going now to Mr. Kirkaldy's experiments, in order to get from his experiments the answer, what was the tension upon those tie-bars represented by .052 of a foot, and I suggest to you before Mr. Kirkaldy can answer the question I must tell him what the corresponding proportionate extension is upon his tie-bar?—Yes.

14,256. That would be one-sixth less?—Yes.

14,257. And that would be .044 of a foot, would it not, taking off one-sixth?

(Mr. Bidder.) In the ratio of the lengths?

(Yw.) Yes.

(The witness.) It is 135 to 125. We have got the measurements here.

14,258. (Mr. Bidder.) Taking these bars between the 15-inch columns as being 12 feet 6 inches, what would be the elongation in one of Mr. Kirkaldy's bars?—The ratio of length is 11 feet to 12-30; those are the real ratios.

14,259. Will you answer me this question? There being .052 extension in the tie-bar which you took, what extension am I to take in these experiments of Mr. Kirkaldy?—The length of the one is 11 feet, and the length of the other is 12-30.

14,260. What is the corresponding extension?—I am just calculating it; I cannot tell you off-hand.

(Mr. Bidder.) You do not suggest that the ratio of extension would be the same in a long bar as it would be in a short one?

14,261. (Mr. Bidder.) I suppose that a certain pressure would produce double the extension in a 10 feet bar that it would in a 6 feet bar?—Not when you got above 10,000 lbs.

(Mr. Bidder.) You have got the gib and the cotters.

(Mr. Bidder.) You are quite right. There is this difference, that the gib and the cotters would be constant in both cases. I think I can make it simple.

(The witness.) I have the length now, .046.

14,262. If you turn it into inches, it is .052 of an inch?—It may be so.

14,263. What do Mr. Kirkaldy's experiments show to be the strain upon one of these tie-bars, gib and cotters and all, in which you said the extension amounted to .052?—It cannot want a calculation.

14,264. Take the two last, you reject the first, the last one gets an extension of .052 of an inch with a strain of 46,000 lbs., that is the middle one, and the last one gets the same extension with a strain of 36,000 lbs., what do you mean by saying it is not in the table?—I am just calculating it.

14,265. I do not want you to calculate it. What do you mean by saying that Mr. Kirkaldy's table does not show the extension due to .052 of an inch?—I did not mean to say that.

14,266. You agree that it does?—Yes.

14,267. Am not I right in saying that Mr. Kirkaldy's testings show that the minimum stress upon these tie-bars under the circumstances of elongations which you have taken in your calculations, is 36,000 lbs., will you please answer that question?—I must refer to the figures and see.

14,268. It is not a matter of calculation?—It is a matter of calculation.

14,269. Take Mr. Kirkaldy's table and tell me whether I am not right in saying as the result of his test that the minimum strain upon these tie-bars when that elongation takes place including the squeezing of the gib and the cotters and everything is 35,000 lbs., I mean of any one of them. It cannot want a calculation. Do take the table and look at it?—I am doing so, but I want first to go through the figures.

14,270. I object to that. I will have an answer to my question first?—I will answer your question...
when I have examined the table sufficiently to answer it. 14,271. Take Mr. Kirkaldy's table and tell me whether, that table does not show, instead of making independent calculations of your own, that the minimum strain upon the tie-bar under the circumstances of elongation, you have taken is 36,000 lbs., is it the last one of the three?—Yes; but the writing is so illegible that I cannot read it.

14,272. Take a copy of the printed evidence?—I have the print at the end of the evidence. The 36,000 lbs. corresponds with an extension in one case of 35, in the next case of 38, and in the third case of 32.

14,273. The minimum strain which in any of those cases would go down, upon any one of those tie-bars is required to produce that tension where you have the squeezing of the girdle and the cotters and everything is 36,000 lbs., or sixteen tons, is not that so?—Yes; that is so.

14,274. And, therefore, am I not right that upon your own assumptions at the time of the overturning the ultimate strain upon the tie-bars that you should have taken into calculation is not what you took, four tons, but sixteen tons—four times as much?—Yes; that does appear to be so.

14,275. Now, I will ask you to amend your figures that you gave us on Friday, by inserting the correct strains, and ascertain the strength of wind required to overturn that bridge—put your own calculations here you not there?—Yes.

14,276. The moment due to the weight, including the train, you gave as 896,492 foot pounds plus 2937 times, the force of the wind?—Yes.

14,277. That remains unaltered?—Yes.

14,278. Just take the figures down, you have four tie-bars—you will have two-thirds of the 36,000, that is 24,000 lbs.; the resolved horizontal is two-thirds?—Yes.

14,279. That is 23,800 lbs.?—Yes.

14,280. That is multiplied by 14 and 42?—Yes.

14,281. That gives you 13,996,400?—Yes.

14,282. As to the other 28 tie-bars, we will not trouble ourselves to see what the increase of them is; we will take them as you put them; they would have been increased of course too, but it is not worth while going into them. As to the other 28 tie-bars, you have given as 36,499,904?—Yes.

14,283. That would be increased in a similar proportion would it not?—Yes; it would be increased in a somewhat similar ratio.

14,284. We will take that without increasing it to say time, I have not worked it out myself; will you put that down unaltered? Then you have as the moment of stability arising from the strain on the bolts 2,525,320—that is your own figure—aggregate moment 29,059,412 plus 2937 times the force of the wind?—Yes.

14,285. Divide that by your divisor got from the surface of the girders, and the leverage 319,032, and tell us what the wind pressure is required to overturn the whole of the bars?—It would be something under 70 lbs.

14,286. May I put it as the result of your own calculations, when corrected by the proper stress of the strain, that this bridge if constructed according to the design, required 70 lbs. pressure of wind to every square foot to overturn it?—Yes; that appears to be so.

14,287. What do you mean by suggesting at the end of your report that the base is insufficient? I will put my question in this way, is not 70 lbs. enough for an engineer to provide for; is 70 lbs. enough wind in your judgment to provide for?—No.

14,288. It is not enough?—No.

14,289. You seriously say that?—Yes.

14,290. What in your judgment would be the wind pressure that a prudent engineer should provide for?—I should not dream of putting up any structure that would go down with less than 200 lbs. I never make a structure that would not resist more than four times the greatest strain to which it could possibly be exposed.

14,291. If you were out in a wind of 70 lbs, where would you go to?—I do not know, I should be sorry to say, I should go in doors as quickly as possible.

14,292. Have you taken the trouble to ascertain what is the highest wind pressure ever recorded?—I have no means of telling you what it is, of course. I have not got all the observations which have been recorded.

14,293. That is your view of the duty of a prudent engineer, namely that he ought to provide for a pressure of 200 lbs. per foot of area?—My idea of the duty of a prudent engineer is that he should always allow a strength of structure equal to four times the greatest weight that can come upon it, never less than a multiple of four; Professor Rankin lays down 55 lbs. as the possible wind.

14,294. Where does he lay that down?—At page 181 of his rules and tables.

14,295. Does he give any authority for that statement?—None whatever; and Mr. Beardsmore gives 40 lbs. as that which should be taken for roofs. In important structures, I think that the greatest possible margin should be taken. It does not do to speculate upon whether it is a fair estimate or not. A prudent engineer would certainly not design such a structure as this, which would have a less factor than four of security, that is to say, four times the greatest strain that would come upon it to allow of course for those imperfections in work and material which are inevitable. I say that a less factor than four should never be allowed in any structure of such a character as this.

14,296. (Mr. Barlow.) When you say 200 lbs., to the square foot you might put in another form, and say 50 lbs. to the square foot, giving a factor for safety, might you not?—Yes; that is so. That is what I mean.

14,297. (Mr. Bidder.) Can you point to any observa1tions to show that there has ever been observed over a surface of the extent of these girders so high a pressure as 20 lbs. to the foot?—No; I have no authority upon the subject at all to consult.

14,298. I must now trouble you to amend your calculation by taking into consideration the additional strains upon the other ties, so I must take you once more back to your figures, and ask you to take into account the real stresses upon the 15-inch and the 18-inch tie bolts, those you have given as 4,649,904?—Yes.

14,299. That would be increased if you took 16 tons instead of 4 in the same proportion, would not it?—I cannot answer that off-hand, but more or less it would be in the same proportion.

14,300. It must be so. You have arrived at that figure by simply taking a stress of 4 tons, and resolving it doubly horizontally through the two angles, and multiplying it by 28 and 42, have you not?—No; I calculated each one independently.

14,301. Let me call your attention to question 13,927, which was put to you by Mr. Barlow, where he asks you 'What does that work out to?' and your answer is 4,390,368 foot-lbs. Dealing with the other columns on a similar principle, I find that the initial strain upon each of those bars would be 1,771 lbs. resolved horizontally, and the moment for that (because there are 28 instead of 14) would be 2,082,696 foot-lbs. ?—You are on the same now—you are on the tie-bars between the 15-inch columns.

14,302. I am not, if you will follow me. 'Dealing with the other columns on a similar principle, I find the initial strain upon each of those bars would be 1,771 lbs. resolved horizontally, and the moment for that would be 2,082,696 foot-lbs. (because there are 28 instead of 14.) With the increased strain which the extension would occasion, you would get a useful resistance strain of 3,564 lbs., which upon the whole of the bars would give you a moment of...
14,308. I do not want to take that into consideration—answer my question as nearly as you can. The breaking strain being 16 tons instead of 4 tons, those figures must necessarily become smaller. Upon your assumption, it would be four times as much.

14,309. Not upon my assumption?—You put it to me so.

14,310. No; I will not have the question answered in that way. The question is, the breaking strain being 16 tons instead of 4, what does that figure become? I do not want an answer upon my assumption, I want an answer to the best of your belief?—Taking it at four times it would become 16,800,000, in round numbers 14,000,000 more.

14,311. The 22,000,000 gave us 70 lbs. that would add over 40 lbs. more?—Just about 40 lbs. I think. That makes the aggregate of the ultimate wind pressure 110 lbs. therefore?—Yes.

14,312. Have you anything to say against that result?—Not at the present moment. I may have when I have gone through the figures.

14,313. If there is anything wrong in it, let us deal with it now before I conclude my cross-examination—I do not pretend to be able to deal with a matter of this sort off-hand.

14,314. I notice by-the-by that in the appendix to your report, you have calculated there what your views were before you got Mr. Kirkaldy’s experiments of the ultimate strain upon these ties at the moment of the bridge breaking?—Yes, I am referring to page 19 of the appendix?—Yes.

14,315. I see, for instance, that at that time you thought 908 lbs. in one case and 850 lbs. in the other was about the ultimate strain?—Yes.

14,316. That is to say, according to your original calculations, at the time the bridge is actually breaking that the 15-inch columns are strained about 3 cwt. of strain—when the whole thing is smashing under the wind—that was your original view of the ultimate fracturing strain upon them?—530 lbs., was it not?—Yes. I am referring to the fact that is correct upon the assumptions that were made.

14,317. It only shows how the most careful and accurate men may make the most erroneous assumptions?—No.

14,318. Did it not strike you at the time you came to that result as rather a droll thing, that the ultimate strain upon these tie-bars at the moment of fracture would only be represented by about 3 cwt.?—No; it was because I knew the assumptions there were not correct that we tried experimentally what the law was. I have given the law there, and that result is mathematically accurate; it cannot be impugned upon the assumption.

14,319. We have got to 110 lbs. of wind. Now let us turn back to pages 16 and 17; there you have given the details of your calculation? The figures you got from Mr. Kirkaldy?—Yes.

14,320. Section 9 on page 16 refers to the “resistance to the overturning of the pier on separate columns”; that shows us the mode in which you have calculated the figures you have given?—No; the same principle is involved, but that does not show the mode in which I have calculated it. In the calculations given on pages 17 and 18 I have assumed that the extension for strain would be identical in the bar and in the bolt—precisely identical—that the bar would elongate to an extent proportionate to its length, and that the bolt was what was assumed. Then I had no other data to go upon, but now we have got the independent rates of extension.

14,321. With that exception, that is the principle upon which you proceeded?—They are both upon the same principle.

14,322. This represents your calculation with that qualification?—Yes; it is the calculation made upon that principle.

14,323. I have dealt with your figures upon your own assumption, and, assuming you are right in your principle, you arrive at that ‘052 of a foot of elongation of the tie-bar by simply taking the proportionate movement of the tie-bar in proportion to the movement of the bottom of it?—Yes.

14,324. And the same with all the piers all the way up to the top?—Yes.

14,325. In so calculating the elongation of the tie-bar, you have assumed these columns to be absolutely rigid and inextensible?—Yes.

14,326. That is to say, taking a column 15 inches in diameter and 76 feet high, you assume it to have absolute inextensibility?—Yes.

14,327. Do you believe that it would?—No.

14,328. If you had taken into consideration the necessary flexure of that column, it would have put an additional strain on the tie-bars, would it not?—On some of them more and on some less. The mean result would have been the same, but the effect would have been this, that with the flexure of the column the horizontal movement of the top would have been greater and the stability of weight would have been lessened.

14,329. I am not talking about the stability of weight, but I am talking about the strains upon the tie-bars?—It would have been less upon the bottom ones and more upon the top.

14,330. In point of fact you have neglected absolutely the flexure of the column?—Intentionally.

14,331. As a matter of fact you have done so?—Intentionally. I have assumed the columns to be rigid. It would have lessened the weight which would have overthrown the structure if I had taken the flexure of the column into account.

14,332. Now I come to an entirely different question. So far we have been discussing the efficiency of this bridge irrespective of the imperfections of its manufacture. Now I want you to answer this question: Assuming imperfections of manufacture such as you have indicated, in what way would they affect the calculation of the stability of the bridge?—The first imperfection that I would point out is the—

14,333. I do not want you to point out imperfections, but be good enough to list them if you have had them pointed out over and over again?—I had better enumerate them to see if we are agreed about what they are. The unequal casting in the cylinder, you say, you do not consider would contribute to overthrow the bridge?—I did not go so far as that.

14,334. You had said about half an hour ago?—I beg your pardon. I said that the failure was not owing to that, but that no doubt it would contribute.

14,335. Your evidence is upon the notes, and I am content that we should be judged by what you said earlier in the morning. Let me see if I correctly follow you. You have pointed out that the strut being an inch and an eighths, and the bolt in an inch and quarter hole, there is an eighth of an inch play
at each end—I have pointed out a great deal more than that.

14,387. That, is one thing? I have pointed out more than that.

14,388. As regards the struts, is it not summed up in this which I put to you on Friday, that in the worst case, the bolt when the hole was at the wrong end of the hole, there would be the possibility of the two columns which it kept apart coming together to the extent of a quarter of an inch?—Certainly not; that is, assuming that the hole is accurately an inch and a quarter in diameter, or that the hole both in the column and in the bar is an inch and a quarter in diameter. They are the most irregular shapes conceivable.

14,389. Have you seen any case in which you could undertake to say that the struts would have come together more than a quarter of an inch?—Yes. 14,390. Where—where pier?—I cannot say.

14,391. What is the maximum that you would undertake to say?—In some cases there was room for the coming together of the struts?—I cannot offer an opinion. Many of the holes having been punched out with blunt tools, there was merely an edge of the upper surface of the iron which would yield. I could not say to what extent, the moment pressure came upon the bolt, it would be impossible for anyone to say that the bolt in those cases would only move to the extent that it would if the surface round the hole were a good surface; but they are jagged and irregular holes, both in the casting and in the channel iron, and they might yield to a very considerable extent.

14,392. If they would yield the moment pressure came upon them, they must have yielded long before the date of the accident, I take it, because there have been heavy thrusts against the flange of the column which is not sufficiently joined to its fellow, and it may come home and move; and the three together may give you sufficient for the structure to fall.

14,393. When they cottered up again those tie-bars which were chattering, they took up, so to speak, the play of the struts necessarily, did they not?—That depends upon how far the column had come back again. It might have moved 4ths an inch and come to the fall of an inch. I have a hole very nearly 1 inch and 4ths long in the channel iron.

14,394. Where is that?—In pier No. 30. Here is a rubbing from it.

14,395. Have you got the thing itself?—No.

14,396. I should prefer to see the position of it.

14,397. (The Commissioner.) Can you tell us the position?—It is one of the bolt-holes in a channel iron. Another one was an inch and 4ths in the same channel iron.

14,398. (Mr. Barlow.) In pier No. 30?—Yes, in pier No. 30.

14,399. (Mr. Bidder.) But must not the play of an inch be of an inch, a quarter of an inch, half an inch, 1 inch, or even in, if you like, have been taken up when the chattering tie-bar was re-cottered?—Certainly not necessarily. I have also in column 35 one of 14 inches in length, and another of 1 inch and 4ths in length—the two in the same channel iron.

14,400. Have you the originals of these?—I am not at all sure that they are not in London. There are some others quite as bad.

14,401. Must not these have yielded previously, and been taken up when the tie-bars were re-cottered?—Not necessarily.

14,402. Why not?—Not necessarily.

14,403. Assume a strut with two imperfect holes, such as you have described, which leave room for the play of the bolts, and assume the vibration and pressure of passing trains coming upon the bridge, and loosening the tie-bars, and causing it to clatter, and it is re-cottered, why should that strut ever separate again?—I say in any case that this strut (pointing to the model) was moved till this very occurrence.

14,404. You have just been assuming that there might be an imperfection that would give way to any pressure; that was your own phrase?—Yes; but if there was a worse imperfection at the lower part, where the strain was greater, that would yield first, and then, if this but cottered up, that would give (pointing to the model); and we know that it was so. The weakest would go first, and, when that was remedied, some other weak point would be discovered.

14,405. The cottering up whenever the tie-bars were chattering would have a tendency to take up any play of this kind, would it not?—No; I do not think that any driving in of cotters would be able to restore the structure to the position to which it had moved from.

14,406. If that is the question I put to you, I have not the most distant recollection of it. My question is whether the re-cottering when there was found to be a chattering would not have a tendency to take up any slackness owing to middle of the bolts and holes?—In the ties.

14,407. And the struts to?—A "tendency," yes; but it would be quite inadequate to the resistance.

14,408. Now, let us go a step further, and assume that there is this play in the struts, and that that has not been taken up, and that therefore it may be a quarter of an inch or even an inch, in the struts at the time when this storm came, and that that space would be taken up, and that the column would approach by that much. When that is done, what is the effect upon the stability of the structure?—You have to take the sum of them. You have first the extent to which the tie itself would yield by virtue of the crushing of the thread of the screw.

14,409. I am talking of the struts?—The whole is combined. That allows the tie to extend. It then thrusts against the strut, and that yields a quarter of an inch. A pull also comes upon the flange of the column which is not sufficiently joined to its fellow, and it may come home and move; and the three together may give you sufficient for the structure to fall.

14,410. I prefer to take things separately? You cannot take things separately that are acting together; you must take the whole. When there is a tie pulling against a strut, the one must extend while the other one compresses, necessarily.

14,411. You have two columns, parallel and upright, with struts between them?—With a strut between them.

14,412. I said struts, because there are six or seven?—Separate struts.

14,413. Those struts have, according to your assumption, more or less slackness. One may be a quarter of an inch, one may be half an inch, and one may be an inch, or anything you like. Those columns cannot come nearer together than the struts will let them, can they?—No.

14,414. Then the distortion by altering the relative position of the columns is summed up by the amount of approach which the struts would permit?—No.

14,415. The approximation of each is limited by the play of the strut?—Yes; the approximation of the two columns; but the approximation of a further lower column and the upper column may be very much greater. The strut comes against and separates those two columns, and after the yielding they cannot come closer, but the pull of this tie is upon another column, which is only connected by bolts. You must take the whole of the structure together.

14,416. Take two columns. Let me call the left-hand one A and the right-hand one B. Suppose that the play of the strut at the bottom has allowed A at the bottom to approach within half an inch of B, and then is jammed up tight, and suppose the play of the strut at the top has allowed A to come within a quarter of an inch of B, what further distortion can take place between those two columns?—I will show you. This column (pointing to the model) has been allowed to go over an inch.
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14,367. (The Commissioner.) What do you mean by over?—To move out of the perpendicular an inch, or nearly so. The whole of the superincumbent weight upon that is now tending to produce greater distortion, and its effect may carry the entire part of the structure with it, bring a strain upon the tie above, and that is pulling upon the column, which is capable of sliding upon the top one. Every one of these ties (pointing to the model) pulls against the strut, which is connected to another column.

(Mr. Bidder.) You have such a habit of diverging into something else which you think interesting, and not answering to my question, that I must put it to you again. I put this to you:—Take the case of two columns, and the amount of distortion that could take place. I suggest to you that the strut at the bottom of the two columns will allow an approach of the one to the other to the extent of half an inch, and at the top it will allow an approach to the extent of a quarter of an inch.

(Mr. Barlow.) Both ties will now be slack? 14,368. (Mr. Bidder.) Yes; both ties will now be slack. Beyond that, what other relative distortion of those two columns is possible?—Very much larger distortion indeed.

14,369. Of those two columns?—Certainly.

14,370. (Mr. Barlow.) What is to prevent their going out of the vertical?—They could not have moved in this way without going out of the vertical; it is impossible. If it is to move half an inch at the bottom and a quarter of an inch at the top, of course it is moving out of the vertical. Fresh strains and brought to bear. You cannot consider the effect of one movement without considering what effect it produces in other respects. If the effect was, for instance, to push the outer column inward, and the channel iron yielded to the extent of a quarter of an inch in doing that, it must bring a great strain upon the other column. You can take the form of a parallelogram without straining the tie that would be extended. You pull then upon the lower part of the column, which is held by another strut, which may yield a quarter of an inch also. You cannot take in a structure of this kind a movement in one particular bar and say that that is the extent to which it will affect the structure.

14,371. (Mr. Bidder.) I did not say that; and you must not put nonsense into my mouth for the purpose of contradicting it. I said the quarter of an inch was the extent to which I would affect the relative position of those two columns. Fix your mind upon two particular columns. I will call it a quarter of an inch for the sake of a definite length, and which are kept apart at the bottom by two struts; those two columns, and those two struts forming a quadrilateral. When you fix the length of the columns and the length of the struts and the point of their attachment you fix the shape of that quadrilateral?—No, not the shape of it.

(Mr. Barlow.) Except the angle.

14,372. (Mr. Bidder.) Quite true. I admit that is so, but I want to go a step further. (To the witness): Assume that all the play of the struts is taken up, and has produced a certain amount of distortion in the position of the column, if you bring a strain of the weights?—Yes; you have got to represent the whole power above upon the top of the column, does not the flexure of the column, and the struts that you put upon it, then necessarily bring into play the stability of the structure in the same way as before, minus this—that you have got possibly a certain displacement at the top, which has diminished the moment of stability of the weights?—No; the moment I imagine a movement of a quarter of an inch on the top of one of the columns, I necessarily have brought a very large strain upon the bolts and all the flanges. I cannot disturb a structure in that way by pushing the columns, which are connected with small flanges, which are long 11 feet long. I cannot move them out of their rectilinear line without bringing strains to bear upon all the flanges, and reducing the lateral pressure or the power of resistance of the structure to a very large extent.

14,373. I am assuming the worst against the bridge that can possibly happen; that every strut was capable of play, and that they all allowed a certain approach of the columns?—I think they were all capable of play; I do not think there was any strut in that bridge which could act as an efficient strut against the strains to be brought upon it.

14,374. You are prepared to go the whole length, and to assume that every strut was capable of play?—There were no means of tightening up the bolts to any great extent; they were between two narrow channels, where nothing but a box key or tightening with a chisel could tighten them up at all; you could not have put any great strain upon them.

14,375. You say you believe that every strut of this bridge was capable of play. Supposing for a moment, that that is so, all the play must be taken up when a heavy strain comes upon the bridge, I suppose?—I do not understand you.

14,376. When a heavy strain comes upon the bridge there will be a distortion of the structure.

(Mr. Bidder.) Do you mean a horizontal strain—a wind strain?

(Mr. Bidder.) A wind strain.

(The witness.) I do not quite follow your question.

14,377. (Mr. Bidder.) Assuming that the struts were capable of allowing an approach of the columns before the structure overthrown, the columns would approach, would they not?—Yes, if the ties allowed, then to do so they would.

14,378. As far as the ties would allow them?—Some would move and some would not. Those which offered the least resistance would move, and would take the strain off those that would offer more.

14,379. The result would be a distorted form of structure?—Yes.

14,380. Given that distorted form of structure, and now, with the struts tight up, why does not that still act as a cantilever?—It does so, but it allowed a great strain to be brought upon the bolts and the several joints, and it has allowed the column to be no longer in its true axis, and we all know the effect of that.

14,381. If there was a slackness or power of play in these struts, how did it escape being taken up when they originally cottered up the tie bars?—I have no doubt that they were cottered up so the extent that they were able to do it, with a hammer, and so forth.

14,382. Do attend to my question. If there was a play in the strut, why was it not that originally taken up in the cottering up of the tie bars?—Because the more driving in of a key would not be sufficient to displace the structure; the strain would not be sufficient, the power of those tough cotters, being driven in by a hamil hammer, would not be sufficient. I understand the question to be this: When the bridge was first erected, whether the keying up of the cotters would not have discovered these weaknesses. I say no; the struts were not sufficiently direct or sufficiently powerful to do anything of the sort.

14,383. Surely the bridge had been subjected to gales before, though probably never so severe a one as occurred on this occasion?—Yes.

14,384. And it had had the vibratory action of the trains passing over it?—Yes; and the result had been a movement to such an extent as to allow about 150 of these keys to be put in.

14,385. This bridge had been exposed to previous gales, and it had also been exposed to the passage of trains; would not, necessarily, those previous gales and those previous trains have developed any slackness, at any rate to the extent of the power of those gales which was capable of being developed, owing to the imperfections you have mentioned?—Yes; and they did develop them.

14,386. And that slackness had all been taken up, as we know, by the tightening of the tie-bars; that slackness which had been developed?—Yes; and as I
explained before, the weakest part goes when the strain comes.

Do not make another divergence from the question; if it is an explanation, by all means give it. It is an explanation of my answer. In the first storm a defect will develop itself, and that will have to be remedied; then the next storm comes, another weak point will be dealt with; then in the next storm that came, a new point would develop itself that would have to be taken up. The weakest always went, but it did not follow that there was not another very nearly as weak that would not have yielded if that one had not,—one lower down, for instance.

14,388. That which remained to be taken up on this occasion was simply the residuum, or play, so to speak, not developed and taken up in the previous storms?—No; it would be in different parts of the structure altogether.

14,389. Do you mean to say that other parts escaped straining in previous storms?—That is my argument.

14,390. I will put my question in another form. The play that was developable on this particular occasion was limited to that which could not be developed by the maximum storm that had ever come previously?

—No, because the bridge is not now in the same condition; because you have strengthened certain points that were weak before.

14,391. Which points, by your own hypothesis, were then the weakest points?—Yes.

14,392. Therefore all the points which remained were not so weak?—Not so weak, and not exposed to so great a strain. A storm might be from the east to-day, and from the west to-morrow; for instance, the tightening up that you might do after a westerly gale would be very little service indeed when you came to an easterly gale blowing in the other direction, which would shackle all those ties which you had tightened up.

14,393. This was not the first westerly gale that had blown upon the bridge since it was put up?—Probable not, or there would not have been the occasion for the other cotters being put in.

14,394. Just follow me. Whatever play there was between the bolt and the bolt-hole and the strut, would not that necessarily be taken up when the envelope were originally cottered up?—Certainly not.

14,395. Just fix your eye upon any one of those struts? you have at each end of it two diagonal ties?—Yes.

14,396. Therefore you have compression equal to the horizontal component of the two diagonal ties?—Yes.

14,397. You assume an initial tension by cottering up of two tons a tie?—I have given the structure credit for it. I do not believe it ever existed.

14,398. Why should not you believe it ever existed if you have given credit for it?—Because I do not think the cotters could be driven in to produce that strain upon it.

14,399. Have you tried any experiments with the view of ascertaining that?—No.

14,400. Proceeding upon the foundation of your own assumptions, that there is an initial strain upon a second of two tons, two-thirds of that is the horizontal component?—Yes.

14,401. Consequently the horizontal compression of the strut upon the two tie-bars would be two and two-thirds tons?—No; you have only got one bar acting against one strut.

14,402. Do you say yes or no to my question?—No; you have only one strut acting at each end.

14,403. You have a strut, at each end of which there are two ties?—Yes; they act against each other.

14,404. At one end they are an end of two ties?—Yes.

14,405. Each tie has an initial tension of two tons?—Yes.

14,406. The two together have an initial tension of four tons, and the horizontal component of that is 2 and 2/3 tons?—No; they pull against each other. You have a pull of 2 tons at each end.

14,407. Do listen to the question: I will put it again. The strut has two ties at each end?—You mean at the top and the bottom.

14,408. Of course I do?—Yes; two at each end.

14,409. You do not suggest that the two are pulling against each other horizontally?—They do not pull upon the strut; they pull upon the column, imperfectly connected with the strut.

14,410. The horizontal component of those two would be 2 tons and 2/3?—Supposing them to act efficiently.

14,411. It would be 2 and 2/3 upon something?—Yes.

14,412. Is not that 2 and 2/3 tons tending to bring the column jam up against the strut?—Yes.

14,413. The only thing to resist that taking up of play is the nip of the bolts upon the strut, is it not?—Yes.

14,414. The nip of the bolts upon the strut you assume as two tons?—No; I have not assumed it at anything.

14,415. In the other part of your calculation you have assumed it, have you not?—I do not refer to them.

14,416. You say in another part of your calculation that the initial strain of the bolts would be two tons?—Upon the flanges.

14,417. Would it be more in this case than in the case of the bolts upon the flanges?—Much less.

14,418. Two tons is over the mark?—Very much over the mark.

14,419. What fraction of that, by friction, would be the horizontal force developed?—Supposing the surfaces of the iron were iron to iron, it would be about 1/10.

14,420. What would be the resistance to taking up the play which the friction of the two bolts with an initial tension of two tons could offer? There are two bolts. What would be the resistance to taking up the play? We have a force tending to take it up of 2 and 2/3 tons; what would be the capacity of the bolts to resist taking it up?—The resistance to the strut to move under the nip of the bolt would be about one ton and a quarter upon your supposition.

14,421. That will not do; there is a tension for the bolts of two tons each?—But they nip two struts.

14,422. You have not got double friction?—Yes; we have two surfaces.

14,423. With a force of friction of one and a quarter to resist taking up the play, and a force of 2 and 2/3 tons to take it up, must not the play be inevitably taken up?—On your assumptions it must.

14,424. On your assumptions?—They are not my assumptions.

14,425. In your calculations on Friday, you told us that you assumed an initial tension of the bolts of two tons, and an initial tension of the ties of two tons. I say, upon those assumptions of your own, does not it inevitably follow, applying them to the struts, that the play must all have been taken up when the tie-bars were originally cottered?—Most undoubtedly not; there never was an initial strain of two tons put upon them. You ask me whether it was possible that the structure could have been—

14,426. I do not ask you anything of the kind?—You do not let me finish what I was going to say.

14,427. What I am asking you is this: Applying your own assumptions to the struts, whether it does not inevitably follow that the play must have been taken up where the tie-bars were originally cottered?—Certainly not; my assumptions were made in order to give the greatest strain possible to every one of these ties; but I do not for an instant believe that any man by driving—

14,428. You do not attend to the question. My question is this: Applying your own assumptions as to the initial tension of the bolts and the initial tension of the tie-bars which you gave, and which I quite agree were made for an entirely different purpose, but
applying them to the case of the struts, does it not
inevitably follow that if you assume those tension the
play must have been taken up?—No.
You have just shown that there would result
in a horizontal compressive force of two and two-thirds
tons, with only one and a quarter tons to resist it?—
There would be many other things to be done also.
Then when you have to move the columns, and you
have to do the work necessary in taking up the
columns; you have to take up the columns or break a
joint, and bring a strain upon the tie-bars resisting it.

What do you mean by the tie-bars resisting it?—The tie-bars in the adjoining panels. You
cannot make efficient struts of these without approaching the whole structure to do it, and you have all the work to do that is necessary to
do that. It is not because a man drives a cotter in
here that he is going to make it an efficient strut; con-
ected as these columns are, he would have to move the
whole structure.

Are you going to the whole structure?—
We are dealing with the whole structure. The work
necessarily involved in moving the columns would
have to be done; you could not move the columns
without moving the whole structure; you could not
move the columns without extending the tie-bars in
the adjoining panels, and also disturbing the connexion
of the train's frame.

I am aware that the column has to be
moved. Supposing there is a taking up of a quarter
of an inch, the top of each column would have to be
moved to the extent of an eighth of an inch?—Yes;
it might be more.

Whatever the slack was, half would have to be
taken up on each column?—Not necessarily.

Are you in a position to say what would be
the resisting power of one of these columns to motion
to the extent of an eighth of an inch of its head?—
No; very considerable indeed.

The next thing I wish to ask you about is
how have you bed at things.

The carriage is undoubtedly, by your own showing, the
lightest of the train, and the one that would be easiest
upset?—Yes.

You have given us, in the first column, the
weight of that carriage?—Yes. You have given us, in the next column, the
half-width between the rails?—Yes.

The gauge, I suppose, is 4 feet 8 inches?—
Yes, I imagine.

Half of which would be 2 feet 4 inches?—
That is not what it would turn upon, of course.

Would not it?—No.

What do you take it to turn on?—The top
of the rounding rail certainly.

Between what points is the 4 feet 8 inches
measured?

It is 5 feet centre to centre.

You must take the centre of the
rail.

Have you considered that the
carriage would be laterally forced up against the
head of the train?—Yes, I have given you the amount of that.

I have given the surface of the carriage multiplied
into the pressure.

No; what would be the distance which the
"carriage would be pushed?—I suppose it would be
half an inch; the flange in contact with the rail.

Let me draw your attention to another
figure which I wish to have a little explanation of,
the height of the centre of wind pressure
above the rails which, for the second-class carriage,
you have given as 5'-90 feet; how have you arrived at
that figure by multiplying the several surfaces into
the height of the centre of those surfaces, and then
dividing the total sum by the total area.

The main surface of the carriage is on the
side of the carriage, of course?—Yes.

And the height of that side above the rails
consists of this—it is 3 feet from the rail to the bottom
of the frame of the carriage, and then there is 7 feet
6 inches for the side itself?—No; there is 11 inches
to be added.

Above the 11 inches you have a height of
6 feet 71/2 inches?—Yes.

The bottom is 3 feet from the rails, and
taking the 11 inches and the 6 feet 71/2 inches, you get
10 feet 63/4 inches, how can you get a mean of any-
thing like 5'-9 feet. I suggest to you that you have
made a mistake of a foot, and that it ought to be 6 feet
9 inches instead of 5'-9 feet?—No, you have taken the
roof as though it were a flat surface. You must not
do that.

That may explain it?—I entered into it
very carefully. Errors are always possible, but I do
not think it was wrong, comparing it with the other
carriages; any error would have been discernible.

You are aware that you have come to a
different result, as regards the pressure that would
act on this carriage, to that at which Dr. Pole and
Mr. Stewart have arrived?—Yes, but Dr. Pole and
Mr. Stewart assumed that there were no persons in it.

That would not make the difference?—I
think also they did not assume the downward pressure
upon the roof.

Just check yourself and see if you are not
wrong in these figures. This carriage was represen-
ted by a rectangle, the bottom of which is three
feet above the rails, and the top of which was 10 feet 63/4 inches, the average centre of that rectangle would be
6 feet 9 inches above the rails instead of 5'-9 feet. I
am reckoning right up to the top of the roof—three
feet is the height from the rail to the bottom of
the frame of the carriage—the sole plate, and then there is
11 inches; and then there is 6 feet 71/2 inches; that is
7 feet 63/4 inches in addition—that gives to the top of the
roof 10 feet 61/2 inches.

The roof and the carriage side are
separated in this calculation.

That may account for part of it, but
I do not think it can account for all of it.

In the next column you find 2'-77/16
roof surface.

The centre of the carriage surface would be about six feet five
inches above the rails, apart from the roof if you take
all the surfaces, it brings it down to 5'-9 feet.

You have made out that
the pressure of the wind on the roof would tend to
keep the carriage on the rails?—It must do so.

If it is going to do that, have you con-
sidered the pressure of the wind on the bottom of
the carriage?—There would be none at the pressure
wa.

Why not?—Because the carriage also is
horizontal.

Are you quite sure of that?—Yes.

Supposing there was a cul de sac for the
wind, do you say that the wind blowing under the
carriage will not have an upward pressure on the
body of it?—I do not say it will not.

Has the wind no tendency when it comes
in gusts to lift boards which are laid horizontally?—It
might do so, as the wind striking underneath the
booms might be deflected on to the roofs of the
carriages. These are trusses which I have not
gone into. The other figures which I give are
the proper resolution of forces; you must neglect the
roof altogether, or resolve it into its components.

You have taken into consideration the wind
pressing the roof of the carriage down, and you
have not taken into consideration the effect of the wind
on the bottom of the carriage?—They are totally different
things. I have not gone into any speculations.

You have not attempted to estimate what
that would amount to?—I have not attempted to
estimate the effect of eddies or irregular currents of
wind.

You have assumed
the wind to be horizontal?—Yes.

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14,463. And you have assumed the roof to be circular?—Certainly.

14,464. And that a horizontal pressure upon that would have a tendency to hold it down?—Yes.

14,465. (Mr. Bidder.) My question is this—assuming it to be horizontal—have you attempted to estimate whether there would not be an upward force under the bottom of the carriage, and what it would amount to?—I have not.

14,466. Supposing this train went off the line, have you made any attempt to form a judgment as to whether the smashing of the train going at twenty-six miles an hour into the girder would upset the bridge—no, the bridge being already in high tension, with an enormous gale of wind upon it?—By train, do you mean engines?

14,467. My question is this—have you made any investigation as to whether, under the circumstances I put to you, the train going off the line into the girder would upset the bridge?—No.

14,468. Have you formed no judgment upon that point?—I have formed a judgment to this extent—that imagining the second-class carriage might be overthrown, I do not think the destruction of the upper part of any of these carriages against the girder would produce any serious effect upon the bridge.

14,469. The second-class carriage and the guard's van weighed about 35,000 lbs.?—But then they are like matchwood against the girder.

14,470. A pound of matchwood weighs as much as a pound of iron?—But matchwood weighs very little.

14,471. I say a pound of matchwood weighs as much as a pound of iron?—Yes.

14,472. The second-class carriage and the luggage-van together weighed about 35,000 lbs.?—The matchwood in it did not weigh 35,000 lbs.

14,473. I did not say it did, but I say you show in your table that those two carriages weighed about 35,000 lbs.?—Yes.

14,474. And with 35,000 lbs., assuming that the train was going at its regulated velocity of 25 miles an hour, it would be nearly 40 feet a second, would it not?—Very likely.

14,475. For convenience say 40 feet: it would be a little less. Supposing that those two last carriages were overthrown and brought up suddenly by collision with the sides of the girders, are you able to form a judgment as to whether the sudden impact of 35,000 lbs. (that is to say, 16 tons) at 40 feet per second, would or would not destroy the bridge, being at the time already in a state of high tension on account of the wind?—I think 35,000 lbs. of weight hurled against the bridge with that velocity, would be very likely to destroy it, but I do not see any possible manner in which 35,000 lbs. of weight could be hurled against it. I think the photographs show that it never was, because the framework of the carriages, where the weight was, are intact upon that side upon the eastern side.

14,476. It is your view that those carriages did not go off the rails?—I do not myself think they did, although I have no data for judging of it other than the force which would be required to overturn them: but if they did, and it was simply the upper part of those carriages that came against the girder, I consider that they would be smashed up instantly without doing much mischief to the girder.

14,477. Why do you introduce another condition and say, "if it was simply the upper part of those carriages that came against the girder?"—I conceive them as turning over. I do not see what would knock them down in the sense in which they would run upon their wheels against the girder.

14,478. Does it occur to you that if the second-class carriage were turned over by the wind, the first thing that would happen would be that the fore right-hand corner of the roof of that carriage would catch against a lattice?—Yes, I suppose so; it would give away instantly.

14,479. The carriage having already tilted over, with two of its wheels in the air, you do not think there would be any fear of the other two wheels leaving the rails under those circumstances?—Very likely, only that the smash would have taken place, and the ruins would have been dragged along the line by the coupleings if they were not broken.

14,480. On what ground do you say that they were not broken?—I did not say that they were not broken; I said, "If they were not broken." But this is all the wildest speculation.

14,481. (The Commissioner.) Do I rightly understand your assumption to be, that if the carriages were turned over at a velocity of say, twenty-five miles an hour against the lattice girders, because the motion would be in the direction of the line, and not at right angles to the lattice girder.

14,482. (Mr. Bidder.) Not at right angles; I never said anything about its being at right angles.

14,483. (The Commissioner.) How would it be carried against the lattice girder?

14,484. (Mr. Bidder.) Carried obliquely if you please; I did not say anything about the angle. I tell you at once, Sir, what I believe happened, that the wind tilted over the second-class carriage, that the roof of the second-class carriage caught upon the lattice, that turned the carriage off the line, and that the second-class carriage with the guard's van telescoping into it went against the leeward girders, and that the total momentum of these two carriages was arrested by the leeward girder. (To the witness): You have not, as I understand, studied the ruins sufficiently to form an opinion upon that point?—I have not seen the ruins at all. I have seen only the photographs, and judging from those photographs I see nothing to indicate that the eastern side of the lower part of either of those carriages came in contact with the bridge.

14,485. (The Commissioner.) Do I rightly understand that the theory is that the van telescoped into the second-class carriage?

14,486. (Mr. Bidder.) I used the word "telescoped," but I do not know that it is the right word to use; when the one before was pulled up the one behind smashed into it.

14,487. (Mr. Barlow.) Then the two together went into the girder?

14,488. (Mr. Bidder.) The two together went into the girder, the one in front and the one behind.

14,489. (The Commissioner.) In the drawing which has been supplied to us they appear to be exactly in the same position in which they would be if they had not gone off the rails.

14,490. (Mr. Bidder.) Of course if the second-class carriage was turned off the line and arrested, the van must inevitably run into it.

14,491. (The Commissioner.) Or if the van telescoped into it, you would naturally expect to find the wheels of the van over the wheels of the second-class carriage, which you do not find here.

14,492. (Mr. Bidder.) You will hear something about that, Sir, afterwards.

14,493. (The witness.) I do not pretend to say that it is not so, but I can only say that I have not seen anything to lead to that impression being produced upon my mind.

14,494. (Mr. Bidder.) Assuming that sixteen tons going at forty feet a second did smash into the leeward girder and was arrested by it, would not that in your judgment be sufficient to account for what happened?—I think it would be a very serious matter, and that that weight hurled against it might very likely lead to the destruction of the girder, but other appearances do not lead me to think that the girder broke and then brought down the structure.

14,495. (The Commissioner.) You say "hurled" against, do you mean a sliding blow?—Yes; it must be that; it must be that having left the rail it would be carried forward.

14,496. (Mr. Bidder.) You never ought to use poetical phrases in cross-examination. I will put it in the most prose form: Assuming a momentum represented by 16 tons weight going at the rate of 40 feet per second to be destroyed by impact with the
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leaves of gilder (and destroyed suddenly—I do not mean by putting on the brake) would that, in your judgment, be, or would it not be, sufficient to destroy the structure of the bridge under those circumstances it being already in severe tension with the storm?—I think it would have destroyed the girders. Whether that would have brought down the piers or not, I can hardly express an opinion; but I must say this: that such a supposition as yours is utterly incompatible with the appearance of the framework of the carriage. The framework of the carriage must have been destroyed as well. You could not hurt the real resisting part of the carriage against the bridge without having damaged the carriage itself, and I do not find the slightest indication of that upon the photograph. The rain itself must have been injured, and there is not the slightest indication of its having been injured.
14,485. Are you aware that the coupling is broken between the second-class carriage and the carriage before it; in fact, between all the carriages in front of the second-class carriage?—I believe that is so.
14,486. And that the couplings are not broken between the guard’s van and the second-class carriage?—That may be so.
14,487. Does that to your mind suggest any probability of what I am putting to you having occurred?—I think it would be possible for that condition to apply, because if the first carriage had been arrested by a blow of that force against the girders, certainly the couplings of the carriage behind it would have gone instantaneously.
14,488. I do not think you follow my suggestion. The two last carriages were the second-class carriage and their van. I suggest to you as a fact, couplings between the second-class carriage and the carriage before it, and between all the carriages in front of it broken; couplings between the second-class carriage and the guard’s van not broken, does not that suggest to your mind that the original point of arrest is at the second-class carriage?—I think it would have been utterly impossible, as I said before, to have kept the second-class carriage against the bridge so as to have destroyed it by the assisted momentum, and of course suddenly arresting the guard’s van behind without having destroyed the couplings between the two carriages, everything would have been smashed. You have got two vans connected by chain, the first coming against the girders and the second follows, and of course smashes everything. The first carriage is eight tons and there is another eight tons behind it.
14,489. If the second-class carriage is arrested and the guard’s van is thrown on to it that would throw no tension on the couplings?—No, no tension; it would smash the whole thing up. Everything would be torn away.
14,490. (Mr. Barlow.) There would be a tendency to telescoping.
14,491. (Mr. Bidder.) Yes.
14,492. (The Commissioner.) But if it telescoped I suppose the couplings would break, that is to say, if the force of the rear came to chain, the first part of the second-class carriage it would be impossible that the couplings could have held?—I should have liked very much to have had the photographs before me when I answered those questions.
14,493. (Colonel Yolland.) Do you know whether the second-class carriage is whole or destroyed?—It is destroyed utterly.
14,494. Might not that have been occasioned by coming in contact with the girders, if that vehicle did get off the rails?—I think that is the result that would follow immediately; it would be smashed up.
14,495. (Mr. Bidder.) What would be smashed up?—The upper part of the carriage; every part of the carriage that came in contact with the bridge.
14,496. Do you notice as a fact upon the photograph that the body of that second-class carriage is absolutely destroyed, whereas the bodies of the carriages in front are, I will not say intact, but I may say comparatively uninjured?—Yes, as I say, it is utterly gone.
14,497. Whereas the bodies of the carriages in front of it are, I think I may say, comparatively less injured?—If you look at the photograph of the second-class carriage, you will see that the buffer is
14,498. Do attend to my question, and do not run off into general commentary upon the photograph; it is your business as a witness to answer the questions put to you in cross-examination. Do you observe that the body of the second-class carriage is utterly destroyed, whilst those of the others are comparatively uninjured?—Yes.
14,499. Does that to your mind suggest that a different fate has met the second-class carriage, from what met the other carriages?—No, it suggests to me that the second-class carriage was one of the old sort and of a different construction.
14,500. I think there is nothing left of the guard’s van but the place where the guard sits and the brake wheel?—That is so.
14,501. Do those two facts together suggest anything to your mind? first of all, that whereas the first carriages are comparatively uninjured, the last two are converted into matchwood; that in the case of the first four carriages and their connexion with the second-class carriage, the couplings are all broken; and that in the case of the second-class carriage and guard’s van, the couplings were not broken, shows that the fact which I take from you at present that the couplings were not broken, shows that there could not have been a sudden arrestment of the second-class carriage with the van following behind it at the speed that you assume.
14,502. Where do you think the guard’s van was when it was arrested, if it was not behind it?—That is not what I said. I did not say it was not behind it.
14,503. You said there could not have been a sudden arrestment of the second-class carriage?—Indeed, I did not.
14,504. What I said was that it could not have been so sudden as to suddenly arrest it without the coupling breaking; but when I look at the photograph, I see that the coupling is all broken to pieces.
14,505. Does that photograph show you that the hinder part of the frame of that carriage has been smashed into?—Yes, it does on the west side.
14,506. Does the hinder part of body, the sole-plate, or whatever you will it, the first of the second-class carriage bear a trace of something having come into violent collision with it on the western side?—Yes.
14,507. (The Commissioner.) May I ask, Mr. Bidder, whether you say “western” inadvertently, or whether you mean the eastern side?
14,508. (Mr. Bidder.) The western side, the back, the end that is nearest the tail of the train.
14,509. (The Commissioner.) And I suppose if it were blown over it would come into collision with the western girders, would it not?
14,510. (Mr. Bidder.) No, that would be the one that would not come into collision with the eastern girders (describing it). (To the witness.) Could anything but the guard’s van have done the damage?—I have no doubt that the guard’s van did it.
14,511. The impact of the guard’s van upon that was the thing that made that destruction, you will observe that the left-hand buffer, the west buffer, is all smashed up by that part of the carriage.
14,512. (The Commissioner.) It has broken down apparently, 14,506a. (Mr. Bidder to the witness.) Is not that in your judgment caused by the violent impact of the guard’s van behind it?—Yes.
14,513. (The Commissioner.) Is it possible that it might be broken down by a column falling upon it?—I do not think it is possible. It is very probable that it did arise by the guard’s van; I think there must be a mistake about the couplings.
14,514. (Mr. Bidder.) Take it if you please, as subject to more careful investigation. I only speak as to what is understood at the moment to be the fact. Now leaving the couplings out, as there seems to be some doubt about it, the engine and the tender you know show comparatively little injury except I believe
principally an injury which was received by the engine in the attempt to lift it?—Yes.

14,507. The tender has hardly a scratch upon it; the first four carriages are comparatively uninjured; the second and third carriage and the guard’s van are reduced to matchwood, and the hind part of the second-class carriage bears traces which you yourself agree with me in thinking are produced by the violence of the impact of the guard’s van into it; do not these facts tend to lead your mind to an opinion of the probability of that happening which I have suggested to you?—No, they do not; I do not think it is at all possible that the framework of either of those carriages can have been carried against the western girders. I am referring to the sole-plate, the strong portion.

14,508. Does not the fact that the bodies of those carriages have been absolutely destroyed as compared with the comparatively little injury done to those in front, indicate that a more violent fate overtook those carriages than overtook the others?—No, I think it indicates a great measure a weaker structure of the carriages.

14,509. Is the guard’s van of weaker structure than the other carriages?—I think so.

14,610. Have you any reason to believe that the guard’s van was weaker than the others?—Yes, I have. It is not braced together in the same way, and it only weighs eight tons, whereas the others are much heavier; it is a much lighter carriage altogether; it is not so strong, and the others, if you observe, are broken away in the middle part where in my opinion they have been carried up by the lattice girders.

14,611. I understand that in your judgment the absolute destruction of the bodies of those carriages, whilst the others were comparatively uninjured, you attribute simply to greater weakness in their structure?—I cannot accept as a fact that the others are comparatively uninjured; they are less injured, but not uninjured. You ask me to make an admission and then to draw an inference from it which is not correct.

14,612. Is it not a fact that the bodies of the other carriages, are much less injured?—Yes, they are less injured.

14,613. Much less injured?—I do not know that I have the whole of them; I have got a third-class carriage here that has a little bit left. The whole of the roof is gone, one end is intact and a very small portion of one side.

14.514. Do not go into details with me?—Then I say emphatically that they are not uninjured.

(The Commissioner.) The assumption which you were making was that the third-class carriages were comparatively uninjured, but that the others were very seriously injured.

(The Commissioner after looking at the photographs.) There is scarcely anything left of this one.

(The witness.) I see another one beyond it. I do not know what class it is, but there is evidently nothing but the floor left, and a great deal of the plastering of the sides also.

(Mr. Bidder.) This is a third-class carriage that I have. I trust I am not represented as saying that they were uninjured, but what I was saying was that they were less injured.

After a short adjournment—

(Mr. Bidder.) I have no further question to put.

(Mr. Webster.) I do not intend to go over the same ground again.

(The Commissioner.) It is utterly impossible to separate Mr. Bidder’s case wholly from yours, and it has been very convenient that he should have touched upon matters which are common to both cases.

Examined by Mr. Webster.

14,615. There are a few matters of detail upon which I must ask you some questions, and my questions involve questions of fact rather than of opinion, and therefore I must ask you to follow me carefully. You spoke, as page 2956, of rough slots being cut or punched in the slings or tie-bars; did you speak of the slings or of the tie-bars, or of both?—Both.

14,616. Will you kindly send for those gibes and cotters, as I shall want them? (The gibes and cotters were produced and put into position by the witness.)

14,517. Is that the correct way to place them?—Yes.

14,518. Have you got one of the slots which you described as being rough punched?—Yes (producing a slot).

14,519. Is this in a sling?—Yes.

14,520. Have you not got the end of a tie-bar naturally?—No, they are heavy.

14,521. It is the fact, is it not, that the roughness is on the sides, and not on the ends?—No, it is everywhere.

14,522. Do you suggest to the Court that there is a roughness or an improper cutting out of the ends of the slings?—Yes, I do, certainly.

14,523. Is that visible in this specimen?—Yes.

14,524. You say that is improper workmanship there?—Undoubtedly.

14,525. Would the roughness of the sides have the least effect upon either the stability of the structure or the tightness of the cotters?—Yes, very greatly indeed. If the cotters bear very firmly against the sides, any slight slackening of the tie will not allow them to become loose for a moment, whereas if they have ample play the slightest slackening will derange them.

14,526. I ask whether the roughness upon the sides would have any effect upon the stability of the tie or the tightness of the cotter?—I think that if the shorthand writer reads my answer, it is the best I could give you. (The last answer was read.)

14,527. I am not speaking about ample play. I am assuming that the cotters are driven together in the first instance; if they are driven together into this groove or slot, will you explain to the Court how the roughness of the sides can have any effect?—I can only repeat the answer, that if the sides fit as they should do, then although the tie may shaken slightly the cotters will remain in their places, whereas if they do not fit the moment it shake everything goes adrift.

14,528. You will not apply your mind to the question; I am asking you what the roughness of the sides has to do with it?—The sides should have been smooth and accurately fitted to the sides of the keys, so that there should be no lateral play.

14,529. I am dealing with the roughness of the sides, and not with the fitting?—Roughness and smoothness are what constitute fitting.

14,530. Then as I understand the complaint is that they did not fit close to the cotters?—That is so.

14,531. You mean that there would not be so much of the surface in contact with the cotter; is that it?—Fitting is making smooth surfaces to correspond.

14,532. What you say is that the roughness would prevent the cotters from fitting close, and therefore there would not be so much adhesion between the two surfaces?—There is some whatever; there is a play in some places of a quarter of an inch, and rarely less than an eighth of an inch.

14,533. Then do I understand you to suggest that the slot is not punched the right size, or that it is punched rough?—That it is punched rough and that it has never been fitted.

14,534. Did it fit at the ends or not?—No, it did not.

14,535. In how many cases do you pretend that you have found the slots not fitted properly?—I make no pretence whatever; I say that in examining carefully I have not seen a properly fitted slot in any part of the bridge. There is no single slot that has been fitted.

14,536. Then, according to your statement, all the cotters were loose?—I did not say so.

14,537. I understand you to say that what you complained of when you spoke of the roughness was that there was not sufficient contact; do you mean to say that all the cotters were loose?—No; I mean to
say that every cotter was loose in its slot when relieved from the pressure which kept it tight. Laterally every cotter had play in every slot.
14,539. Is not the pressure upon the ends?—Yes, the pressure is upon the ends.
14,540. Assuming the ends to be tightly drawn up, and the gibbs and cotters to be fixed at the ends and so to remain, is the absence of close contact between the sides at all material?—Not while they remain so.
14,541. Did you ever find any slot drawn out at all?—No. I do not understand you.
14,542. Did you find any slot drawn out or elongated or altered in shape at all?—I have found the ends of some upset.
14,543. Have you got any of them here?—No.
14,544. Have you any notes of what you say you found upon?—No.
14,545. What do you mean by upset?—Indicating marks of great pressure.
14,546. That is what you mean that you discovered in the sides of the slots?—The ends.
14,547. You have spoken of the capability of the compression of the cotters; did you find any compressed cotters in the ruins?—No, I do not think I did.
14,548. It is a very important point with reference to what you have been suggesting with regard to the holding of these ties. You have pointed out that the possibility of compression was a weak point, and you have given a calculation to show that the compressive strain was only a quarter of the tensile strain of the whole tie, speaking roughly; if you could have discovered a compressed cotter, it would have been a very strong fact; did you look for them?—No.
14,549. And you have, I believe, seen a very large number of cotters?—No; not a very large number.
14,550. How many?—Well, because you cannot ascertain that point unless you drive them out; they are still in the slots.
14,551. Have these come out of the bridge?—These have, and that one is upset already.
14,552. That you have discovered now when your attention is called to it?—I have no doubt that I should discover it in all that I looked at.
14,553. Except what may be discovered in these cotters, you cannot produce a compressed cotter?—I have not any more to produce. The first one I take up chances to be so.
14,554. The Court will judge of that from what they can see themselves. You spoke of an alteration in the mode of attachment of the ties and lugs in those ties as compared with some ties upon the north shore?—Yes.
14,555. You remember pointing out that the mode of attachment suggested by Mr. Gilkes in a drawing handed to me of two cotters and one gib did exist in the north part of the bridge, and you are quite correct in saying that here were two gibbs and one cotter; I want to know whether you suggest to the Court that the mode of attachment of the two gibbs and one cotter was inferior in any way to the other one?—No. The arrangement of the cotters in this part of the bridge is better than in the other, because you have what are called folding wedges with two parallel surfaces, and it is better than the two gibbs and one cotter.
14,556. You have answered the question perfectly fairly. By this means you get a perfectly straight bearing, do you not?—You get a parallel bearing, which is better.
14,557. Therefore in the event of any unavoidable irregularity of the pull of the tie, by this means you get an almost invariably straight pull?—No; it does not much affect that, but in driving in the key you are not driving against an inclined surface. It is more mechanical and better, but it does not affect the other.
14,558. I want to know in what condition you have found any of the gibbs and cotters which you can speak to as existing before the accident; in the first place, have you found any place where the little piece which is called the packing piece, is out?—Only in one place, but there I think it may have dropped out during the accident.
14,559. You cannot point to any place where you say the packing piece was out or the gib or cotter was out before the accident?—It would be impossible. There is one that is gone, but you cannot say when it fell out.
14,560. Are you well acquainted with ironwork construction where gibbs and cotters are used?—You mean, am I used to such a mode of construction?
14,561. Yes?—Very well indeed.
14,562. Is it a matter which you have had the maintenance of in any case?—Yes.
14,563. Where?—I erected three towers some seven years ago almost identical in their proportions with these.
14,564. Ask you whether you have had them under your care for maintaining?—Yes. I am consulting engineer, but they have never required any maintenance.
14,565. Where are they?—In Perumbuco.
14,566. That is a long way off?—Yes. I have photographs of them if you wish to see them.
14,567. Have you had any bridge over your care where there has been either tie construction or lattice construction necessitating the use of gib and cotters?—No. I should not use them in a bridge. In a constructed pier of this sort they would be used. I have never built a bridge with a pier constructed in this manner.
14,568. You have mentioned two or three times in the course of your evidence that this structure would be liable to vibration from the wind?—Strain rather than vibration.
14,569. And the trains, of course, would cause vibration?—Yes.
14,570. In such a structure, with such a large number of cotters, would you not expect to find some cotters work loose?—Yes; that is why I should have them so very carefully.
14,571. There was no necessity to add, that after you had answered the question?—Excuse me; I think it was necessary and proper to add it.
14,572. You would expect in the ordinary wear and tear of a bridge of this kind, with trains passing over it, and liable to winds, that some cotters would work loose?—Yes; if they were properly fitted they would not work loose.
14,573. You said just now that you expected it; is it not the common experience that cotters of this kind work loose?—Cotters of this kind would work loose, but properly fitted cotters would not work loose.
14,574. I understand you, as an engineer of experience, to say that cotters, that is to say, an application for drawing up a tie-bar in a structure of this kind and subject to these influences, would not work loose?—If they were properly fitted with fitted surfaces they would not work loose.
14,575. Can you, of your own knowledge, tell me of a single bridge where you know that cotters have been used and have not worked loose?—I have not put them into any bridge, and so I do not know. If they were properly fitted they certainly would not work loose.
14,576. Your estimate of 150 packing pieces is simply derived from a division of so many pounds of metal into so many pieces?—Certainly.
14,577. Do you know the actual number that you have found?—I think I produced a bundle of thirteen the other day that I have picked up out of the small portion of the structure that remained.
14,578. Now I want to take you, if you please, to a so-called defect that you have pointed out in connection with these tie-bars, and which also touches upon what you have been asked about this morning, and that is the channel iron; you have called attention to the cutting out of an angle of the channel iron. Do you remember it?—Yes; to make room for the bolts.
14,579. I understood you to say (I only read your evidence, and I may be incorrect) that that cutting out was necessary in order to screw up the bolts which attach the channel iron itself?—Undoubtedly. I will give you a sketch of it, and you shall see it. It is in column No. 5, panel No. 5, and one channel iron is 8ths of an inch above the other.

14,580. Just show me where the corner is cut out?—There (pointing it out), and on the bottom of the corresponding one on the other side. It is about as slovenly a piece of work as ever I saw in my life.

14,581. How many places do you find that in?—Only one with that peculiar characteristic. Those two ought to have been four and fast, but one looks double, and the other looks up (describing it); they were obliged to cut away the channel iron here to get the bolts through at all.

14,582. What have you been pointing out I understand is that in one place you have found this necessity to cut away the corner of the channel iron in consequence of the improper fitting?—Yes.

14,583. It is not anything that you complain of with regard to the fitting of all the channel irons, but only in this particular case?—It is in this particular case.

14,584. Owing to an improper fitting of the channel iron there required to be a piece cut out there?—Yes.

14,585. Do you say that that weakens the strength of that channel iron?—No; it does not interfere with the strength of the channel iron.

14,586. Do you suggest that that in any way contributed to the fall of the bridge?—Certainly not.

14,587. Is there any other complaint with regard to the way in which the channel irons are attached?—They are affecting the stability of the bridge as far as cutting the channel irons is concerned?—No.

14,588. Of course it is a fact which you have pointed out, and you have fairly told me that it did not in any way affect the stability of the bridge; what was your object in pointing it out?—It was in answer to a question put by Mr. Bidder as to the difficulties of screwing up the bolts, that in some cases they had had to cut it off to get access to the nut at all.

14,589. You have already said that this is a thing that you have discovered in one place?—Yes.

14,590. It may or may not be an accidental circumstance, as it was not in itself of any importance; do you suggest that there was anything of difficulty whatever except in this particular instance in screwing up bolts?—In every case when you get, in a space of five inches, two bolts of an inch and an eighth with a column preventing your working a spanner round, it is the most difficult thing to tighten them up; it can only be done by what is called a box spanner, or by driving the nuts round with a chisel, as I have seen some indications of here.

14,591. Do you not require a curved key?—A curved key would be quite useless.

14,592. You called attention to the cutting off of half an inch of iron from the side of the channel iron; do you remember that?—No; I do not.

14,593. I think I can refer you to the paragraph I put down at the time. It is at page 381 in the evidence.

14,594. I think I can refer you to the paragraph I put down at the time. It is at page 381 in the evidence. 12,642: Will you point out "a" which part of drawing No. 32 you are referring to?—(A) This (pointing to the drawing) is the "tie-rod", this is the quadrant, this is the channel iron, this is the lug. The quadrant was secured by these two bolts passing through the return flange; the piece "a" of metal which I bold in my hand was that piece. The bolt has been split, and the channel iron, instead of being about an inch, as shown there, was "a" never more than half an inch; they have broken in "every case." Will you point out on the drawing the piece you are referring to?—That is the piece (pointing to the drawing).

14,595. The cutting off of this piece of the channel iron?—No; the reduction of the thickness of the flange of the quadrant piece.

14,596. It has nothing to do with the channel iron?—Nothing whatever.

14,597. Will the strain be in compression or in tension?—Transverse strain principally.

14,598. In which direction?—The pull is in the direction of my rule (describing the same).

14,599. It is a horizontal pull, is it not?—Yes, entirely.

14,600. Could the cutting off of that metal or the reduction of thickness, as I will call it, there in the least affect the horizontal pull?—Undoubtedly; if it had double the thickness, it would have double the strength.

14,601. Which is the section of the iron on which the strain would come?—The very part I measured.

14,602. You say that the strain at that point comes upon the place where the weakness of that iron is?—Yes; most undoubtedly; and in every instance it is broken through that point.

14,603. You mean that in every instance you have found it broken after the accident?—Yes.

14,604. In how many places did you find it broken?—In dozens of places.

14,605. Are you sure?—Confident. You can count them on the photographs.

14,606. Now I go to the next thing of importance. As a matter of fact, you have spoken of the bolts to attach the girders to the top of the columns; I suppose you mean by that the L-girders?—Yes.

14,607. And in one place you found four bolts instead of eight?—Yes.

14,608. In which column was that?—I cannot tell you, because it is physically impossible. The plate was fished up from the bed of the Tay. 14,609. When pier was it?—That I cannot tell you. It was one of the plates which has been picked up, and it has been deposited at Wormit Bay.

14,610. How far away was it picked up?—It was picked up in the operations for raising the girders; it is certainly one of the first five piers.

14,611. You do not know the place from which that came so as to be able to say which pier it came from?—It was one of the first five.

14,612. Could you show me on any drawing or anything the four bolts which you say were out?—I did not say the four bolts which were out, but the four bolts which were in. The plate is in London.

14,613. Your answer is that there were four bolts instead of eight, which were out?—No.

14,614. Which pier was it?—That, I cannot tell you. It was one of the plates which has been picked up, and it has been deposited at Wormit Bay.

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14,618. Your answer is that there were four bolts instead of eight, which were out?—No.

14,619. Which pier was it?—That I cannot tell you. It is upon sheet No. 30, upon the drawing to the right-hand side which is underneath "side elevation of girder." There are four bolts shown upon each side of the eighteen-inch column.

14,620. That would be upon the left of the picture?—Yes. Even that would have been exceedingly imperfect. There you see an 18-inch column and a 16-inch column.

14,621. Now then, just point to the four bolts?—The four bolts are seen in elevation under the words "Angle iron."
14,619. There cannot be a mistake about it?—I have no doubt upon the subject.
14,620. And of course that was something that did form part of the bridge?—I think there is no doubt about that.
14,621. Do you say that there was any weakness there causing the calamity?—Very great weakness, and tending to cause the calamity.
14,622. Do you say that the absence of those bolts was a cause of the calamity?—Yes; it was a cause tending to it; not the cause of it; it assisted.
14,623. Do you say that the absence of four bolts caused the bridge to come down?—Oh no; certainly not.
14,624. What do you mean by saying that it tended to cause it?—That being secured only by a small part of the outer margin of the column, the whole of the resistance, would have been offered by bolts properly placed on the inside, which would have had a great effect, because far from the turning point, was lost.
14,625. They were at the top, were they not?—They were at the top.
14,626. What was the holding power of four bolts?—Very slight indeed.
14,627. What was it? what is the shearing strain of those four bolts?—Mr. Kirkaldy's experiment shows it, I think, to have been about 16 tons each bolt, but not what they were called upon to produce.
14,628. You said that was a cause of or tended to the calamity; did the attachment between the column and the girder give at all; were they not apparently as tight when you saw them as they ever had been?—Very likely they were.
14,629. Do answer my question. You have suggested that those four bolts not being there was a cause tending to the calamity; I put it to you that, having gone through all that it did go through, and fallen to the bottom of the river, when the whole column came up with the L-girder on the top of it, was it not as tightly attached as ever?—No; they were not at all loose.
14,630. A moment ago you said it was attached?—It was attached, no doubt, and we had to knock off the heads of the bolts to get it off, but it was very loosely attached.
14,631. Have you any idea of the looseness of those bolts?—My note shows me that it came from pier No. 30; "Remains on shore at Worr, ni, an opening of 4feet between the top flange of the 15-inch column on the inner side."
14,632. I thought you told us an 18-inch column just now; you certainly pointed it out as an 18-inch column.
(The Commissioner.) He pointed it out here as a 15-inch column.
14,633. (Mr. Webster.) But the four bolts are only on the 18-inch column in the picture?—It is as simple as possible. I can explain it in a moment. The piece that was brought on shore was the L-girder, and it had attached to it a piece of a 15-inch column, and it had the plate attached to it still to which the 18-inch column had been attached. My observations with regard to the bolts applied to the 18-inch column. The column was gone, and the bolts were all loose and slack.
14,633a. I want to get distinctly what you saw. You told us a little time ago that when the piece came up, that is to say, the column and the L-girder, you found four rivets or bolts in and four absent?—Four that were shown in the design, but that had not been put into the work; not absent.
14,634. Instead of there being eight bolts to attach the head of that column to the L-girder, there were only four bolts?—That is so.
14,635. You told me distinctly that you saw that there never had been the other four put in?—Yes.
14,636. Was the top of the column, or the piece of iron, whatever it was, still attached to the L-girder?—No.
14,637. It was separate?—Yes.
14,638. Then the column had come away from the L-girder altogether?—Yes.
14,639. Had the bolts sheared?—No, I think not. We broke off two or three, but whether we broke off the whole I do not know.
14,640. I want to know whether you say that when it came up the headpiece of the column, or the plate underneath the girder, had become detached from it or not?—That I cannot tell you; I can only speak of it in the state in which I saw it.
14,641. Was it loose?—It was gone when I saw it.
14,642. Had it been broken off before you got to it?—Yes.
14,643. Then whatever had been done to the bolts had been done before you saw the thing at all?—I apprehend by the accident.
14,644. Do not at the present moment understand the condition in which the thing was; was the head of the column still there?—No, it was not.
14,645. Had the underside nuts gone away, or were there no nuts on the underside?—I remember now that they were gone, and what we did break off were bolts which connected the plate with the L-girder; the column was gone.
14,646. And you cannot tell me what the condition of the plate was with reference to the head of the girder?—Only that it had parted company, and the bolts were gone.
14,647. Do you mean that the bolts had disappeared?—Yes.
14,648. Altogether?—Yes.
14,649. All four?—Yes; I will not say that a broken bolt might not be in the hole, but I do not think there was one.
14,650. Just read me now what note you have got about this 18-inch column?—I have no note about the 18-inch column.
14,651. Was it an important thing or not, finding this defect which you say was something tending to cause the disaster?—I brought the plate to town with me, and the court has seen it.
14,652. You said very frankly the other day that the bolts you now found were of sufficient strength and of proper iron?—I think so; I have no cause to complain of the quality of the iron at all.
14,653. (The Commissioner.) Does that apply to all the iron?—As far as I have seen. With the wrought-iron I have no reason to find fault.
14,654. Nor with the cast-iron?—Nor with the cast-iron, beyond the fact that it was not a good mixture.
15,654a. (Mr. Webster.) You have said something about the holes. Do you or do you not complain about the holes through which the bolts went which connected column to column?—Yes; the holes for the flange bolts.
14,655. On what ground?—That the bolts could not act as stay-gluing-pins; that the bolts were not turned to fit them accurately.
14,656. Was it intended to turn them?—They should have been turned.
14,657. Do you mean to say that the complaint is that they were not ordered to be turned?—Yes; they are specified to fit, and they do not fit, and it is their not fitting that I complain of.
14,658. I ask you whether you complain of their not being turned?—I do.
14,659. Do you suggest that it is not possible to make a proper joint, excepting a hole is turned?—Yes; for such a purpose as that I do.
14,660. Holes made even for a forged bolt?—It is a mistake to have a forged bolt; they should have been turned, and that is my complaint.
14,661. Both the bolts and the holes should have been turned?—Yes; and accurately fitted.
14,662. Did you ever have to construct, under your own supervision, columns such as these are?—Yes, precisely similar.
14,663. Where?—In the three towers of which I spoke at Pernambuco, which were fitted and marked at Glasgow, storey by storey.

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14,664. But they were going out by ship?—I do not mean shipping marks,—engineer's marks.
14,665. Do you not know perfectly well, that when things are going out to a foreign country it is the commonest thing to number them in parts?—You would not number them otherwise than you would number them in this country; you would put shipping marks of course, but you would not mark them beyond what it was necessary to mark them at home.
14,666. Mr. Bidder has asked you a question which I want to put to you again to get it clear. You have spoken a good deal about the holes in the channel irons, and of the way in which the channel irons were attached to the lugs; do I rightly understand you to say that there was not sufficient friction between the channel irons and the lugs to act as a strut?—Most undoubtedly.
14,667. Do you find any place in which you are able to say that the channel iron, as a strut, has moved before the accident?—How could I? I did not see the bridge before the accident.
14,668. On what do you found you judgment that, as struts, they did not act efficiently?—They could not, from the fact of the imperfect manner in which they were fitted.
14,669. What was the amount of friction between the two surfaces?—Exceedingly small. The court has seen some of those holes; there is a ridge or knob of about, perhaps, a quarter of an inch, which the most injudicious thing to put those flange, and I think had I thickened them would wash and there is evidence, that they neglected to turn what you call the inside of the flange when they might have done it.
14,670. As I understand you, your answer is distinctly that these channel irons never did act as struts?—They acted as struts, but most imperfectly.
14,671. And they were always loose?—No, I do not say anything of the sort.
14,672. Would screwing up tighter have made them right?—What is the defect?—The defect is that they never were fitted; that the bolts did not act as steadying pins, and that they had no abutment whatever.
14,673. Now I come to another thing?—You have said that the undersides of the flanges were not turned down as well as the tops?—Yes; the outer face of the flange is the best term.
14,674. The inside of the flange I should call it, but I will call it anything you like?—It is the outside of the joint.
14,675. It would be the top side at the bottom of a column, and the bottom side at the top of a column?—Yes.
14,676. Do you suggest that they should have been turned in a lathe?—Certainly.
14,677. Were there any brackets on them?—Yes; and it was a most injudicious thing to put brackets. With those brackets you could not turn them; they never should have had brackets.
14,678. As the columns were made with brackets, turning was an impossibility?—Quite impossible.
14,679. Therefore it is not as I gathered from your evidence that they neglected to turn what you call the inside of the flange when they might have done it; but that the flange had brackets on the top which prevented their turning it?—Quite so, and that it was a most injudicious thing to put those brackets.
14,680. I did not ask you anything about its being judicious or injudicious?—The reason why I object to brackets is twofold; first, that it does prevent you from facing the inside of the flange; and, furthermore, those brackets have to be loose pieces on the pattern, and there are so many more points where the sand will wash down when you mould. I have never used them in my own practice, but I make sufficient thickness of flange, and I thicken the column up for about six inches. It is only in rough gaswork, and work of that sort, that you use them.
14,681. I must ask you this; Do not the brackets materially strengthen the flanges?—They do strengthen the flanges, but you could have strengthened them in a much better manner; and the brackets add to the probability of getting imperfect castings.
14,682. What thickness were these flanges?—They vary very much.
14,683. Never mind variations; what are they supposed to be?—An inch and a half.
14,684. I am not speaking of breadth; I am speaking of thickness of iron?—Yes, an inch and a half.
14,685. An inch and a half flange on to an inch and a half pipe?—Yes; they are 1½-inch in the one case, and 1¾-inch in the other.
14,686. If the upright of the columns is 1½-inch, you think the flange is 1¾-inch?—It is so; it varies very much.
14,687. I am asking you what it is supposed to be, according to the contract?—That I do not know; that is a different matter altogether.
14,688. (Mr. Harlow.) Take it at 1½-inch.
14,689. (Mr. Webster.) How thick should you make the flanges in preference to having brackets?—About the same.
14,690. You think that the brackets were unnecessary?—I think they were a mistake.
14,691. You told the court a few minutes ago that you would dispense with the brackets, and make the columns very much thicker?—I did not say that.
14,692. (The Commissioner.) All that he said was this: that brackets would tend to strengthen the flanges; but he did not say that in this case the flanges required strengthening.
14,693. (The witness.) I did not.
14,694. (Mr. Webster.) Certainly I understood him to say that he should have dispensed with brackets and made his flanges thicker?—No; I said that my practice was to make the flanges thicker and the body of the column also thicker. Any engineer in the room will understand me.
14,695. (Mr. Webster.) Unfortunately, I am not an engineer. Would you then make it with a tapering thickness up to the top?—No.
14,696. With an angle, or what?—You carry it up with a little shoulder. It is the most usual thing in the world to make columns so. Water columns are always made so next to their sockets.
14,697. (The Commissioner.) With a little shoulder at the flange?—A little thicker for appearance; because more stress comes upon the column at that point.
14,698. (Mr. Webster.) For what work did you ever make a column with this swelling shoulder for the purpose of supporting the flange?—For this very tower that I tell you of.
14,699. At Pernamboxu?—Yes; and I can produce the contract drawings and photographs of it.
14,700. Have you ever erected any other columns besides the Pernamboxu ones?—No; but I have erected towers of a similar description to that. There were three there.
14,701. Now, about those male and female joints and the spigots; in how many cases of columns above the base do you say that you found a spigot missing?—I am not prepared to tell you. Very few columns are left above the base.
14,702. How many did you find?—I must look through my book to see. The most important of all is the bottom.
14,703. Is it important with reference to above the bottom or not?—Yes; but not so important. It decreases by sixths as you go up, as the strain decreases.
14,704. In how many cases of columns above the base, that is to say, above the bottom joint, will you undertake to say that you found the spigot missing?—You see I can only deal with your answer as given, and I must ask you to give me the fact, that I may deal with it afterwards?—I have one note bearing upon the subject of the spigots.
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14,719. We are not upon that point for a moment, although you are very careful to put it in of course; but I will ask you again whether you attribute the accident to the shifting of these columns?—Yes, and many other columns in a similar manner, the combined influence of the whole.

14,720. (The Commissioner.) You do not mean that the accident actually did arise from that one cause, but that it may have conduced to the accident?—Of course.

14,721. We take all your answers in that sense?—Certainly, that is the common sense view. They all contributed, but no one alone was the cause.

14,722. (Mr. Webster.) Could you tell me of any other pier where there was any shifting of any column in any place?—Every column almost has shifted and broken tie bolts and bent them. Every one, I think, I may say, has moved. In most cases the bolts are gone.

14,723. I gather from all your calculations without going over the ground, that in making your calculations you have eliminated the continuity of the girders altogether?—The girders have nothing whatever to do with my calculations.

14,724. You have treated them as separate spans in each case, and each bearing the same weight?—Yes; it would have increased the weight upon one, but it would have lessened it in the same proportion upon the other.

14,725. You have seen the way in which the bolts: that hold down the base plates were fastened into the stone?—Yes.

14,726. It is the fact, is it not, that the way in which those bolts were originally fastened must have been by putting them in through a hole, and then pouring in cement?—Yes, but it need not have been done before the base piece was put on.

14,727. But that is the way in which it must have been done?—Yes.

14,728. (The Commissioner.) There can have been no doubt about it.—No.

Examined by Mr. Balfour.

14,729. You told us, I think, that you had examined the contract and the specification for the execution of the bridge?—I have.

14,730. I do not propose to go into the detail of it, which you have done to some extent already; but, taking it as a whole, did it specify good material and good workmanship?—Yes, it did so dispose.

14,731. Would you say that it was to be material and workmanship of a high class?—Yes; the cast iron was of a very high limit, and the Low Moor bolts, of course, were a most unusual specification. It did provide for good work and for the bolts accurately fitting.

14,732. You have told us a number of particulars in which you consider that the work was not done conformably to the contract?—Yes.

14,733. If the work had been done conformably to the contract, would it have made the bridge materially stronger?—Yes; it would have made a difference in the strength of the structure.

Re-examined by Mr. Teather.

14,734. At the foot of page 9 of your report, you state that "considering that the columns are 78 feet in height, with a wind pressure of only 20 lbs to the square foot, a pressure of 387 tons will be thrown upon the eastward 18-inch column at the time of the passage of the train"?—Yes.

14,735. You were cross-examined upon that by Mr. Bidder at some length as to how you brought out, the pressure of 387 tons; have you gone over your calculations upon the diagram appended to your report No. 4, so as to test the accuracy of that figure?—I have.

14,736. Will you give us the results?—I have, as stated, a horizontal strain at the top of the pier of 37½ tons, which has to be multiplied by 77 feet, being the height of the pier, to give the moment. That
amount has to be divided by 13·7, the horizontal distance of the centre of resistance of the pier as a rigid structure, which is equal to 208 tons. The vertical weight upon column No. 18 is 129 tons, and the two added together give 387 tons. Mr. Birdie put to me that it would bring a strain of 15 tons upon the ties. I had worked it out carefully. 374 tons at 77 feet would become increased to 684 tons at 42 feet, the mean point of application of the ties; and that divided by 14 would give 12·92 tons, being only 8 tons upon the square inch. Dr. Pole and Mr. Stewart estimate that the same strain on the same bars under the same pressure of wind compared with my 12·92 tons is 11·25 tons.

14,736. (Mr. Bidder.) Just let me follow that. Where have Dr. Pole and Mr. Stewart put 11·25 tons?—In their report. If you turn to page 28 of Dr. Pole’s report, you will see it there stated that the tension on those bars is 679 tons per square inch. They state on the previous page that the section of those bars is 1·65; and if you multiply the one by the other, you get 11·25 tons.

14,736a. (The Commissioner.) Then there is not much difference between you?—No; that is mathematically correct. The difference between us with regard to the strain is because of the difference in the estimated weight at the top—the weight of the structure was slightly different.

14,737. (Mr. Traynor.) I believe there are still some experiments being made by Mr. Kirkaldy which are not completed?—Yes; the experiments upon the log, which are the most important of all. I received a note from him to say that he would be ready to make those to-morrow; and if the Court wished to see them, it would arrange that they should not be done until after the Court rises.

14,738. (The Commissioner.) Then you are not in a position to tell us how the effect of these experiments will bear upon your idea of the stability of the structure?—No; I am not in a position to do so. To day he is testing the tensile strain of the cast iron. He tries them all in one machine, and he has to change the machine from one purpose to another.

14,740. There was a matter that I wanted to ask you something about, but I have not had any time to look into it myself. It was with regard to the difference brought out in your calculations on Mr. Birdie’s cross-section between pressure of wind that it would require to upset this structure, and that which you had previously calculated?—I cannot answer off-hand. I will go through all these calculations, and whatever is the difference I will accurately state it.

14,741. That is the difference between what you gave as a four tons strain and what Mr. Bidder said should be four times four?—Yes.

14,742. You cannot do that now?—No.

(Mr. Bidder.) I beg your pardon, he has done it, and I have given him every opportunity of correcting it.

(Mr. Traynor.) He is going to take your challenge, and work it out.

(The Commissioner.) His answer was given upon certain data which were given to him, up on which he made the calculation in Court, as I understand.

(Mr. Bidder.) Upon Mr. Kirkaldy’s tests.

(The Commissioner.) Yes; it was not the result of any calculation between pressure of wind that it would require to upset this structure, and that which you had previously calculated?—I cannot answer off-hand. I will go through all these calculations, and whatever is the difference I will accurately state it.

14,744. You told me that all the slots in these ties had rough edges and rough ends?—Yes.

14,744. And, as I understood you, the pressure, of course, would be at the end of the slot?—Yes.

14,745. That is where the slot would give way I suppose, under the pressure?—Yes, where it would yield.

14,746. And it is partly in that way that you suppose that the cotters became loose and the jangle took place?—Yes, and that other parts. The slings not being fixed, yielded under a small strain.

14,747. Let us confine ourselves to the slots. You have supposed that one of the columns of what we will call the ties, although it might remain parallel to the one with which it was connected by a tie, would get out of vertical position?—Yes.

14,749. Supposing, for instance, that the cotter had given way by the action of racking or from the trains, or from the wind at the lower part of it, thus elongating the tie, it would elongate the slot in the tie, would it not?—No, it would not tend to elongate the slot in the tie, because the keys bear against the upper end of the slot in the bar and the other end of the slot in the tie, and there is no pressure to elongate the slot itself. Nothing presses against each end of the slot either in the sling or in the bar, but the gib presses against the top of the two slings, and the cotter presses against the tie.

14,750. Then the slot is elongated?—At one end.—

14,751. It is depressed at one end?—It is depressed at one end, and at that end it would elongate; it would give at one end.

14,752. It would give at one end by the pressure which was exerted upon it?—Yes.

14,753. And that would be the upper end?—The upper end are the slings and the lower end is the tie.

14,754. Would it be the lower end of the slot which would elongate?—The lower end of the slot in the tie, and the upper end of the slot in the slings.

14,755. And, as that elongated, the top of the opposite column in which it was fixed would fall over, would it not, outwards?—It would be the movement of the column that would produce the strain—it is the movement of the column that strains it.

14,756. Having moved outwards, having moved, we will suppose, by elongating the slot in the tie, the bottom of the slot would be in connexion with the cotter, would it not?—In hard contact with the cotter.

14,757. When you came to put a piece of iron into it, you would not be drawing back that pillar into its original position?—It would have drawn back a little before you discovered that it had moved—it would rattle.

14,758. All that you would hear by the rattling would be that it had come backwards and forwards, but the position that it would assume would be a pressing on the lower part of the slot in the tie, would it not?—Yes, but the great strain which produced the first elongation must partly come off or else it would not rattle.

14,759. It would rattle by the effect of the trains going backwards and forwards, but when it came to a position of rest, no doubt it would be pressing on the lower part of the slot, would it not?—No, it would not be pressing on the lower part of the slot when it was in strain.

14,760. When Noble came to put in the pieces he would put them probably so as to fill up the empty space in the upper part of the slot, would he not?—No, I think the history would be this. Having been drawn the parts would be compressed, the gib would back a little, they would then be loose enough to rattle, the looseness which produced the rattling would also enable Mr. Noble to drive the keys a little back and put in a piece of iron, and then he would wedge it up tight again.

14,761. Mr. Banister has just been good enough to make a drawing for me (handing the same to the witness); and that would be loosened, would it not, and would rattle, and a b would be tightened?—Yes.
14,762. Then if you put in at the bottom of the pillar a piece of iron, you simply retain, do you not, the pillars in the distorted condition in which they were before?—In that case you do. I was rather imagining a case where only being a temporary lateral strain it allowed it to come partly back again, but there is no doubt that if the strain continued at the time of the rattling, and he filled it up, then he would preserve the strain in a distorted condition.

14,763. And if the pillar was out of the perpendicular, the strain would probably be continued in that direction, would it not?—It would.

(Mr. Bidder.) Is not that assuming that he keys it up again during the storm?

14,764. (The Commissioner.) No, I am not assuming that. It is a question of what he got out of the vertical, would it or would it not have a tendency to remain over the column?—No; I think it is most likely that it would remain partly distorted, because it could not have moved without moving a good deal of the structure, and the disturbance of the struts in a line with not allow things to be restored to what they were before, unless an equal strain came in the opposite direction.

14,765. Then if these separate tiers of the column were distorted, I suppose a great deal of the strength of that column would be taken away?—It is so; it would be thrown into a totally different position at the last strain.

14,766. If you refer to plan 30 you will see there your L-girder. Now the L-girder apparently rests upon the top of the three columns; two 15-inch columns and an 18-inch column?—Yes.

14,767. The girder runs upon the top of that in a line with the two 15-inch columns, does it not?—No, not in a line with the two 15-inch columns midway between the two.

14,768. In a line parallel with the two 15-inch columns?—Yes.

14,769. That is to say, midway between the 18-inch column and the 15-inch columns?—Yes.

14,770. One portion of the longitudinal girder rests upon the upper part of the L-girder, wo will suppose?—Yes.

14,771. That weight I suppose is borne half by the 15-inch columns and half by the 18-inch column?—That is so.

14,772. Of which rests upon the upper part of the girder, half rests upon one 15-inch column, and half rests upon the other 15-inch column?—Yes.

14,773. Consequently the 18-inch column bears half the weight that is borne by the one 15-inch column and half that which is borne by the other?—Yes.

14,774. Therefore it seems to me that it bears double the weight of either of the 15-inch columns?—Yes. I would wish to make a further observation upon that. If you turn to Dr. Pole's Report, at page 21, you will observe that he has given an even strain upon all the columns, measuring that strain by the stress per square inch of metal. Now, inasmuch as the areas of these columns are not proportional to the stress that they have to bear, it is difficult to understand how that has been arrived at. The sectional area of the 18-inch column is, say roughly, 75 inches and of the 15-inch column, roughly, 50 inches; therefore it is quite clear that if double the weight is put upon the 18-inch column that is put upon the 15-inch column the strain must be half as much again per square inch as the 15-inch column. That was to have been properly explained by saying that the weight would adjust itself according to the sectional area. But I would wish to assume for one instant that instead of this being only 75 inches in area, it is 100 inches. Then undoubtedly there would be the same strain per square inch of metal—that is to say, there would be three-quarters of all. That Dr. Pole and Mr. Stewart allege is correct, if I set a man with a file to reduce the thickness of this metal down to the 75 inches, while he does so, and by the act of doing so the weight will adjust itself at the top, which is an incredible supposition; and at the moment that he files away all the metal the whole of the weight will have gone away of itself.

14,775. You have seen this specification of Messrs. Hopkins, Gilkes, and Company, have you not?—Yes.

14,776. Do you observe that under the head of "Piers," it is stated that the flanges of each length are to be accurately drilled, so that any two flanges being applied to each other, the bolt holes would be true and fair, and the lengths may be properly fitted together. Then in another paragraph it is said that "The rivet-holes in the whole of the plates, bars, angle irons, &c., must be punched quite true and fair, and when the parts of the girders to be rivetted, together are fitted in position, the rivet holes must be perfectly true and fair with each other." Is that paragraph that you refer to?—No, I refer to the paragraph on page 8 on the blue copy, "All bolts to be made of Low Moor iron."

14,777. Do you mean by that that all the bolts in the construction of these piers were to be made of Low Moor iron?—No, I mean that they were so specified, but I was coming to the last paragraph, which is that the bolts were to fill the holes.

14,778. Were they all to be made of Low Moor iron?—It says so.

14,779. "Or such other make as shall be specially sanctioned by the engineer"—Yes.

14,780. And you think the iron of which those bolts were made was sufficiently good?—I think it was very good iron.

14,781. You did not mean in answer to Mr. Balfour to convey that it was all Low Moor iron?—No; he asked me as to what was specified, and I said that exceptionally good iron was specified, and very good iron was used.

14,782. Then it says there that the bolts are to be carefully forged and screwed, and made to fit the bolt-holes; but you say that they did not fit the bolt-holes?—Undoubtedly, they did not.

14,783. And, therefore, they did not act as steadying pins?—No; that combined with the fact of the angular channel in the flange prevented them.

14,784. Are you aware or were you aware, before that, in the month of August 1874, an order was given for 9,800 ¼ inch bolts?—I am aware of it from awing.

14,785. And you are aware that in the September following that was altered to 1½ inch bolts?—Yes.

(Mr. Webster.) I think it is 1¼ inch to 1¼ inch.

14,786. (The Commissioner.) It is 1¼ inch to 1½ inch. There is a difference between the two of ½ths of an inch?—Yes, the strengths would be as 1 to 1½.

14,787. Would not that make a very great difference in the holding-down strength?—Yes, as 1 inch to 1½ inch, as the square was insufficient.—I do.

14,788. Do you concur also with Mr. Grothe in saying that you attribute the accident very much to the narrowness of the base?—Yes, a wider base would give so much less strain upon the struts.

14,789. And also if instead of there being one column externally there had been two, it would have been better?—Yes, for on account of the sectional area of the 18-inch column, is, say roughly, 75 inches and of the 15-inch column, roughly, 50 inches; therefore it is quite clear that if double the weight is put upon the 18-inch column that is put upon the 15-inch column the strain must be half as much again per square inch as the 15-inch column. That was to have been properly explained by saying that the weight would adjust itself according to the sectional area. But I would wish to assume for one instant that instead of this being only 75 inches in area, it is 100 inches. Then undoubtedly there would be the same strain per square inch of metal—that is to say, there would be three-quarters of all. That Dr. Pole and Mr. Stewart allege is correct, if I set a man with a file to reduce the thickness of this metal down to the 75 inches, while he does so, and by the act of doing so the weight will adjust itself at the top, which is an incredible supposition; and at the moment that he files away all the metal the whole of the weight will have gone away of itself.
14,792. You would have connected the L girders at the top, would you?—I certainly should, I should have made a complete structure of the upper part by which the weight would then have been more equally distributed.

14,793. And then you would have put additional struts?—Yes, I should have carried struts from the outer columns direct across.

14,794. From one to four, supposing that the same form of structure had been employed—if they had been put in one plane, then they could have been made continuous and given the same effect.

Examined by Mr. Barlow.

14,750. First of all, with regard to the question, the increase of width, would the increase of width have diminished the action upon the holding-down bolts, if any arose?—Not as turning over individual columns, but as turning over the entire structure, the broader the base the more the strain would have been reduced.

14,796. All other circumstances being the same, would increase of width in the piers alter in any way the action of the cross bracings required?—Yes, it would have reduced again the strains upon those in a similar manner.

14,797. Are you sure of that?—Yes, it would have altered the action of the bracings, and they might have been more direct.

14,798. The angle being the same, would it alter in any way the strength required for the cross bracings?—No, if they were so arranged.

14,799. Is not the cross bracing required for a structure of this sort dependent upon the lateral action of the wind acting horizontally upon the work, and not upon the width of the base?—The base gives the power of resistance to that strain of the wind. The greater the base, the more the columns are spread, and if the ties are attached to the same heights they will become more horizontal and more capable of resisting the strains of the same wind pressure at the same height.

14,800. Taking the same angle, supposing that you double the width of the base and put half the number of tiers, you would have then just the same angle in your wind ties?—Yes.

14,801. Would you not require just as much strength in your wind ties if the base was doubled?—Yes, more really, because those were inadequate.

14,802. But to resist the same amount of wind in every tier you would require the same extent of wind ties whether your base is a broad one or whether it is a narrow one?—Yes.

14,803. Then it merely affects the holding down bolts, and it does not affect the wind ties?—No, so long as the angle is the same.

14,804. As regards the positive question of width it is rather a matter of width taken in connection with weight, is it not. Supposing, for example, that you built up that brick base of its present width all the way up to the underside of the girder you would then think that it would be a strong enough pier to hold this bridge, taking the foundations to be sufficient?—Such a pier as might have been put upon a circular base would be of great strength. A hollow cylinder of brickwork would be of immense strength and lightness.

14,805. If the foundations were capable of bearing the weight of such a pier as that, such a pier as that could be put there?—No doubt. Hollowness would give it stability and avoid weight.

14,806. Could you say straight off what would be the weight per square foot upon the foundations, assuming that a hollow cylinder of the size of 31 feet in diameter had been carried up to the top?—It is very easily calculated, and I could tell you to-morrow morning. The engineer mean of 31 feet diameter carried right up to the top—would taper, reducing it, say, to 16 or 17 feet.

14,807. Could you construct upon that foundation a sufficient brick pier to hold this bridge, and give us to-morrow morning the pressure per square foot upon the foundation?—Yes.

14,808. With regard to these outer columns, do you agree with Mr. Grothe that a complete fracture in that top column on the outer side would have the effect of bringing down this girder?—It depends a good deal upon the direction of the fracture. If the fracture was across at right angles to the axis of the column—

14,809. Supposing it were an oblique fracture?—I think it is certain to come down; certainly it will come down if it is greater than the angle at which the column will break under compression.

14,810. Would that happen in the column below?—The lower it went the greater would be the weight upon it; at the same time the base would resist a little, but the weight would inevitably bring it down.

14,811. Would you like to go over the viaduct in a train if that bottom column was taken out, for example?—Certainly I would not do it.

14,812. If there had been two columns put upon the outside instead of one, would a fracture of one of those columns have brought down the viaduct?—No, I do not think it would.

(Mr. Webster.) May I ask that Mr. Law will be good enough to tell me accurately to-morrow morning the number of columns above the base that had no spigots on them. I do not want Mr. Grothe to leave until that question is answered.

14,813. (Mr. Barlow to the witness.) You found, I think, several of those keys and pieces which had been used for tightening up the keys?—Yes, "packing pieces," I have called them.

14,814. Could you state any particular pier and any particular ties in which you found those pieces?—I found in pier 29, which is the first pier which has fallen on the southern side, a packing-piece in the tie which extended from column 5 to column 6, another in the one which extended from column 5 to column 3, and another in the one which extended from column 5 to column 4. Everyone of those three ties has a packing-piece in it. Column 5 has a packing-piece in the three ties which united its bottom.

(The Commissioner.) In all the three ties at the bottom—in all the three there was a packing-piece.

14,815. (Mr. Barlow.) Are there any other in which you could distinguish the exact position in which they stood?—I may have notes of them, but in many cases the columns are in ruins, and I cannot say exactly where they came from.

(The Commissioner.) Then to-morrow morning Mr. Law will bring us first these calculations, and after that, if there are any questions to put to Mr. Grothe, they will be put: and after that what do you propose to do, Mr. Trayner?

(Mr. Trayner.) I propose, Sir, to examine another witness, a skilled man, who has inspected the bridge, as to his view of what caused the casualty, and I hope I may ask my learned friend who represents Messrs. Hopkins, Gilkes, and Company that Mr. Grothe's examination may not be long, because the witness whom I hope to examine to-morrow is staying here to-morrow at his own great inconvenience, for the purpose of not inconveniencing the Court.

(Mr. Macrory.) I am quite sure the number of questions put to Mr. Grothe will not be very large or take any great length of time.
Further examined by Mr. Webster.

14,816. Will you kindly tell me upon how many columns above the bottom, that is to say, upon how many joints above the bottom you observed a spigot wanting?—I cannot say upon how many I observed it, but I can tell you how many I have a note of. I have a note of one on the second tier column No. 1 of pier 30; the 18-inch column No. 1 on pier 30.

14,817. (The Commissioner.) The second counting from the bottom?—Yes, and the second tier column.

14,818. (Mr. Webster.) I asked you yesterday if you could speak distinctly to any other?—I cannot speak distinctly to any other.

14,819. Is either of those visible in the photographs?—No; they are. If I look at one of the photographs here I would tell you directly.

14,820. Do not trouble to look now. I do not want to occupy time. I ought to have asked you yesterday, have you ascertained whether or not the spigot of the bottom column was specified?—I do not know at all. I might tell by referring. There is nothing in the specification about it, I think.

(The Commissioner.) It is not in the specification.

14,821. (Mr. Webster.) It would not be in the specification.

(The witness.) I have no knowledge of it.

14,822. You have not ascertained from the working drawings, or anything of that kind, whether it was shown to be absent or present?—No. I have asked once or twice for the working drawings of the piers, but I supposed they were given in at Court at Dundee?—Yes, they were, but I have taken away again, and got mislaid in Mr. Walker's office.

14,824. (Mr. Webster.) Will you just give those two again?—One was in No. 1 column.

14,825. (The Commissioner.) Not No. 1 column?—No, No. 1; the second tier of No. 1 column of pier 30.

14,826. That is an 18-inch column.

14,827. (Mr. Webster.) And the second one?—That was in pier 34—those cases were in two piers having corresponding ironwork in each.

14,827a. (The Commissioner.) You were to give us what would be the weight of the brickwork if raised up to the top?—Yes, I have gone into that matter, and I have made a little sketch which I will show you, which shows what I think might be done. The suggestion there is that two piers might have been made each 15 feet in diameter at the bottom, and tapering up to 7 feet at the top, placed at the same distance apart as the existing girders, which they would have had to carry, and having at every 5 feet of brickwork a floor of Bradford foundation lands, that is to say, stone about a foot thick forming an entire floor. Such a pier as that would be enormously strong. I have calculates the strain upon the brickwork—that is upon the section of the brickwork that I have assumed, which is 18 inches in thickness; that would give about 84 tons per square foot at the top, and 84 tons to the square foot at the bottom.

14,828. (Mr. Barlow.) At the bottom of the cylinder?—Yes, where they rest on the cylinders.

14,829. (Mr. Bidder.) You mean per foot on the area of the section of the brickwork?—Yes, the section of the brickwork. Then I have looked into the relative weights of the foundations, and I have taken out the total weight upon the ground itself is the case of the present pier, that is calculating the weight of the existing 31-feet cylinder, which is 21 feet deep, and filled with concrete, the weight of the hexagonal pier above that, and the weight of the ironwork above that, and that amounts in the present pier to 1,584 tons.

14,830. (The Commissioner.) What would that give us per square foot?—I have not taken that out, but it is a very simple calculation.

14,831. The girder is a constant?—Yes. Then I have taken out the weight of that substitution which I suggest, and the weight of that would be 1,528 tons.

14,832. (Mr. Bidder.) What is that?—The weight of the brick piers which I suggest, Mr. Barlow having requested me to see what could be placed there. The weight of those brick piers and stone work, and the whole construction of wrought iron girder which I suggest should be put across the top, 2 feet 6 inches deep and 7 feet in width, making the complete entablature or box girder of wrought iron, the whole together, would weigh 1,526 tons.

14,833. (The Commissioner.) As against 1,584?—Yes.

14,834. That 1,584 tons being the weight of the present ironwork together with the brick pier at the bottom as it now stands?—Yes, and the cylinder and the caisson.

14,835. There is a pressure upon the ground of 1,584 tons?—Yes.

14,836. Are these piers which you suggest solid piers?—No, these piers are 18 inches thick with a floor of landing at every 3 feet.

14,837. Is the centre of the pier filled up?—No, the centre of the column is not filled up at all.

14,838. What is the thickness of the pier?—18 inches, the brickwork with a floor at every 5 feet of 12 inches of stone.

14,839. With the centre hollow?—Yes.

14,840. And that gives a weight, including the caisson underneath of 1,528 tons?—Yes.

14,841. (Mr. Bidder.) Including the brick piers?—Including the brick piers—the whole together—the wrought iron girders upon the top of it, and the caisson.

14,842. Do you mean it is less weight than the iron pier?—Yes. The surface exposed to the wind above the level of the base plates is identical with the present one, that is to say, it is 900 feet of spherical surface, equivalent to 400 feet of flat.

14,843. I suppose this red thing is a section of two hollow piers?—Yes.

14,844. Will you kindly tell us if you have calculated what force of wind would blow that over?—I have not calculated what force of wind would blow it over, but I have calculated what surface would be exposed to the wind.

14,845. (The Commissioner.) The surface exposed to the wind you say would be the same as the present?—The same as the present.

14,846. (Mr. Bidder.) What is the brickwork?—Eighteen inches of brickwork in cement, with a floor of stone work 4 feet thick at every 5 feet between the floors.

14,847. (Mr. Webster.) A floor of stone work at every 5 feet?—Yes, at every 5 feet, in slabs, the larger ones at the bottom would be in two pieces, and
go right through, and the smaller one would be got in easily of what are called Bradford foundation
buildings.
14,484. (The Commissioner.) Would that be a very expensive pier?—I took out the quantities at the contract
prices, and I found that the existing pier at the contract prices would have come to 2,636l.
14,485. That is the pier including the caisson—Not including the caisson, from the top of the caisson
I found that the hexagonal brickwork pier, and the pier itself as now above it, was 2,636l.
14,4850. That is at present, you mean the six columns?—Yes; the entire pier. The structure
which I have suggested at the same prices would have cost 1,361l., that is taking the scheduled prices.
14,4851. Then it would have been half the price of the other?—Somewhat more than half the price.
14,4852. (Mr. Barlow.) Now as to the pressure on the foundations?—The pressure on the foundations
would have been slightly less, it is very easy to calculate that. The difference is very little in the
two cases; it is two tons and a tenith in the present pier, and it would be a trifle less in the other.
14,4853. Have you calculated whether that would give a wind pressure of 50 lbs. to the square foot, and
have a factor of safety of four?—I have not, but I
could do that and give it you. I need not detain you
now by making the calculation.
(The Commissioner.) We are not bound by that
plan you have before you, Mr. Bidder.
(Mr. Bidder.) I am glad to think that you are not bound
by a good deal.
(The witness.) I do not mean to say that a better way might not be arranged. I was asked by Mr. Bar-
low to arrange something at once, and I have done it.
I might arrange something better if I had time to
think over it, but I have given the result of my first
impressions upon the subject.
(Mr. Bidder.) This suggestion comes upon us
rather as a novelty—it follows out the question sug-
gested by Mr. Barlow, but it is not the thing sug-
gested by Mr. Barlow.
(The Commissioner.) It was the original suggestion
in the original design.
(Mr. Bidder.) No, I beg your pardon.
(The Commissioner.) I mean there was an intention
originally to build the piers of brick.
(Mr. Bidder.) The original idea of Sir Thomas
Booch was one brick pier, and the thing suggested by
Mr. Barlow in his question last night was a hollow
circular brick pier.
(Mr. Barlow.) I did not suggest any form of pier,
merely suggested a brick pier.
(Mr. Bidder.) I so state in the last page, 569, of the
evidence, No. 14,806, "Could you say straight off
what would be the weight per square foot upon the
foundations, assuming that a hollow cylinder of the
size of 81 feet in diameter had been carried up to
the top?" Then the answer was, "It is very easily
calculated, and I could tell you to-morrow morning.
You hardly mean 81 feet diameter carried right
up to the top. It would taper, reducing it, say to
16 or 17 feet," so that the thing which is now
brought before us is a new idea, quite distinct from
that which was suggested as an improvement.
I do not wish to reopen the cross-examination, but I should like the
Court to ask Mr. Law if he ever built a bridge with a
pier of that description as such is shown upon that
plan.
14,844. (The Commissioner to the witness.) Will
you answer that question?—No; I have never built
one of that; it is very similar in principle to many piers that have been built, only they usually
are built square instead of circular. Circular is the
more economical.
14,855. (Mr. Bidder.) The bridge you built was a
bridge in Peruambuco, was it not?—When you say
the bridge I built, I have built a great number of
bridges. I did build one bridge there.
14,856. (Mr. Bidder.) I would just like to
ask one question upon that—are there not at Dundee,
and at Glasgow, very tall chimneys which are hollow chimneys, somewhat similar to this, and which have
resisted great wind pressure?—Yes; I never guess at
results and not take it, for I am not concerned with
wind pressure. I would not guess at it, but I am
quite confident that the greatest amount of wind
possible would not upset this structure which I
suggest.
14,857. But you are perfectly well aware that there
are chimneys rising to a height of 400 feet?—I know
one of 390, that is Mr. Cox's chimney.
14,858. That is hollow?—Yes.
14,859. That is, I will not say very like this, this
seems to be rather stronger built?—This undoubtedly
is stronger than any chimney.
14,860. And those chimneys have not been blown
down?—No.
14,861. (Mr. Barlow.) Are you quite clear that
the weight of that brickwork would not exceed the
weight of the present pier?—I have gone carefully
into it; the sectional area of the two is 90 square feet
—I am speaking of the brickwork only—the mean
sectional area of the brickwork for the two piers is
90 square feet. I have taken the weight of the brick-
work at 105 lbs., to the cubic foot, and I have taken
the height at 107 feet 6 inches, that is 80 feet above
the present base piece, 107 feet 5 inches is the height.
(The Commissioner to Mr. Bidder.) Mr. Law will
be staying here. You have his statement, and the
gentlemen who are with you may, if they like, corre-
oe his evidence by this morning. Whatever may be the
merits or demerits of
re-open the cross-examination, but I should like the
Commissioner.) That I do not know.
(Mr. Webster.) At present at all events, I may
say that there is nothing before you to show that any
suggestion was made to them—I merely put it in the
negative—I know you can only act on the evidence
present, but it has not been suggested to you
affirmatively that any statement of that kind was made.
Now in view of a possible conflict between Mr. Law
and myself, as to the existence of certain things at the
time that the bridge was actually handed over and
inspected, I do venture to submit on behalf of Messrs.
Hopkins, Gilkes, and Company, that nothing could
be more satisfactory to the Court than that a perfectly
independent person, as the Commissioner, should not
be in the presence of the matter. I am most anxious
to avoid anything like controversy in fact, and any
statement made by General Hutchinson of course would have the greatest weight.  

(The Commissioner.) I might state that the Court has expressed to the Board of Trade its opinion that General Hutchinson should attend and be examined before it; we have so intimated, but at the same time we do not call upon the Board of Trade to produce General Hutchinson now; we leave it of course to the Board of Trade to produce General Hutchinson whenever it may be convenient.  

(Mr. Bidder.) Quite so.  

(Mr. Trayner.) I think it only right to say that it has always been the intention of the advisers of the Board of Trade in this matter to produce General Hutchinson before the inquiry is closed.  

(The Commissioner.) We do not think the inquiry could be completed without General Hutchinson's evidence; I think that is Mr. Trayner's opinion too.

Mr. John Cochrane sworn.

Examined by Mr. Trayner.

14,862. You are a member of the Institute of Civil Engineers?—Yes.

14,863. And you have had, I believe, very large experience in the erection of bridges on columns, such as those that were erected in the Tay Bridge?—Yes, similar.

14,864. Just give us some idea of your experience—when did you commence?—The first very large work 1 did was the Great Exhibition in 1851. Since then I have put up several bridges over the Thames, including Westminster Bridge, the Charing Cross Bridge, and the Cannon-street Bridge; I also have put up a large bridge over the Mersey at Runcorn.

14,865. (The Commissioner.) That is a girder bridge?—Yes, and the suspension bridge at Clifton, having removed it from Charing Cross, and many other large works.

14,866. (Mr. Trayner.) You went to visit the ruins of the Tay Bridge?—I did.

14,867. You were there on the 1st of April, and you were also there on the 11th and 12th of April?—I was there on the 1st of April and two or three days afterwards.

14,868. And you were accompanied on both occasions, I think, by Mr. James Brunlees, also a Civil Engineer in London?—I was; I went with him.

14,869. Did you make your examination together?—Yes, I did.

14,870. I believe you both went there at the request of the North British Railway Company?—We did.

14,871. (Mr. Trayner.) I should say, Sir, that the North British Railway Company, having been requested in a letter from the Court to communicate its views upon the cause of the disaster, as you are aware, took this mode to ascertain their views, and they have communicated the report of these two gentlemen to the Board of Trade, as I believe to others who are represented here. (To the witness): What was the purpose for which you were instructed to make these visits, what were you to report upon?—Particularly with reference to the alleged inferior quality of the iron used in the castings of the columns forming the piers, the imperfect workmanship, and the concealment of defects in the ironwork.

14,872. Also as to the quality of the material, and the workmanship of the wrought iron used for bracing up the piers, and the superstructure?—Yes.

14,873. I understand that you were also to form an opinion as to what caused the disaster?—Yes.

14,874. I will take you first to the quality of the material, and first to the quality of the wrought iron—what opinion did you form as to the quality of the wrought iron?—I formed the opinion that it was very good.

14,875. That opinion being formed from an exami-

nation of the remains which you saw, but not from tests—Not from tests.

14,876. But still you satisfied yourself that the quality was very good?—From the way it was torn and twisted and bent about. I came to the conclusion that it must be very good iron.

14,877. Now with regard to the cast iron, what do you say?—The cast iron I considered to be of a very fair quality, so far as I could judge from the fractures I saw, and from the general appearance of the cast iron—the general appearance of the metal.

14,878. Again without applying any tests, I suppose?—Certainly.

14,879. So that, in a word, you had no fault to find with the material of the iron that was used in the construction of the bridge?—None whatever. I thought it was very good.

14,880. Then we will take next, if you please, the question of the workmanship?—I considered that the mode adopted for casting the 15-inch columns, as I was informed—of course I did not see it—was not good.

14,881. Will you tell us, in order that we may compare it with what we have otherwise in evidence, what was your information as to the mode in which the castings of the 15-inch columns were made?—I was told that the patterns were bedded in the sand on the floor, and that a top part only was used for the upper portion of the mould, no bottom part being used; so that when the metal was poured into the mould it would be necessary to have large weights on the box to keep them down to the mould, or they would be lifted.

14,882. Floating with the force of the metal; that was poured in?—Yes, from the force of the metal—to keep them from lifting.

14,883. (The Commissioner.) On what is called the flasks?—Yes, the top flasks, there being no bottom flasks at all. To keep those flasks in their places, I understood from the gentlemen who were the ironmongers, that the flasks were fixed by means of guides, so that when the flask was lowered over the mould after the pattern had been removed, those flasks would guide it down into its proper place. I think that was a mistake. I think there should have been a very much better mode of doing it: in fact I think that there should have been two flasks, and not one.

14,884. (Mr. Trayner.) What would you expect to find as the natural result of that faulty mode of casting on the column itself?—I should expect to find frequently that the top part of the box did not go into its proper place, and that laterally the thickness of the metal at the joint would be reduced on both sides of the column.

14,885. Would the column be thicker in one place than in another—would there be a larger deposit of metal on one side than at the other?—There would be a projection on the outside of the column in each case, the projection on one side would be in the top, and on the other side in the bottom, and therefore the thickness of the metal would really be reduced on both sides of the column.
14,886. (Mr. Bidder.) I do not quite follow that. — If the bush had sunk when it was lowered into its place, it would be a projection of metal on the side, and also on the other side.

14,887. The two semi-circles would not quite come close? — No.

14,888. (Mr. Trayner.) Those projecting pieces would require, if the column was used, to be reduced by a chisel, or in some other way? — They would be chipped off.

14,889. And in that way you would have thin metal at each side of the column? — You would.

14,890. Upon that, just let me ask you this, did you see anything at the bridge which led you to the belief that that had actually happened? — I saw two or three of the columns which showed that they had had a good deal of chipping on the sides of them? — At the joint.

14,891. Chipping the protuberances produced in the way you have mentioned? — Yes.

14,892. Were these columns so examined by you, among the columns that had fallen, or within the range of the high girders? — They were some of those that had fallen.

14,893. Was anything else about the castings that you thought objectionable, or the mode of casting, I should say, except what you have detailed? — I did not like the recess in the flanges, which is cast in them; I should also prefer a smooth surface to have seen the flanges faced over the whole of the surface with no recesses.

14,894. But apart at this moment from the flanges, was there anything on the column proper between the flanges which you found objectionable, except the reduction of the thickness of the metal by the blunder which appears to have been the rule for these piers, or the mode of acting, I should think that the inside would always be liable to get a certain amount of porosity, as you may call it.

14,895. Why? — I do not think the attachment is good. In casting any large expanse on a column, whatever little impurities there may be in the metal would come into that part; especially if it was in the upper part of the columns, and they would be liable to the weak. In addition, at the junction between the lug and the main body of the column you are always liable to get a certain amount of porosity, as you may call it.

14,896. (The Commissioner.) Sponginess? — Yes.

14,897. In cooling, one draws away from the other especially in horizontal columns — columns cast horizontally, I should say.

14,898. That is between the lug and the flange? — Between the lug and the column, or between the lug and the flange either — at the junction of the two.

14,899. (Mr. Trayner.) Did you notice anything on the columns themselves to indicate weakness at the junction between the column and the lug? — I noticed in one or two cases, that the slag or refuse that would be in the iron had accumulated at the junction of the lug and the column, and had made a bad place. That is a thing that I think you would always be liable to under the same circumstances.

14,900. Did you see anything of the nature of a cold shut in any of the columns? — Yes, I saw one or two.

14,901. Would you kindly just tell me how that is produced? — It would arise principally from the iron having been put into the mould in not a sufficient hot state, so that when it rose from the bottom and came up round towards the top, the two liquid surfaces as I may say meeting together, would not be in a sufficient state of fusion to properly unite.

14,902. If the iron was of a sluggish character, and full of scoriae, is that a result which would likely enough be produced? — If it were so; but I know a great deal about Cleveland iron, and to say that it is sluggish means to say that it is not hot enough — that is practically what it means.

14,903. Is it possible that whether produced from want of heat, or from any other cause, would result in the cold shut that was produced on the columns? — I can hardly say the sluggishness — I say because it was not sufficiently hot.

14,904. The want of heat? — Yes.

14,905. Was there anything else in the columns, in so far as the casting of them was concerned, that you have to remark upon? — I particularly noticed that the holes in the lugs to which the diagonal bars are attached by the bolts were not uniform in diameter through; they were not parallel.

14,906. (The Commissioner.) Will you just repeat that? — I noticed that the holes in the lug to which the diagonal bars are attached by the bolts were not parallel; the holes themselves were tapered from the outside to the inside of the lug.

14,907. (Mr. Bidder.) On both sides? — On both sides.

14,908. They were tapered? — Yes.

14,909. (Mr. Barlow.) When you say both sides, do you mean in the pair of lugs both sides were tapering inwards? — Both sides were tapering inwards.

14,910. (Mr. Bidder.) Were they wider inside? — Yes, they were wider inside.

14,911. So that the bolt would bear on the two edges? — Yes, on the two outside edges. (The witness made a sketch and explained it to the Court).

14,912. (The Commissioner.) The hole for one lug is conical? — Yes, the hole for one lug is conical.

14,913. (Colonel Volland.) Both are conical? — From outside to inside.

14,914. The largest diameter being inside? — Yes.

14,915. (Mr. Bidder.) It is a double cone, in point of fact? — Yes.

14,916. The two together would form a double cone? — Yes.

14,917. (Mr. Trayner.) What effect had that when a strain was put upon the bolt? — When you put the bolt through, and put a strain on the tie-bar, the effect would be to bend the bolt, and I found on the piers several bolts so bent.

14,918. If the holes had been of the same diameter, and parallel, would the bolts have been so apt to give? — Certainly not, because they would have had a very much shorter bearing.

14,919. (Mr. Bidder.) I do not know whether you can tell us whether you have observed the extent of that conical enlargement, the difference in diameter internally and externally of the hole? — I did not measure it; but supposing that the hole on the outside was 1½ inches in diameter for a 1½ inch bolt, which appears to have been the rule for these piers, I should think that the inside would be more than ⅜ of an inch larger; I should think it would have been nearer a ⅝ of an inch, but certainly more than ⅜ of an inch larger.

14,920. (Mr. Trayner.) As regards the casting, did you observe anything else that you thought defective? — I should say that I was not at all surprised; to find the castings made in that way, because I know that the moulders, as a rule, would be almost certain to make those holes conical. There is the greatest difficulty in the world to get moulders to put a parallel core into the mould; unless you stand over and watch them, they are certain to rub it to make it conical, they rub it down with the base of the mould, and they do something to make it wrong.

14,921. Now that you have told us of the practice of these moulders, can you give us any insight into their purpose, why do they do it? — I cannot tell you, because they are stupid.

14,922. It is perseverence on their part? — Yes.

14,923. That, however, is a thing that you are on your guard against by supervision and inspection? — Yes, I think the holes under such circumstances should have been either bored or reamed out, or something to make them parallel.

14,924. And in important works under your own charge, do you see it is so? Always when I have a chance of doing so I always see to it, I always give directions that it should be looked to at all events.

14,925. It has an important bearing upon the stability of the structure? — I think so.

( Mr. Bidder.) That is rather a strong question to put in that form in examination-in-chief.
Mr. Trayner.] If you object to its being put in that form I can put it in another, but it is really not worth discussing the form of the question, I think, especially when it has been answered.

(Mr. Bidder.) I do not think I am unreasonable in suggesting this, that when my friend Mr. Trayner in an inquiry of this description in examining a skilled witness like Mr. Cochrane comes to a point which he considers of vital importance to the case, he ought not to put the question in that form.

(The Commissioner.) After all he had got Mr. Cochrane's answer before you objected. It was merely Mr. Trayner summing up.

(Mr. Trayner.) Leading to another question.

(Mr. Bidder.) I have been listening attentively, and up to this moment I have not heard the slightest expression of opinion on the part of Mr. Cochrane as to the bearing of this imperfection upon the safety of the structure; and I do think that under those circumstances Mr. Cochrane should be asked to state his views in his own language.

(The Commissioner.) No doubt that would be the proper course.

14,926. (Mr. Trayner to the witness.) Do you, looking at the effect with such a possibility of yielding of the bolt, have under strain, in works under your own charge, take care, by inspection, to prevent the possibility of that, so far as you can—I do; and with a view to provide against such contingencies. I know I would, and which I know you cannot get rid of. I should make those bolts larger in diameter to provide against such a thing.

14,927. (Mr. Bidder.) Larger than what?—I should increase the diameter of the bolt to provide for its having to bear a strain at a larger distance between the points of support. Suppose the bolt is that long, you would increase its diameter to enable it to bear its strain, to support it there and there instead of there and there.

14,928. You would increase it beyond what you would otherwise make it?—Beyond what I should otherwise make it, but what would be better of course would be to have the hole made parallel.

(Mr. Trayner.) I understand you to say that if the casting were intended for an inch and a quarter bolt, or an inch and a bolt, you would make the bolt a little larger than that size.

(Mr. Bidder.) He did not say that; he said, larger than he otherwise would have done.

(Mr. Bidder.) Perhaps you will kindly let me put my question.

(Mr. Bidder.) I really must object to you putting into Mr. Cochrane's mouth that which he has not said. What Mr. Cochrane has said is, "I would make the bolt, as far as the castings are concerned, a little larger than that size." He did not say, I would make it larger than that size.

14,929. (Mr. Trayner to the witness.) I want to know what that means; am I right in understanding, or wrong in understanding, that if the bolt was of a specified size you would make the bolt larger than the specified size, to provide against the probable increase of the hole?—No, I do not mean that at all.

14,930. What do you mean?—I mean that in designing a structure of that kind I would provide for the contingency of the hole not being truly cast, if it was going to be cast. If the hole is going to be made parallel then there is no necessity for increasing the size of the bolt.

14,931. (Mr. Barlowe.) Is it made parallel by riveting or drilling?—Yes.

14,932. (Mr. Bidder.) You would fix the diameter of the bolt in designing with reference to that contingency?—I would.

14,933. (Mr. Trayner.) Is there anything else about the castings that you thought defective?—I think not. That is what I think is the principal fault, as far as the castings are concerned.

14,934. Now as to the flanges, I understood you to say that you would have preferred the flanges to have been cast with a full plain surface?—I would.

14,935. These particular flanges were cast with an annular channel?—Yes. Do you happen to know what was its size?—what were the dimensions of the channel?—I cannot say positively, but I should think about half the width of the flange, I should say 2½ inches, or perhaps it might be 3, or 2½ inches. I do not know exactly.

14,937. (Mr. Bidder.) In that the reason?—Yes, I suppose it was that.

14,938. (Mr. Trayner.) What effect had the recess—in what respect do you think that was a mistake, or how would you have preferred it otherwise?—I should have preferred having the holes drilled through the flanges for receiving the bolts; you would then have got the bolts so that there would have been an absolute stop at the point where the two services met, and you would have made them steady pins really as well as bolts; that is supposing you had the holes drilled only a shade larger than the diameter of the bolts.

14,939. The holes in these flanges were drilled, so I understand you?—In all the 15-inch columns I think they were.

14,940. Was there perfect coincidence produced in that way?—There would be, because as I understood, the holes were drilled by a machine all at one time, and therefore they would be all uniform and alike. There would be, and there always is, in drilling holes through flanges, through flanges, there would be for drilling them, a shade of variation, they meet with a hard spot in the casting which would cause a little spring on the drill on one side; but taking eight bolts through these flanges I think, in fact, I am convinced, that perhaps six or seven out of them might be put in with the finger and thumb, pushed through the holes, but at all events one, or probably two, out of the lot would require the assistance of a hand hammer to lock them in, and therefore you would know that you had really filled the holes up with bolts for all practical purposes.

14,941. (Mr. Barlowe.) If the upper column was fitted on to the lower column with the spigot and facet, would not the necessity of pins be avoided in that way?—It might be to a certain extent avoided in that way, and perhaps altogether; but I myself should prefer to have the flanges faced all over and brought close together, I would prefer to depend upon the bolts, that is what I would do from my experience.

14,942. And not let one column into the other?—I think I would do that in addition—I think it a very good thing—I consider the spigot and facet an exceedingly good thing.

14,943. (The Commissioner.) I understand you to say that you would have that in addition?—Yes, I think it is an exceedingly good thing, and I think it would be advisable to have it in addition.

14,944. (Mr. Trayner.) You have spoken to the holes in the flanges in the 15-inch columns. How were the holes put into the flanges in the 15-inch columns?—I believe they were all cast. I should mention in reference to the holes in the 15-inch columns that they were drilled an inch and a quarter in diameter for an inch and an eighth bolts; I think that was too much increase in size; I think there should have been what I should call full an inch and an eighth.

14,945. (The Commissioner.) They were drilled an inch and a quarter, were they?—I believe I am right in saying an inch and a quarter.

14,946. (Colonel Yolland.) Those are the 15-inch columns that you are speaking of?—Yes.

14,947. (The Commissioner.) You think that gave too much play?—Yes, more play than I would have allowed.

14,948. (Mr. Trayner.) Did you inspect any of the 15-inch columns so as to be able to say whether the holes had been drilled or cast?—They had been cast in those that I saw, and they were cast with a larger amount of play in them than in those, that
were drilled as a matter of necessity to provide for the irregularities in putting in the bolts cores.

14,949. Then had the flanges more play in the 18-inch columns than in the 16-inch columns?—Certainly they had.

14,950. Is that a thing that you approve of?—No, I think the holes in the 18-inch columns ought to have been drilled, just the same as the 16-inch columns.

14,951. You have mentioned the spigot and faucet adjustment, did you find that existing in all the columns?—No; it does not exist in the bottoms of the columns that connect to the base plates. I cannot speak as to the upper columns, because I did not notice those, but I saw a great many with spigots and faucets on, and I concluded that that was the principle.

14,952. Do you think they should have been at the base plate?—I do not think they would be absolutely necessary at all if the holes and the bolts were properly fitted.

14,953. Would you have recommended it as an additional security at the base plate?—Unless there was some great inconvenience in doing it in the manufacture, there may have been many reasons why it should not have been done.

14,954. Will you tell me next as we are upon imperfect workmanship, any other thing that you observed that you thought had any effect upon the stability of the bridge, will you go to the connexion of the tie-bar with the lug?—I have no other objection to the connexion of the tie-bar with the lug beyond what I have already stated in reply to the question.

14,955. (The Commissioner.) And in reference to the lug too?—Yes, to the lug and its connexion with the column. I think it would have been advisable that there should have been no lugs cast upon the columns at all.

14,956. (Mr. Trayner.) Did you observe any of the holes in the channel iron?—I did, and I noticed that some of them had been elongated to enable them to fix the bolts properly, but I do not apprehend really that there was much in that.

14,957. Did the elongation of the holes there not tend to give-play and prevent the rigidity that would otherwise have been preserved?—Provided the elongation was in the same direction in both holes, it undoubtedly would, but I was not prepared to say that it was in the same direction in both holes, you might get the one bolt acting and the other not.

14,958. Did you observe any place where packing pieces had been put in at the side of the cokers?—I did not. With regard to a great many of those which I have heard were found, I should say the probability is that they were removed before I got there at all; because I understood that Mr. Law took away several. I did not see them, but I heard that they had been used.

14,959. You have given us your opinion as to the quality of the material and the workmanship. Will you tell us now what opinion you formed as to the causes of the disaster?—I think that the disaster arose from the extraordinary pressure of the wind on the night of the storm; and I think that in that action of that wind and previous winds that may have taken place a great many of the bolts connecting the diagonal ties of the columns may have been bent; probably were bent. That would allow of a considerable lateral motion in the pier, because I am quite convinced that if you could have kept the pier rigidly upright, it was strong enough for its purpose. The distance between the centres of the bolts in the lug at the top of a column, and the lug at the bottom of its adjacent column, you get rid of your rigidity.

14,960. (Mr. Bidder.) You increase the horizontal distance between?—The moment you increase the distance between the centres of the bolts, or the centres of the bearings of the diagonal ties—

14,961. You take off the tension of the ties?—The moment a bolt goes through there and another through here (pointing to the model, and I am disregarding now whether the jib and the cokers which are in a different position), if that bolt bends, and that bolt bends, the distance from centre to centre of those points is increased, and it will allow the structure to go over. If that goes on all the way through to the top you will get a large amount of tendency to go over at the top. I think that in all probability many of those that bent were bent before the great storm on the night of the destruction; I believe that these packing pieces that I hear of as having been put in were necessitated by the bending of those bolts, and not by any compression which took place in the jibs and keys, or extension that took place in the diagonal bars.

14,962. (Mr. Trayner.) Would the bending of the bolts in the way you have described be indicated by the shaking of the tie-bars?—It would. I am told that upwards of 100 packings were put in, and that they were put in where they found a shaking. If they had found no shaking at all, and nothing loose, then I should conclude that the bolt had not bent; but on the night of the great storm I think the probability is that it set to and bent them all right up to the top.

14,963. Is there any probability in your mind that some of those had bent before the night of the great storm?—I think so; I think it is highly probable, because there had been heavy gales of wind there since the structure was up, independently of the exceptionally heavy gale on the night of the accident.

14,964. (Mr. Bidder.) I understand you that you attribute the chattering that was taken up by the packing pieces to that cause?—Yes.

14,965. (The Commissioner.) To the bending of the bolts?—Yes.

14,966. The bolts at each end of the tie-bars?—Yes, if that bending amounted to as much as the sight of an inch in each bolt, that would allow for a quarter of an inch packing. I do not know what the thickness of these packings are.

14,967. (Mr. Trayner.) Did you approve of these ties, looking to their dimensions?—That I could not tell without going into calculation—I have gone into no calculations of the strains, and therefore am unable to answer that question.

14,968. Do you think it would have been better to have bad those ties to act both as struts and ties?—I think unquestionably it would. There is always a difficulty in connexion in making struts act as ties, because you have no adjustment.

14,969. (Mr. Bidder.) There is always a difficulty in what?—There is always a difficulty in making a strut act as a tie, because you have no adjustment—you cannot pull it up—you cannot stick in a jib and key and pull it up.

14,970. To make the same thing, both a strut and a tie is practically a difficult thing to do?—Yes, it is a difficult thing to do, it requires very great care in the workmanship.

14,971. (Mr. Trayner.) But it is done?—It is done constantly; it is done here (pointing to the model), there are two sets of struts, which are also ties; they are riveted securely at each place, and that makes them right, and it could have been done equally well in the pier, if the distance between the centres of the bolts in the lug at the top of a column, and the lug at the bottom of its adjacent column, you get rid of your rigidity.

14,972. You are dealing now with the cause of the disaster?—I am stating what I believe took place.

14,973. In your opinion, did the yielding of the bolts tend to the disaster?—I think so.

14,974. Is that a matter that would have been discovered, the yielding of the bolts, by a careful exami-
tion of the bridge?—I think it is exceedingly doubtful that any examination would have discovered it—it is one of those things you find out after they have taken place.

14,975. Did not the chattering of the bars indicate looseness?—Certainly.

14,976. When these bars were found to be loose, presumably from the yielding of the bolts, was the mode adopted, of packing, in your opinion, the best mode of remedying what had taken place?—I should be very sorry to say so.

14,977. As a man of skill, what course would you have adopted if you had discovered the ties giving by the bowing of the bolts?—I should have immediately communicated with the chief engineer, and have called his attention to the point, with a view of devising some means of preventing the possibility of its recurring.

14,978. The girders in this bridge were continuous?—They were, as I am informed.

14,979. Had that continuity of girder any effect in producing the disaster, looking to what you have assumed to have taken place in the columns below?—I think in all probability it had.

14,980. Will you kindly explain how?—Supposing that the locomotive and tender had arrived within 40 or 50 feet of a pier, say the fourth pier as I call it—I mean the fourth—that is down.

(Mr. Bidder.) No. 32.

14,981. (The Commissioner.) No. 28 is the last answer to Mr. Bidder. Then it would be No. 32. Suppose that the engine and tender had arrived within 30 or 40 feet or 50 feet of the fourth pier, the girder being continuous, the effect of that would be of course defection to a certain amount, whatever the amount is, of the fourth spans. The girder being continuous—that defection would lift the overhanging part of the fifth girder which acts as a cantilever, as is the case in all continuous girders, say up to a third of its length, that would relieve the weight to a very great extent on the fifth pier. I have not heard any observation made as to the effect of the upward force of the wind in this case. I think myself it is an element which might be decided upon being taken into consideration. The upward force of the wind, as is well known, is the thing that you have to guard against more than anything else in large suspension bridges, and therefore as it acts on these, I do not see why it should not also act on such a bridge as this. If you have a very large upward pressure on the fifth girder, at the same time that you are helping to lift it by a load on the fourth girder, I think it is probable that the force of the wind horizontally, that is to say acting horizontally at the same time that it is acting vertically, which for some reason or other does although I cannot explain why— I think then the effect would be to cause such an amount of motion on the pair of girders at the fifth pier that it might set them sliding off.

14,982. (Mr. Barlow.) Might lift them out of their rollers?—Might lift them out of their rollers—the rollers have got flanges upon them and these flanges are bevelled, and I think it is quite possible that it might have that effect. When I had put up the suspension bridge at Clifton I had a temporary bridge made of wire ropes put across. The bridge is 700 feet span. These ropes were connected together by inch and a quarter inch and a half boards 7 inches wide, and about 5 feet long; that made a temporary bridge for the men to work over while the chains were being fixed. The pier that was completed before any chains were fixed, we had a gale of wind that lifted our temporary bridge considerably above the horizontal.

14,983. (Colonel Yolland.) You said it lifted it above the horizontal?—Yes, it was lifted considerably above the horizontal line by the upward force of the wind: I have no doubt Mr. Barlow will remember something about it, as he was the engineer for the bridge.

14,984. (Mr. Barlow.) In that particular case if the wind was blowing at a point not at right angles to the line of the bridge, it would catch the undersides of the planking on one side of the bridge?—It did do so.

14,985. That was the case you referred to?—Yes.

14,986. The wind was oblique, and caught the undersides of the planking, and threw it up in that way?—Yes, I understood that on the night when this accident took place the wind was not blowing at right angles to the line of the bridge; it was blowing, to a certain extent, obliquely, so that probably something of the same effect may have taken place; but that, of course, is a matter of pure assumption on my part.

14,987. In one case the bridge was nearly horizontal, whereas in the case of the temporary bridge that you speak of it partook of the form of the chain?—Yes.

14,988. (Mr. Bidder.) Was there any one on the bridge at the time you are alluding to?—No, fortunately not.

14,989. (Mr. Trangner.) Have you finished your answer to my question?—I think so.

14,990. You said that the effect of the wind with its vertical pressure would be to slide the girder off the rollers?—It would have a tendency to do so. It would lighten the load so much that the horizontal force of the wind at the same time might have the effect of causing it to pass over the sides of the rollers.

14,991. At that point where you are supposing the wind to have its pressure, at the top of pier No. 33, how were the upper girders connected with the supports?—It is an expansion joint. They were not connected at all, but simply lying on the supports.

14,992. Do you think that that was sufficiently attached to its supports in this bridge?—It is exceedingly difficult to make an attachment of a girder to a pier where you have got a lot of sliding going on, and where you have to provide for the expansion and contraction of a girder 1250 feet long in round numbers. At two points you have a very large amount of motion, and it is exceedingly difficult to make a very good attachment to that pier because you must let it slide; but I think it might have been so devised as to render it absolutely impossible for the girders to move sideways at all events.

14,993. So far as you know, in the design of the bridge was there any thing at all to prevent the girders moving sideways?—The flange of the rollers.

14,994. (The Commissioner.) What is the depth of the flange of the rollers?—I do not know— I think about 2 or 3 inch.

(Mr. Bidder.) It is shown upon the plan.

14,995. (Mr. Trangner.) Was that sufficient, or do you think there should have been something more to prevent the side motion?—I think there should have been something more. I do not mean to say that that took place, or that that was the cause of the disaster, but I think that that is an element to be dealt with. The piers are really, as far as my judgment goes, two distinct piers, each consisting of three columns. I think the tops of these three columns should have been connected so as to have made a pier of six columns. I do not think that simply a horizontal tie at the top is sufficient.

14,996. You would have carried the L-girder or angle girder?—Right round?—Yes.

14,997. You have expressed an opinion against the continuity. If the girders had been separate girders from pier to pier would that have admitted in your view of a more satisfactory attachment to the columns that were supporting them?—I think it would.

14,998. Would that have been an element of strength?—I think so.

14,999. At the ends of the girders was there any transverse tie or strengthening?—There was, I believe —there was a strut a certain distance down from the tops of the girders across at the ends, and a set of diagonal bracing.

15,000. (Mr. Bidder.) Not shown on the model?—No, not shown on the model. I do not know how far that went down—I believe about 9 feet—I think it would have been a very great advantage, and would have added largely to the stiffness of the girders if there had been a diaphragm 9 feet deep there instead of that simple strut and a couple of diagonal ties, it
would have given an admirable point for departure of the diagonal bracing which connects the top bows of the girders together.

15,001. (Mr. Trayner.) Did you notice that on some of the piers the lower tier of columns had been forced to the westward?—I did.

15,002. The great mass of the superstructure we know went over to the east?—Yes.

15,003. How do you explain what forced the columns westward?—At No. 5 pier the eastern set of columns is underneath the eastern girder crushed up.

15,004. The eastern set of columns are under the eastern girder?—Yes, as it lies on its side, or as it did lie on its side at the bottom. The western columns are upper to the top of the western girder, and that renders it absolutely clear to my mind that the three eastern columns gave way first, that the structure went over sufficiently quickly, and that then the three outer columns or western columns fell over on to the top of the girder, and so they are found.

15,005. (The Commissioner.) The eastern columns were above the girder?—Yes.

15,006. Showing that the eastern columns fell first?—Yes.

15,007. (Mr. Barlow.) Showing that the eastern and western parts separated from each other? —That they separated from each other. I think the probability is that that separation would not have taken place had the angle girders at the top been connected together so as to have brought the whole six columns in unison.

15,008. (Mr. Trayner.) From that state of facts, have you any opinion as to the point on the eastern side, between the base and the angle iron, where the bridge may have been placed, was it the point or was it somewhere else?—I think that is absolutely impossible to tell. The weakest place is the bottom, of course, and there it may have given way.

16,009. (The Commissioner.) That is to say the greatest strain, not the weakest place?—Yes.

15,010. And if the strength was equal all the way up, that is the place where it would give way?—Yes.

15,011. (Mr. Trayner.) Do you think that at that point the bridge gave way under a crush or under a push?—Under a push.

15,012. (Mr. Bidder.) Lateral?—Yes, I believe that the columns were amply strong to carry the dead load and the rolling load; I mean as long as it was in a state of repose.

15,013. (The Commissioner.) And as long as the columns were quite perfect, and as long as the bolts were perfect?—As long as the columns were vertical.

15,014. There are none of them quite vertical?—No, but they are practically vertical.

15,015. (Mr. Barlow.) If those columns had been strongly cross-braced, strongly fitted, and strongly held down by holding-down bolts, do you think that the bridge would have been sufficient?—I believe that it would have been standing at the present moment; it is a question of the strength of the bracing of columns.

15,016. (Mr. Trayner.) You have told us what you would have preferred in the matter of the angle girder at the top of the piers; you have told us that you would have had it continuous?—Yes.

15,017. Go from there to the base; have you anything to say about the sufficiency of that base?—The boxes in the columns have stood, and therefore I do not think you can say anything about them. They have done their work.

15,018. (Mr. Bidder.) You cannot say anything about what?—I cannot say that any alteration was absolutely necessary; they have stood, and the answer to the question is, they are.

15,019. Do you know what was below them—the masonry?—Yes, certainly.

15,020. (Mr. Trayner.) Are you aware whether these piers and bases have moved at all?—Some of them have moved, but in one or two of the piers, I did not notice any sign of movement at all. I believe that the columns were swept clean off at the joint, and there is the end of the columns sticking on the pier. In one or two of them, one of the holding-down bolts was broken, but it is evident that what was broke was by the action of the column falling and striking it, I do not think they gave way from the strain.

15,021. You have said that you did not approve of the piers being made distinct piers of three columns each?—No.

15,022. Something was said (I think it was in the original design) about it being proposed that there should be four columns on each side?—That unquestionably would have been better.

15,023. You could not have got two additional columns upon that pier and base as it exists now?—No, not upon this base (pointing to the model), two more columns could have been carried up probably if it had been rectangular.

15,024. Supposing you had been proposing to put up four columns in each of these clusters, you would then have adjusted the base for the one to be added on each side?—I would have put the four columns on each side in a line with each other.

15,025. (The Commissioner.) Instead of this outer one you would have had two?—Yes.

15,026. (Mr. Trayner.) Do you approve, as a matter of engineering, of the position which these 16-inch columns bear to the girder above them?—You have got a good many difficulties to deal with. You have a column, which you may call a column to a certain extent—that is the cylinder foundation 31 feet in diameter carried up a certain height—that only gives you a certain amount of room to work on, if there had been ample room to work on, and if this cylinder had been either larger in diameter or oval and with a longer axis on the direction of what you call the length of the pier, then I should certainly have preferred to have put the 15-inch columns directly plumb under the girders, and I would have used the two outside columns, which I should certainly have preferred to see instead of one, as raking columns to stiffen the structure and not to weight.

15,027. Am I right in saying that the line of the 15-inch columns is in this model within the girder?—Yes, certainly.

15,028. (The Commissioner.) The girder is intermediate between the 18-inch columns and the 15-inch columns?—It is.

15,029. (Mr. Trayner.) Given that base that we have existing, could you have placed the columns so as to come directly under the girders?—Not with the hexagonal pier as it is built, it would be impossible.

15,030. But on the cylinder which is below, on which the hexagonal pier is erected, you could have had such a pier as would have permitted of the erection of the 15-inch columns directly under the girder?—I do not know whether this model is correct or not; if it is, there would be very little space. It would be a matter of drawing.

15,031. (The Commissioner.) I think you can see it from these plans, which are accurate (showing the same to the witness), it would not have been easy to put them immediately under the girders on that sized caisson.

15,032. But there would have been no difficulty, I understand you to say, in putting the two outer ones in the place of that one outer one?—I think not; this (pointing to the plan) being carried up in an oblong form instead of hexagonal. (The witness looked at the plan.)

(The Commissioner.) Mr. Cochraned, after looking at the plan, says that there would be just room to put two outer ones in the place of that single 18-inch column in the same line with it.

(Mr. Webster.) At the same distance from the line of the two 15-inch columns.

15,033. (Mr. Trayner.) You heard the suggestion that the train had gone off the rails and knocked over the bridge; have you formed any opinion as to whether the train had gone off the rails, and by so doing had contributed in any way to the result?—
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think it did not from all I saw. I do not believe the train left the rails.

15,034. You have seen, have you not, the train as recovered?—I have.

15,036. And the girders as recovered?—All those of the train that I observed to recovered up to the 12th of April.

15,038. And in view of that examination you have given the opinion you have expressed at this moment?—Yes.

Examined by Mr. Bidder.

15,037. [Mr. Bidder.] May I put it to you, that according to the views you have expressed the principal matter you referred to in your opinion contributing to the accident was the bending of the bolts slackening the diés?—I think that was one of the principal causes.

15,038. Perhaps I ought to have begun a little further back. May I take it that you have been led to look to the cause of this accident as arising from imperfect workmanship from want of any other apparent and sufficient cause?—Of course I consider that the cause of the accident was the excessive force of the lateral strain placed upon the structure. I think that the probability is that the portion that first gave way, and which contributed to the accident was the bending of those bolts.

15,039. But your opinion is that if we put it on a little further back, without going into detail, as I understand, according to your judgment the bridge as designed, if perfect in execution, would have standing now?—Of course, that will necessitate going into calculations of the bars, and determining that everything was sufficient for the purpose.

15,040. I think I correctly represent what you stated in your examination-in-chief as being your opinion?—Not having gone into questions of strains that came upon those particular points, and not being able to say whether those bars are of the proper area or not, I should say that the structure was amply strong for its purpose.

15,041. If properly constructed?—Yes.

15,042. The principal qualification to your answer being, as I gather from you, that you are not in a position, not having calculated it, to say whether those tension bars were of sufficient area and strength to take the tension which would come upon them in extreme cases?—I cannot say whether they were or not.

15,043. That you are not in a position to speak to?—I am not in a position to speak on that.

15,044. Assuming that the tension bars had ample strength to take any strains that could come upon them, then in your judgment the bridge as designed was sufficient?—And of course with no bending of the bolts.

15,045. With no failure of workmanship then the bridge, as designed, was sufficient, that is your opinion?—Yes. Of course there were plenty of points in the structure as you will have gathered from what I have said that I do not think right.

15,046. I suppose there must be a bridge, or perhaps I might say a structure of any kind carried into effect by any engineer, but that other engineers would have made it in a different way and thought they improved it by so doing?—In all probability.

15,047. We all start with the fact that upon the night of the accident the accident did come down. You said that you had seen nothing to lead you to the belief that the train went off the rails, have you formed any opinion as to whether, supposing the train or part of the train had gone off the rails at a considerable speed and had come into violent collision with the leeward girdler of the bridge that would not have been sufficient cause to account for the accident?—I may say that I heard you ask that question yesterday, and I think, of Mr. Law, in which you put it into figures. You asked whether, if I remember rightly, 18 tons travelling 40 feet a second would cause the destruction of the bridge.

15,048. Projected violently against the leeward girdler?—I think if you could concentrate the eighteen tons, and make that traverse the bridge at the rate of 40 feet a second and that struck any portion of that structure, it would destroy it.

15,049. Therefore if it was a fact (I am not asking your opinion whether it was or not) that a portion of the train with that weight (I think it was sixteen tons, not eighteen), was projected at that velocity, and came into violent collision with the bridge, there would be sufficient cause to account for what happened?—If it was concentrated, if you brought it into one mass.

15,050. And, of course, I suppose that it would be a fortuitous thing, the happening at a time when the bridge by the necessity of the case was in a state of extreme tension, bearing all the severe strains of the wind?—Unquestionably, if it took place, it would be at that time as a matter of necessity.

15,051. I mean to say that the fact of all the parts of the bridge being necessarily in a state of tension, under that extreme and severe storm, would make the effect of an impact more disastrous than otherwise?—If you put a heavy strain upon a bar, and then give it a blow with a hammer you will probably break it, that is what you mean I think.

15,052. That is what I mean, and that leads me to ask you this question. You do not understand my question?—I do not know how far you put it definitively—that you did not think the train left the rails, what reason have you for coming to that judgment?—I saw a portion of the fifth girder mired with four carriages; there is a photograph of it with four carriages in the interior of it, and it is manifestly evident from the appearance of the bar that they certainly did not strike against anything. I afterwards saw the remains of other carriages, which were picked up and put on tracks, so as to represent as nearly as they could how they were found down below, and judging from the state of everything in connection with them, I am of opinion that the carriages did not leave the rails.

15,053. Did the condition of the carriages that you saw give any indication whatever of their having had violent treatment?—Certainly violent treatment, there is no question about it.

15,054. Did that give any indication of their having been in collision?—I think the probability is, that they were horribly smashed by things falling on the top of them.

15,055. I do not know whether you noticed what Mr. Law in my cross-examination yesterday, or whether you will agree with my statement, that the two last carriages, the second-class and the guard's van, bear evidence of more violent treatment than the carriages forming the fore part of the train?—I think they do to a certain extent bear such evident, but they show so clearly that they have been injured on both sides very much alike, in fact, I think the west side rather more than the east, that I do not think it led you to come to any definite conclusion that the carriages could have left the line.

15,056. (Mr. Commissioner.) The second-class carriage?—The second-class carriage and the guard's van. The guard's van is exceptionally strong, the sole bars of the guard's van are plated, iron from end to end. Had the second-class carriage left the line from the couplings in front of it breaking, I think the guard's van would have smashed the thing in front of it all into smithereens. That is the second-class carriage?—That is the second-class carriage and the guard's van. The guard's van is exceptionally strong, the sole bars of the guard's van are plated with iron from end to end. Had the second-class carriage left the line from the couplings in front of it breaking, I think the guard's van would have smashed the thing in front of it all into smithereens.

15,057. Or had the second-class carriage been stopped by the girder, the guard's van would have come into it and smashed it up?—Yes, it must have utterly destroyed it.

15,058. (Mr. Bidder.) Did you notice that the south end, that is the end of the second-class carriage which would have been in contact with the guard's van, is in a condition which very much approaches to smithereens?—No, I did not.

15,059. Let me point out to you with reference to that second-class carriage (handing a photograph to the witnesses) that the left hand is the north end, which was not in contact with the guard's van, and the right
hand is the south end, which was in contact with the guard’s van. I do not know whether that picture approximates to what you would call smithereens?—No, it does not; nothing like it.

15,060. What would be the exact amount of demolition that you would describe as “smithereens”?—Practically nothing left of it—all to pieces.

15,061. Look first at the left hand picture at the bottom; the north end of that carriage is not as much destroyed?—Not so much. It is seriously damaged, the axle is bent upwards.

15,062. And bent in a way that no other axle has been bent?—It is bent in a way that all the axles on the carriages were bent.

15,063. If you look now at this other right hand picture, there you see a great destruction at the back end?—I saw it in the carriage itself.

15,064. And especially at that place which was the western part of it, as it travelled?—Yes.

15,065. If that carriage had been blown over by the wind so as to be inclining to the east, or the right of the picture, the eastern buffer would have been, so to speak, clear of the van to a great extent. If that carriage had been tilted over on its wheel base by the action of the wind and the eastern buffer would have been by that tilting carried clear of the corresponding part of the guard’s van?—Is this the eastern side.

15,066. No, that is western, that is the one that would have come within the guard’s van?—It would come into the western part of the guard’s van.

15,067. The eastern buffer would be carried clear of the framing of the guard’s van?—No, I do not think it would be carried clear of the framing of the guard’s van by any means.

15,068. That is a question of degree?—Yes.

15,069. To what do you attribute that which is apparently the fact, the photography, that the western side of the back of that second-class carriage is destroyed in a way which I think I may say no other framework of the end part of any carriage in the train was destroyed?—There may have been innumerable causes for it, there were explosions of dynamite blowing the girders to pieces just about this place. It might be the effect of dynamite, it might be the effect of something falling upon it very heavily. I think it is utterly impossible to give a reason, or to account for that.

15,070. It may be the effect of the guard’s van running into it?—I think not, because the guard’s van does not run into it.

15,071. The guard’s van, you say, is very much stronger than the carriage?—Yes.

15,072. If you look at this photograph of the guard’s van, I think that you will see that I am justified in saying that the end of the guard’s van meets the second-class carriage, though not destroyed to the extent that the end of the second-class carriage bears traces of harder usage than the other end of the guard’s van, considerably?—If it came into contact at all, as a matter of course it would. You cannot fairly say that it bears traces of injury.

15,074. You see the woodwork is split; look at it by comparison with the other end, is not that so?—No, I think not.

15,074. I suggest as the result of an inspection of these photographs, that the end of the guard’s van which was in contact with the second-class carriage bears distinct traces of a much more violent treatment than the other?—No, I think not. That is the back end of the guard’s van. This is the end of the guard’s van that is suggested was in contact with the second-class carriage, and which smashed the second-class carriage. This is the end supposed to have been destroyed.

15,075. If you look at the photograph of the guard’s van, you will see that the end of the guard’s van, that is the north end of the guard’s van, has the framework split.

(The Commissioner.) Just by the coupling-irons.

(Mr. Bidder.) And if you look at the south end of the guard’s van there is no appreciable damage done to it at all. (The Commissioner.) There is a little fracture by the coupling-chain.

15,075. (Mr. Bidder.) There is no sign of splitting, or anything of that kind, at the south end of the guard’s van. (To the witness.) I do not know whether your attention has been drawn to this also—that the bodies of these two carriages are gone to “smithereens,” may I say?—Yes.

15,077. The bodies of the other carriages, though greatly damaged, are not smashed in the same way?—The tops of every one of them were off, and the sides, to a certain extent, injured. In one of them I saw a pane of glass unjutred just as it came out. I do not think for a moment it can be supposed that any one of those left the line.

15,078. I am addressing my questions to you rather to contrast the condition between the two last carriages, and that of the four carriages in front?—Yes.

15,079. The result of your inspection is to show you, is it not, that whilst the bodies of those former carriages are undoubtedly greatly injured, yet the annihilation of those bodies is nothing compared with the carriages behind?—I think you can base much upon the annihilation of the bodies of the carriages, the fact of the second-class carriage falling into the water when it came into contact with the water (it was an old carriage in all probability), knocked it all to pieces. The guard’s van was a very much stronger thing.

15,080. The guard’s van was very much stronger than any of the passenger carriages?—Probably—I cannot tell. I cannot tell whether it was stronger than the body of the first-class carriage.

15,081. Bear these facts in your mind—four carriages in the former part of the train with their bodies damaged, but not destroyed, and the other four that the four carriages in front. It is not the bodies of those carriages, whilst the bodies of those former carriages might have all been destroyed in lifting there are fifty ways to account for it, because there would be no strength in the structure of the carriage itself; the body of the carriage possesses nothing about it to enable it to resist a big force of concussion.

15,082. I do not know whether you are aware of it, but I am told from the reports of the divers, it appears that the condition of the carriages following to their bodies was such as I have now described before any operations for raising the carriages, or before any explosion of dynamite had taken place?—That I do not know—probably, that is quite correct. I think in my own mind there are fifty ways to accounting for the broken body of the carriage. I do not think it came in contact with the girder.

15,083. Are you aware of this also, that there is this contrast between these two carriages and all the other four carriages, that the four carriages in front were found within the girders standing in their own proper vertical position, wheels downwards?—Yes.

15,084. Whereas these two carriages were found lying on their side?—I do not know that.

15,086. Does that suggest anything to your mind?—No, I do not think it would. It would not alter my opinion in the least.

15,086. Can you tell me anything I can suggest that would alter your opinion?—I would directly, if I could. My desire is straightforward. I think, taking your view of the matter, supposing a carriage to have been tilted over, as it was travelling along at the rate of 40 feet a second, it would have been the second-class carriage and not the guard’s van.

15,087. I am supposing the cause of the accident is the second-class carriage tilted over?—Supposing it to have tilted over, it would have brought a powerful action at once upon the coupling chains to pull it down again in connexion with the carriages that
not leave the line. The only portion of that carriage that could have come in contact with the girder would have been the roof. The side frame of the carriage could not possibly have come in contact with it unless it had been bodily lifted off the line and travelled outside.

15,088. It will save you trouble if I put a little more clearly what I suggest did occur. I go with you in the first part of your observation, that assuming a tilting of the second-class carriage occurred, the portion of the carriage that would come in contact with the bridge would be the roof which would strike the lattice of the bridge, there would probably be an instantaneous smashing of the matchwood construction—would not the consequence of that be that the carriage itself would be turned off the line?—I think it would be turned back again on to the rails.

15,089. If the carriage beeled over on its side, travelling at the rate of 25 miles an hour, and with the leeward corner of the roof catching violently against a fixed obstruction, would not it be turned off the line?—I think not.

15,090. Running on two wheels?—Running on two wheels, I do not think it would for a moment—other wheels would not be out of the guard rail—it is as much as ever they would.

15,091. Have you calculated that?—I have not, but I think you would find it so.

15,092. The height of the carriage is 10 feet, and the distance to the girder is 3 feet?—Yes.

15,093. A lateral motion of 3 is not?—Scarcely, because the carriage is so low and so near the body of the structure of the bridge that you could not get an upward effect of the wind on it. I do not know whether you are alluding to a question that you asked Mr. Law about the force of the wind on the top of the carriage tending to keep it down, and the force of the wind on the bottom of the carriage. I do not think there is anything in either of them. I do not think the force of the wind would keep the carriage down, and I do not think it would lift it up in that case.

15,094. As I understand you, you have seen nothing to make you believe that any such collision between the carriages and the girders took place as would account for the disaster, you therefore have to look to other causes for explaining what happened?—Yes.

15,095. You do not find those causes in the insufficiency of the design, therefore you are compelled to look to the insufficiency of the workmanship?—I have pointed to variations which there might have been in the design which I think are very material.

15,096. I thought we had agreed some time ago that every design is capable of improvement. I think I got your opinion, and I do not want to go over that ground again—that the design if perfectly carried out was in your judgment sufficient?—But an alteration of the top of the pier in connexion with the angle iron girder was a most important element. If that had been done you would have converted it into a pier of six columns instead of a pier of three columns to a very considerable extent.

15,097. The two pairs of three columns are connected the whole way up both with struts and ties?—They are.

15,098. And at the top does not the girder itself form a connexion with the pier?—No, because it is loose on the top of it.

15,099. It is not loose laterally, is it?—Yes, it is loose laterally; it is on rollers not attached to the pier itself.

15,100. It is on rollers with flanges?—Yes.

15,101. It is incapable of lateral movement, is it not?—I could not say. I care not there is a little play allowed, but I do not consider that that is an attachment. One thing that plays loose on the top of another is not attached to it except by gravity.

15,102. Let me remind you of this, that a comparatively small force is sufficient to lift it. Just consider that again. Take the case of a carriage upon its two wheels heeled over?—I am alluding to all above the framework.

15,103. I know that. All above the sole bar. You have a blow on the front corner which lifts it, or which tends to lift it?—You could strike no blow at the front corner by any possible means that would lift the wheel.

15,104. Not by a single inch?—Not by a single millimetre part of an inch, in my opinion. I do not believe you could lift it. I believe you could strike any blow that would lift it all.

15,105. In your judgment nothing that could happen to the body of the carriage could ever turn it off the rails?—No, that is a totally different thing. I do not say that. You could have a force of wind applied at the side of the carriage that would turn it clean over.

15,106. Nothing in the shape of a collision, one blow, or anything of that sort, that could happen above the sole plate would turn it off the rails?—No, I do not think it would. I think it would sweep the body clean off.

15,107. About the force of the wind. You said in connexion with another matter that the upward force of the wind was, in your judgment, a matter sometimes of considerable moment?—I think so. I have never calculated that, and I am unable to give you any figures.

15,108. That upward force would apply to the case of a carriage in such a position as this, as well as to the girder itself?—Scarcely, because the carriage is so low and so near the body of the structure of the bridge that you could not get an upward effect of the wind on it. I do not know whether you are alluding to a question that you asked Mr. Law about the force of the wind on the top of the carriage tending to keep it down, and the force of the wind on the bottom of the carriage. I do not think there is anything in either of them. I do not think the force of the wind would keep the carriage down, and I do not think it would lift it up in that case.

15,109. As I understand you, you have seen nothing to make you believe that any such collision between the carriages and the girders took place as would account for the disaster, you therefore have to look to other causes for explaining what happened?—Yes.

15,110. You do not find those causes in the insufficiency of the design, therefore you are compelled to look to the insufficiency of the workmanship?—I have pointed to variations which there might have been in the design which I think are very material.

15,111. I thought we had agreed some time ago that every design is capable of improvement. I think I got your opinion, and I do not want to go over that ground again—that the design if perfectly carried out was in your judgment sufficient?—But an alteration of the top of the pier in connexion with the angle iron girder was a most important element. If that had been done you would have converted it into a pier of six columns instead of a pier of three columns to a very considerable extent.

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15,113. And at the top does not the girder itself form a connexion with the pier?—No, because it is loose on the top of it.

15,114. It is not loose laterally, is it?—Yes, it is loose laterally; it is on rollers not attached to the pier itself.

15,115. It is on rollers with flanges?—Yes.

15,116. It is incapable of lateral movement, is it not?—I could not say. I care not there is a little play allowed, but I do not consider that that is an attachment. One thing that plays loose on the top of another is not attached to it except by gravity.

15,117. I cannot quite accept that proposition. Supposing that a girder is resting on rollers, loose in the sense of being free to move longitudinally, but fixed in the sense of being by the heads of the rollers

...
15,118. No, I will not say that. Reasoning by analogy is always inconclusive. Perhaps you will stick to the girder and the roller, and the girder resting upon the rollers, and the rollers having flange heads, which prevent lateral movement of the girder, so long as that girder is there why is not that an attachment to all intents and purposes? I cannot call it an attachment. I call it an attachment where one thing is securely fixed to another; it is simply resting between a couple of guides, and not attached at all.

15,119. The girder is 288 tons weight upon the pier?—Yes; still that is not an attachment, at least, not to my mind:

15,120. Just think for a minute. Take away the girder altogether. I suppose nobody would suggest that that pier standing without any girder upon it would stand any stress of weather?—I think it would.

15,121. The stress that is brought upon it is brought upon it by the girder itself?—The extra stress.

15,122. The extra stress is brought upon it by the girder itself?—Yes.

15,123. And as long as the girder itself is rigid horizontally, as well as vertically, transversely, perhaps, it is better—it is as long as the girder is rigid transversely, surely it is obvious that the girder cannot introduce anything that would tend to separate the pier?—Theoretically you may be right, practically I do not think you are; I would not trust to it.

15,124. Suppose you have got two posts in the earth fixed, two columns, and you put a heavy weight upon them, and then you put upon them lateral strains, whether by the wind blowing upon that weight, or by the impact of a hammer or anything else communicated through that weight, weight would tend to separate the top of the columns?—I think it might. I think that unless you secure them together, it is quite probable that it might. As long as everything is in a state of repose it would not have any tendency to move.

15,125. Given the most violent lateral strain possible, can any inference be introduced at the top sufficient to separate the columns, I grant you when you come to consider the stability of the pier as a pier to resist overturning forces you come to forces that had to be met by the ties, that is another question altogether.—I do not quite follow you. Supposing you apply lateral force to these girders the tendency is to alter the shape of the rectangle and to put it out of position.

15,126. But not to alter the distance apart of the portions of the girder that form its base?—The moment that you alter the shape of the rectangle you have altered all your conditions of strains.

15,127. Let us understand one another as we go. Mr. Leader is that the girders, as girders, were perfectly sufficient?—I believe the girders, as girders, were abundantly sufficient; they have shown themselves sufficient.

15,128. For all purposes do you suggest the girders were not sufficient as girders?—I have suggested what I considered would have added very largely to their strength as girders.

15,129. Anybody may suggest things that will make any structure stronger; you can suggest a thousand things—if you suggest that something might have been done which might have added very largely to the strength of these girders. I admit it at once?—I think it would have prevented an action taking place which in all probability has taken place.

15,130. You mean that the girders did not preserve their rectangular form?—I think certainly not. I do not believe that they did at the time the accident took place.

15,131. Have you calculated the strength of these girders for the resistance of the strains put upon them?—I have not made any calculations of strains whatever.

15,132. Supposing they had changed their rectangular form, that is to say, supposing the action instead of being rectangular becomes an oblique parallelogram, how would that affect the question as regards the columns?—You would be putting weight on this side and lifting it off that (pointing to the model) if you got into that shape. In doing that the tendency is to lift that end and to put extra pressure on this (pointing to the model), and I think in all probability that is what took place.

15,133. The moment there is any separation of the two triads of columns, does not the girder itself, through the medium of the rollers and the roller heads, come into play as a tie?—To prevent them from separating?

15,134. Yes.—To a certain extent, of course, they must do. You have there a large structure of enormous weight, and to cause that weight to move laterally required enormous power.

15,135. I do not like the answer qualified by "to a certain extent." What I mean is this: you know that the rollers have got roller heads?—They have flanges on the ends of them.

15,136. There may be a certain amount of play, 1⁄4 inch or 1⁄8 of an inch?—There would be a certain amount of play, of course.

15,137. The moment that play has been taken up to the extent of 1⁄8 of an inch or 1⁄4 of an inch, or whatever it was, no further separation of the edges of the two sets of columns is possible without either the girder lifting on the roller or the roller head giving way?—No, so far as the roller head is concerned.

15,138. Therefore, it is not "to a certain extent," but absolutely?—Unless some portion of it gave way, it would remain in its natural position.

15,139. Therefore absolutely the girder, till some portion of it gave way, or the roller gave way, forms a tie which prevents the two sets of columns from separating beyond the play of the rollers?—Perhaps it might.

15,140. I have some questions to ask you with reference to these imperfections of detail which you have pointed out. You said that you found no fault with the material, either cast or wrought iron, but as regards the casting and the columns which you observed; do you say that those defects were of sufficient extent to make the columns insufficient for their purpose?—I see that the fact staring you in the face, that in almost all the cases the lugs have broken.

15,141. What I intended to ask you about was the shifting of the top flange and the consequence of that and the cold shuts and so on?—I think there is, as a matter of course, so large a margin of sectional area in the columns to bear the superincumbent load—I am not alluding to lateral strain now—that there is ample material to bear the strain and I do not mean to say that a column 1⁄4 inch or 1⁄8 of an inch thick one side and 1⁄8 the other is as strong as a column of the uniform thickness of 1 inch.

15,142. Obviously a column uniformly distributed must be the strongest. No one will dispute that proposition.

15,143. (The Commissioner.) But what you say is this, that that simple defect of difference of thickness in the columns would not be sufficient to account for this?—I think not.

15,144. (Mr. Bidder.) Now I go to the lugs. As I understand you have drawn my attention to the fact that in almost all the cases or the great majority of the cases it is the lug that has given way?—In the cases I have seen I do not think I found any tie-bars broken at all, practically it is the lugs that have gone.

15,145. Does it follow, if you consider it very carefully, that the lugs were insufficient for the purposes
of the bridge or that their attachment to the columns was insufficient for the purposes of the bridge?—They broke.

15,146. Let me suggest this to you—the connection between the two columns to resist the tension is of a composite character, partly cast-iron lug, and partly wrought-iron tie. If the final cause which caused the fracture was not a strain—not a steady pressure, but a blow—whether a blow from the train upon the girders or a blow upon that particular column by something else falling upon it, would not you expect the lugs to be the parts to give way casts parsimonious?—If anything in the shape of a weight struck one of the lugs in falling, I should expect to see it break, not the bar.

15,147. What I put to you is this—lug and tie in tension—and we will assume for the purpose of the question of equal strength for resisting that tension. I mean the section of the lug and the section of the tie. The lug and tie being in tension a sudden blow is given, from whatever cause, tending to fracture the whole. Would not you expect that the cast-iron would give way and not the wrought-iron to that blow?—Not unless it was a direct blow on the iron itself.

15,148. Let me make an experiment as it were. Suppose I hung from a hook in the ceiling a piece of cast-iron—continued by a wrought-iron bar, the two being of sections which gave them equal strength to resist tension so that they would break at the same tensile strain. They would thus form a continuous rod, at the bottom of which suppose I had a plate with a hole, and drop a rod on the rod, and the rod drop from the ceiling so that it got a blow at the bottom, the two being of equal strength to resist tension, which would you expect would break?—I think it is very doubtful which would break—one might go first or the other might go first.

15,149. What is the resistance of shot, cast-iron or wrought-iron?—Wrought-iron; but anything falling on the plate you are speaking of suspended by that bar loses to a large extent the force of concussion by being absorbed in the weight of the plate, the same way as in an anvil. I think if you have a pair of cast-iron lugs with a bolt through them, a bar hanging at the bottom, if you apply a force of concussion sufficient theoretically, to break both lug and bar, the lug will break and not the bar.

15,150. I am now going to the question of the conical form of the holes in the lugs. I think you said that it is a thing very difficult to guard against? I know from my own practical experience that moulders will alter the cores if they can, do whatever you will.

15,151. And you said that it is also a thing which is almost impossible to detect?—No, not at all; certainly not; it is palpable—as plain as a pikestaff—after the bolts are in their places it is not easy to see.

15,152. That is to say it is palpable to any one who takes a hole and looks at it whether it is conical or not, but in my opinion it is almost impossible to see those holes when the bolts are in their places?—The jaw is small; you cannot get to see the hole.

15,153. As I understand so difficult is it to prevent its being done by the moulders that you in your practice would make an allowance for the probability of its occurring and would put an increased size into your bolt for the very purpose of meeting that?—Or would you give an increased size to the hole and make it perfect.

15,154. Koch, I correctly took it as evidence that you would allow an increased diameter of bolt?—I would—I would increase the hole so as to make it parallel. I prefer the latter very much for many reasons. If you make a larger hole in the lug you have to make a larger hole in the diagonal bar and you must therefore increase the width of that.

15,155. Did you make any estimate whether these bolts being of the diameter of 1½ of an inch were sufficient to meet the strain that might be brought upon them?—As I have told you I have made no calculations at all. I saw the bolts actually bent.

15,156. You cannot tell whether that actual bending took place before the fall or because of the fall?—I think it is self-evident. I do not think it took place because of the fall, I think it must have taken place before the fall.

15,157. Supposing the cause of the fall was a blow you cannot tell whether the bending of the bolt was the result produced then or previously, can you?—Of course I cannot tell when it was produced. I believe that it was produced by an excessive strain at some time or other, either before or by the fall.

15,158. The probability is in favour of its being produced at the time when the strain was the greatest, is it not?—Certainly; there cannot be any doubt about that.

15,159. Which time, in all probability, was the time when the bridge came down?—I think, as I stated before, there is every probability that a number of these bolts were bent previously to the fall of the bridge. I do not think all these bolts would get bent upon one particular occasion. I think that is evident from the rattle that was observed. I think it shows that something was discovered previously that I believe that was not due to any extension of the bars, but due to the bending of these bolts.

15,159. Assuming you are right in that, that there had been a bending of the bolts, and that that is the cause to which we may attribute the chattering of certain of the tie-bars that was observed, the bolt, having bent itself to the form of the hole in the lug, would be ever after as serviceable as it would have been under any other circumstances?—I do not think it would bend any more.

15,160. It would take its bearing and would be as strong as under any other circumstances?—Yes; but it might have injured the lug in doing that, and it probably did.

15,162. We have been told that there was a packing up and a cotterring up of the tie-bars. If the tie-bars were cottered up till the chattering was entirely taken up, would not that make all things rigid again?—It would make that particular bar rigid; it would not affect any other one.

15,163. You have, as a general view, that there had been, as no doubt there had been, previously heavy gales, and those gales had more or less tried the various parts of the structure and found out the weak places, bent those bolts that would bend, loosened those ties that would loosen; that having occurred, if you go carefully through the bridge, and tighten up every tie which is loose, have not you practically restored the bridge to its original condition, and, in fact, to a better condition, because you have taken up that which might give way under the strain of any ordinary gale?—You must suppose that you have done that to every diagonal bar.

15,164. I think not. You have had the bridge subjected for a considerable time, to heavy gales occasionally and the passage of trains constantly, and all the tie-bars and bolts that would slacken under those influences have slackened, you have gone through the bridge carefully, you have noticed every tie-bar, that chattered and tightened it up till it is rigid and tense again?—Then, I think, as I said before, you would have had to do it to every one of them. I do not think they could all have been noticed.

15,165. You traverse my fact then. I am afraid you must not do that in answering my question?—What I would like you to understand is that my view is simply this. As I understand there are from 100 to 150 of these packing-pieces, therefore, according to my view from 100 to 150 bolts were found bent, consequently, if your statement is right, none of the other bolts were bent.

15,166. You have gone a little too fast—there is a step wanting—you assume too much. If it were the fact that there were from 100 to 150 cases in which packing was used, it does not follow that that takes in the number of cases in which the cotter bar was
tightly upon the bridge which I had opened for some time, and has been exposed to such storms as have occurred and to the passage of the trains, every tie-bar which in any way chattered was tightened up again effectually by the introduction of tightening pieces and the hammering home of the cutters—assume this—that is done?—It is done, if it is a dummy tie-bar which I cannot do—if I assume that statement to be correct, then you would have restored the structure very much to its original condition.

15,168. And better, would it not have been?—No.

15,169. I mean better in this sense—that that which would give had given, and that having been taken up it could give no more?—Exactly, so far as that goes, but I do not have that you must have injured the lugs.

15,170. Why must you have injured the lugs?—The bolt is passed through the lug, and is screwed up tight; if you bend the bolt you bring an undue strain upon the lugs.

15,171. How?—Because you bring the head and nut to bear upon one side only instead of uniformly over the circumference.

15,172. You pinch the lug more on one side?—You pinch the lug on one side and not on the other; therefore: I think—that to a certain extent you must injure the lug.

15,173. You suggest that the pinching of the lug in that way weakens it for the purposes to which it is putting one of those strains on it that you were speaking of; you give it a little extra tap, and away it goes.

15,174. The whole hypothesis assumes that the strain on the nut is gone, or else it would not give?—No, you start with screwing your bolt up tight—you pinch the lug up tight; you tap it with the nut, you nip with the nut the outside of the lug. You do not nip the bar; the bar is loose.

15,175. The very act of screwing up the lug tight is injurious to the lug?—It is to a certain extent. I have seen a lug broken many times during screwing up; unless it is packed up fully in the inside you are very likely to do it.

15,176. I want you to follow me a step further. I put you a question just now upon the assumption that all the tie-bars had developed slackness, and had been cotted up. I now put my question upon another assumption; suppose they had not, suppose there were certain tie-bars upon the occasion of this exceptional lateral strain being brought upon the bridge which were capable of yielding with a half of an inch, or a 1/4 of an inch; or whatever the pressure might be, what then?—You would then get a lateral motion produced in the pier which would be due to that room for play.

15,177. A lateral motion of a 1/4 of an inch or a 1/2 of an inch—a great deal more.

15,178. How much more?—That which is due to the difference in the lengths of the bars, and that would accumulate.

15,179. Let us take the experiment case, I think you will agree with me that the point of the pier where the greatest displacement due to such slackness of any would be the top of No. 4 or the leeward column. Suppose the wind was blowing from that end of the room here, I think you will agree that the top of this right-hand column would be the point in the pier that would be most displaced by any slackness. May not we take the top of the 15-inch column to leeward as being the point at which such effect would exhibit itself to the greatest degree?—If it were an accumulated defect, certainly.

15,180. No "if's" if you please?—Then I cannot answer your question.

15,181. I am asking you this; select the point in any of the columns which in your judgment would move most, and let us discuss it; take any point you please?—Am I to take this as a fixed base?

15,182. Take the pier as it was, and assume that the tie-bars are slack for the purpose of the question?—All the way down.

15,183. For the present we will take it all the way down, that every tie-bar in the whole pier is more or less ready to give?—The greatest amount of motion will take place there (pointing to the model).

15,184. That is at the top of one of the 15-inch columns of the leeward trial?—And that would diminish till it got to the bottom.

15,185. If the structure—well, in good order that column would be prevented from moving to leeward by the tie connecting it with the corresponding column of the other trial?—It would help it, of course.

15,186. Let us for the sake of argument take the amount of play which was named yesterday as a quarter of an inch, possible in that tie-bar, we will assume without binding you to that particular figure that that column might move laterally by whatever is the horizontal equivalent of that quarter of an inch lengthening of that tie-bar?—In that length.

15,187. Beyond that we must add this, inasmuch as the other end of that tie-bar is fastened to another 15-inch column, the hypothesis being that the tie-bars supporting that column are capable of yielding we must add whatever yield can be got that way?—Yes.

15,188. If you follow the thing down the tie-bar, I first spoke of leads us down to the bottom of the top column of the other trial?—It leads you to here (pointing to the model).

15,189. Follow that down diagonally, the thing that prevents that play moving to leeward is the tie-bar carrying you downwards to No. 1 column?—There is very little in that; that is the principle. I admit that it is so, but before you would get any good action out of that you would bring that one into bearing, in my opinion (pointing to the model).

15,190. I want to put it plainly to you. The lateral motion at the top of the column is not the cumulative horizontal motion of the slacknesses of all the tie all the way down, but it is simply the cumulative horizontal motion in the direction of the ties upon which the steadiness depends?—I do not quite follow you. My opinion is this, that if a strain is passed through that bar, and that bar is allowed to be strengthened by any process you please, that point will go over (pointing to the model).

15,191. Till it has gone a certain distance then the tension becomes the same as before?—Till it is brought into tension again; if the force is still acting on here the strain that was brought through here has passed through it, it is brought on to that point and then it is brought on to this point (pointing to the model).

15,192. Let us take an assumed figure without binding ourselves to it exactly. Supposing the extension of the top of the tie-bar permits a lateral motion at the top of the column to the extent of half an inch, when it has moved that half an inch the tie-bar is taut?—Yes.

15,193. The strain is then thrown through the medium of the next struts on to the top of the next tier of the column?—Yes.

15,194. Similarly a motion by half an inch of that tier of the column will bring its tie-bar taut?—Yes, and upon down to the bottom. What I wish you will agree this, if the top of this column is moved forward half an inch in this direction, you put a strain upon that bar, or you bring it into action, it not having previously been in action. Your strain is still continued. The strain passes through this strut, and it is brought on to this diagonal if that diagonal is able to give, that point will go over another half inch and so on all the way down, and ultimately you have an accumulation.

15,195. You said some point will go another half an inch, but you forget this, that if you add half inches together you get the column farther away to the leeward that the ties will permit?—You bring...
The question is whether you have got so much. The question is, whether the tension bars are doing as much duty as they would have done if the pier had been absolutely upright?—They must be doing more.

15,214. Then that is going rather further than I should have gone?—They are bearing an extra strain; that is what I meant to imply by their doing more duty. You are giving them more to do.

15,215. Starting with a column upright, and the tie-bars slack to the extent that we have agreed, they are doing no duty, of course, so long as they are slack?—No.

15,216. The columns begin to lean over?—Yes.

15,217. As they lean over they take up the slackness of the tie-bars?—They bring the tie-bars into play.

15,218. Until the tie-bar is in as great tension as it was before?—Before it was in no tension at all.

15,219. You are quite right. Until the tie-bar is in as great tension as it would have been if it had been upright. Supposing that the pier was perfectly upright, and that there was a certain tension, and we will now again for the sake of illustration take a nominal tension of 10 tons on the tie-bar, what would happen? The tension on would have no tension on all beyond what you put on by straining at the bar so long as the piers were upright.

15,220. Supposing that the piers are upright, and that the wind, as on this particular night, required each tie-bar to do 10 tons of duty in order to prevent the thing overturning, but that in point of fact the tie-bars were slack, and putting an extreme case that all of them were slack, then the pier must incline over?

—Yes, until the tie-bar will not let it go any further.

15,221. And until the tension in the tie-bar has risen to 10 tons?—It would be more than 10 tons in that, because it would be due to a different angle.

15,222. No. It would be less, because the tie-bar is more horizontal; so the tension of the tie-bar tension is horizontal?—Yes, I am wrong.

15,223. However, is that not a great matter one way or the other?—No, but there is a difference at any rate.

15,224. Therefore, I think I am right in summing it up in this way: tie-bars slack, inclining over, the pier and putting an extreme set of it, which you have put upon it. Against the bars, because you have altered the superstructure below your load is no longer acting.

15,225. I say I quite agree with you that, whatever that is worth, if the pier is sliding and the lattice over here (describing the same) instead of doing anything to keep the thing steady, it would have a tendency to overturn it. (The Commissioner.) But that is rather an important difference.

15,226. [Mr. Bidder.] That is a separate question. The importance of that question depends upon the degree; but, however, keeping the question clear of that (and agreeing with Mr. Cochran entirely that that is a separate matter, and it may be, we will say, an important matter) so far as the tensions of the structure are concerned, have I not rightly put to you what will take place?—I am afraid I scarcely follow you. Supposing that the column goes over a certain distance, and to go over that distance it puts a strain on the diagonal bar.

15,227. The same strain which it ought to have had when vertical to keep the thing in position?—But as long as it is vertical there is no strain on it whatever, at least, no strain except what you put upon it.

15,228. Take that pier, and suppose it to be absolutely perfect, and put a strong lateral wind force...
upon it, what will happen?—If you applied a lateral force it would be different.

15,230. We are talking of the behaviour of the pier under lateral force. Take that pier as being perfect, and in my question I want it to be clearly understood that I am putting on one side the displacement of the weight above, which may be an important thing, put upon it, a lateral pressure from a storm of wind of, say 20 lbs. or 30 lbs. per foot, or whatever it may be, that will throw a certain tension on to those tension bars, say 10 tons to each bar?—Yes.

And that tension on each bar will be sufficient, we will assume, to keep the pier of the bridge upright?—That is to say, it will be sufficient from your argument, to hold the columns from going beyond a certain distance out of the perpendicular.

15,232. The structure being perfect, it will be sufficient to prevent them from going further than the fracture of the columns will permit; assuming that is the case whilst it is perfect, and assuming that there are no imperfections of workmanship and no slackness of the tie, and assuming a tension of 10 tons on each tie, and that that is sufficient?—And that the columns then remain perfectly upright.

15,233. Now then I come to the imperfect pier exposed to the same influences, and assuming that every tie-bar in that imperfect pier is slack in the way we have described, so that the tie-bars therefore are not doing their duty, the columns will begin to incline to leeward; as they incline they will bring the tie-bars with them, and when they have inclined so far that the tension on the tie-bar has risen to the 10 tons you will then have got equilibrium?—You will have got equilibrium, only you will have got your column out of the upright.

15,234. That course being subject to and independent of the question of how far by putting the centre of gravity of the superstructure upon one side I have diminished in that way the stability of the structure as a whole. There was one other matter that I wanted to ask you about that was referred to in your examination-in-chief, and that is this—you said, and said correctly too, according to the facts, that you had observed that in the bottom columns the spigot and facet were absent?—I did.

15,235. Does it occur to you that there was a very good reason for that?—I was not aware of any reason until I was reading Mr. Grote's evidence, when I found that the tops of the 15-inch base pieces (I do not know whether it applied to all of them, my memory is not sufficient for that) had to be dressed, not to a level, but to a certain inclination.

15,236. The columns themselves being raking so long as you are simply joining column to column, their axes are of course in a continuous line. When you came to the bottom column you could not use the spigots and facets?—No; that is on the 18-inch columns. I do not know whether that applies to the 15-inch columns as well.

15,237. They rake also, but to a less degree?—You might have put the spigot in there, but it would have a little more play. You have a little play in the columns as I believe.

15,238. It has been suggested in examination-in-chief that two columns at the end would have been better than one; and I think you said that that was in your opinion?—Yes.

15,239. Would not that depend upon this—whoever supposed you could get as wide a base with the eight columns as with the six?—Of course it would be to a certain extent, but with eight I think you would get more than you would with the six.

15,240. I put it to you hypothetically. You have not calculated it, I presume?—I have not.

15,241. You could not with any pier that you could create get as wide a base as the means of the construction now adopted. Does not that mean to you a distinct advantage of the hexagonal construction?—I think you might have reduced the surface in the front of this base-plate so as to be able to have brought the columns out nearer to the outside.

15,242. Still, would it not be the case that with the eight columns you could not get so wide a base by something like 20 inches?—I think it would have required a great deal of consideration to come to the conclusion which was the best. It would have to be gone into carefully.

15,243. The additional width of base is a thing worth obtaining if you can do so?—Oh! yes; I think so.

15,244. It might be a question, I suppose, upon which two engineers might come to different conclusions as to whether it would be better to have eight columns on a narrower base or six columns on a wider base?—If you can get eight columns on the existing base, as a matter of course it is better to have eight than six as far as strength goes.

Examined by Mr. Webster.

15,245. Nearly every question that I had to put has been anticipated by my learned friend Mr. Bidder. You remember speaking about the holes in the lugs this morning?—Yes.

15,246. And you mentioned either a larger bolt or a riving out?—Yes.

15,247. And you said you preferred riving out?—Yes.

15,248. It is the fact, is it not, that riving out implies using a larger bolt?—No, because you would make a smaller hole to start with.

15,249. Assuming that a given mould is given to the moulder to put in, and that he puts the hole in the way that you suggest, in the wrong place, there would be two ways of remedying that, of course, either by altering the thing that was going through the hole, whether it was straight or not, or by riving out the hole?—Yes, but there is another way, and that is by making the hole right to start with.

15,250. I am assuming the moulder to have shifted the core. Now, riving out would mean a larger bolt, would it not, in that case?—Certainly, if you make a bigger hole you want a bigger bolt.

15,251. And a larger bolt would mean a larger hole in the tie or in the lugs?—Certainly.

15,252. Which would weaken the cross strain upon the tie?—It would weaken the bar, of course.

15,253. Therefore you could not have rived out the hole and used the larger bolt, I do not say to what extent, because I have not calculated it, without weakening the bolt certainly not, if the tie is of the same strength as the bolt.

15,254. As I gather from your answer to Mr. Bidder's question, you believe and you have formed a judgment that a good many of these bolts were bent before the accident happened?—I saw a good many of them.

15,255. But do you say you believe that they were bent before the accident happened?—I think it is highly probable.

15,256. You have not examined the extent of compressive strain of the cutters as compared with the bending strain of the bolt?—I have not gone into calculations of the strain at all.

15,257. And you could not tell me without calculation whether the bolt would bend before the cutter was compressed?—I think the bolt would bend long before the cutter would be compressed.

15,258. I understand that you have been a good deal engaged in the construction of iron structures; you are very well acquainted with such things as jibs and cutters?—Yes.

15,259. And I dare say you know a good many structures in which a considerable number of jibs and cutters are used?—Yes.

15,260. When you have piers of this kind (I will not call them piers, because I am not sure that that is correct,) built up of columns tied together with struts and tie-bars, and the tie-bars pressed up and brought into tension by cutters, is not that a kind of structure in which you expect to have time to
time to tighten up the various parts?—I do not think you ought to. I think you ought to put your initial strain upon it sufficient to prevent your having to do it.

15,261. I put it to you, although of course I may have to call direct evidence upon the subject, you have, of course, seen the form of jibs and croters adopted?—I do not think I saw one of them, but I think I have seen the sketch.

15,262. In this kind of structure so constructed with many thousands of these appliances for tightening up the tie-bars subjected to the influences of temperature, the influences of wind and trains going over it could surely, I think, do out as said Mr. Bidder suggested, would you not expect (I will not say to what extent) from time to time to find that a tightening up of these croters was required?—I think not if they were driven well home to start with. The croters are split croters, after they are driven in, they are opened at the ends which prevents their moving backwards out of their places.

15,263. Do you know how this bridge was tested?—No, I do not know anything about it.

15,264. I suppose that six goods engines weighing 73 tons each and 4/8 feet over all, the total weight being 438 tons, the length of the six engines together being 291 feet, that is to say 1/2 tons to the running foot (assuming these facts from Mr. Bidder) would as far as weight in space is concerned be a very heavy test indeed, would it not?—Yes, I should think that six engines of 70 tons each would be a decided load.

15,265. And 1 1/2 tons to the running foot is a very high weight, is it not?—It is a big test.

15,266. Assuming for a moment that these six engines so coupled were sent over that bridge at a speed of 40 miles an hour, would that be an operation that would, so far as the vibration is concerned, test the tightness of such things as these croters to a material extent?—I should think if any of these were loose it would be sure to find them out.

15,267. I gather that you had not, previously to giving evidence, any personal knowledge or information as to the actual test to which the bridge had been subjected?—No. I understood that it had been subjected to a big load, which I quite expected to find.

15,268. I am told that when I said 40 miles an hour, I ought to have put four engines instead of six, that it would be 24 tons in a length of 160 or 170 feet, or 1 1/2 tons to the running foot?—To the running foot for that length, I suppose not.

15,269. It is very nearly the whole length of the span, you know?—Four engines 48 1/2 feet long are less than 200 feet; they would be 194 feet, and the span is 245 feet, so that there is a good deal of difference.

15,270. I am not new speaking of the dead resting weight which was the six engines, but would not the four engines coupled together, each weighing 73 tons, or a total, roughly speaking, of 300 tons, running over the bridge at a speed of 40 miles an hour, in your judgment, have caused much larger croters if they had at that time?—It would produce a very large amount of vibration, and I should certainly expect that if there were any loose croters it would have shown them.

15,271. You saw the croters that were broken off, as I understand?—Yes, I saw a lot of them which had been broken off.

15,272. Do you form an opinion as to whether a very large number of these croters (I do not say all, because nobody could say that) were broken off by things falling from above?—I should think not.

15,273. About the casting, you have said very fairly that in your judgment whatever the defects of the casting may have been they do not affect the question of bringing them together, because the margin was so large?—I think so.

15,274. Do you object to horizontal casting altogether?—Yes; for a structure of that kind.

15,275. Is it not the fact that if you had to cast a column with a good many excrescences (that is not a very technical word I am afraid, but you know what I mean; lugs and brackets underneath, the flanges and things of that kind) horizontal casting is the best for that?—Yes, I think, would almost necessitate the castings being made horizontally, or, at all events, at a slope.

15,276. The lugs and excrescences would almost necessitate the castings being either horizontal or at a slight incline?—Yes, the incline would be very much better.

15,277. Certainly not vertical?—It would be very difficult to make them vertical, and that is one of the reasons why I think they ought not to be in at all.

15,278. That is one of the reasons why you say, you would have attached these lugs not by casting them on but in some other manner?—Yes.

15,279. (The Commissioner.) You do not say horizontally, but with a slight incline?—With a slight incline; as much as you could get; about 30 degrees perhaps. I do not think it would make any difference in the casting; it is the question of the moulding. If they were moulded in boxes it is very easy to tip the box.

Examined by Mr. BALFOUR.

15,280. Have you had a great deal of experience of the use of cast-iron columns in bridges and piers?—Yes, I have.

15,281. For very many years?—Yes.

15,282. And have you found that when these structures are properly designed and properly constructed the cast-iron piers are a satisfactory material?—Unquestionably; there are miles of them in existence.

15,283. And they have answered perfectly well?—Perfectly well.

Re-examined by Mr. TrayNER.

15,284. Four engines going over at a rate of 40 miles an hour would produce you say very considerable vibration?—I should expect so.

15,285. But do you think that four engines passing over the bridge once or twice at that rate when the bridge was just completed would necessarily develop all the weakness arising from the looseness of the ties?—I think not, certainly.

15,286. While it would have an effect, it would not bring out the full weight of these ties; the piers were capable?—If the wheels were in a state of rest, their being no wind or anything of the kind, and the four engines travelled over at the rate of 40 miles an hour, I think the probability is that they would not produce any bending in any one of the bolts.

15,287. The subsequent vibration by the use of the railway and its subjection to the wind pressure on both sides would gradually develop the weakness which is supposed subsequently to have existed?—I think it would.

15,288. There was a matter which Mr. Bidder spoke about last which I am not sure that we followed; perhaps you will kindly explain it to me. Mr. Bidder said that taking these tie-bars and the column, we might separate geometrically possibly and only possible between each two columns?—Yes, I do not agree with that, I say there is not.

15,289. Assuming that he is right in that matter, and we will make it for the sake of clearness 1/4 inch, if the tie-bars in the lower part of columns gave to the extent of the 1/4 inch that was possible, that would give the columns, would it not, an inclination to the extent of 1/4 an inch one way or the other out of the vertical?—Yes.

15,290. Now, if the two columns immediately above that also gave to the extent of 1/4 an inch?—I think Mr. Barlow's sketch answers your question (Handing Mr. Barlow's sketch to the learned commissioner) This is the result of a giving of a certain quantity from the base to the top.

15,291. Talking of the mode in which the girders were attached and in your opinion should have been attached to the piers, Mr. Bidder asked you whether the rollers did not of themselves form an attachment,
and you have said "No;" is there any more attachment, in the proper sense, between the girders and the pier on those rollers than there is between a railway carriage and the rails which it is running on?—No; of course it is exaggerated, but it is the same principle. 15,229. (Mr. Bidder.) On the contrary, a railway carriage does not prevent the rails separating?—It does not; the wheels have no double flanges, therefore the rails might go outside, but they cannot come together.

(The Commissioner.) And therefore there is an advantage rather in the rails, that is to say, they can go one way.

(Mr. Bidder.) There is nothing in a railway carriage that prevents the rails from separating.

15,295. (Mr. Truog.) Was there any attachment between the pier and the girder except that which the side of the roller gave?—Certainly not on those where there are rollers, at least, so I understand.

15,294. Now I want you to look at these two photographs again (handing them to the witness); one is the guard's van, and the other is the second-class carriage. If the second-class carriage left the rail, it would tilt over, you said, and the leading corner would be projected against the lattice-work of the girder?—That is Mr. Bidder's suggestion.

15,295. In that case which side of the second-class carriage would be most likely to be run into and injured by the train following, the east or the west; if a carriage running along is tilted up, and a carriage is coming behind it, would the east or the west side of the back of the carriage be subject to most injury from the carriage behind?—I should think the east side.

15,296. Would not the east side, if it was tilted up in the way that I have suggested, be beyond the line of the carriage behind it?—I do not think it could be tilted over so much as to avoid the buffer.

15,297. You think it is the east side that would be most injured?—I should think so.

15,298. Look at the photographs; is it not the west side that is most injured?—I understand that it is so.

15,299. Does that tend to confirm you in the view which you have expressed?—I would not attempt to answer that so much on the west side of the carriage at all; I do not see how I can. The frame of the guard's van, which came behind, is practically not damaged.

15,300. (The Commissioner.) Just so; follow up that question. As I understand, there is the second-class carriage immediately followed by the guard's van?—Yes.

15,301. The theory is that the second-class carriage is tilted over from the west to the east?—Yes.

15,302. So that its roof or head would come in contact with the lattice girders?—Yes.

15,303. Your idea is that the roof would be cut through just like a piece of cheese?—Yes.

15,304. Supposing that it were not, and that it offered any resistance, what would the effect be? It reposing simply on two of its wheels would not be the effect of the forces we have thrown to the west part of the east side of the carriage round towards the guard's van?—I think I understand what you mean.

15,305. Supposing, for instance, that it tilted over in this way (describing it), and came against the girders there, would not the effect be to turn it that way?—Yes, supposing that it was sufficiently rigid.

15,306. If it were not sufficiently rigid it would cut it straight off?—Yes.

15,307. If it were sufficiently rigid it would turn the guard's van, which would be to impinge upon the lattice work at the rate of 40 feet per second; as I apprehend, the assumption is not that it impinges at right angles against the girders, but that it cuts them by a sliding blow, as it were?—I conclude that that was so.

15,310. It could not turn round of course, because there is only 3 feet between them?—Of course.

15,311. Under those circumstances, striking it in that way and striking it with the weakest part of the carriage, should you not necessarily suppose that the top of the carriage would be cut completely off?—I should.

15,312. Supposing, however, that it was so strong as to knock away one of those lattices, would that bring the bridge down?—I am afraid it would.

15,313. One of them would bring it down, would it?—I think so. I do not think there would be any question about that.

15,314. But, at any rate, I suppose you think that that carriage would be very nearly in the same condition that Stephenson's cow was, and that it would be broken up "all to smithereens," which I think was your expression?—Yes.

15,315. (Mr. Bidder.) I do not think Stephenson went further. Sir, that is to say that it would be "the worse for the cow."—Yes.

15,316. But at the same time, in your experience, does it not sometimes happen that a very severe test may be applied to a bridge and yet the defects may not immediately develop themselves?—I think so.

15,317. And that what would cause the development of the defects, or the indication of the defects, would be the repeated running of trains over it; is that not so?—Certainly, I think so.

15,318. And even if there were a slight defect that defect might be magnified by trains running over it?—I think it might.

15,319. You told us also that you thought the bolts would bend before the cotters would be compressed?—Yes.

15,320. But supposing that those cotters were in slots, the ends of which were very uneven, the cotters being loose, the carriage bearing upon the end of the slot, the end of the slot might give way, might it not?—I think it might.

15,321. I suppose in that case the ties would get loose, would they not?—Yes.

15,322. That therefore might tend to loosen the ties as well as the bolts giving way?—Yes.

15,323. And consequently the loosening of those ties might be due to two causes; first, the bending of the bolts, and secondly, the giving way of the slot in the ties, without the cotters being indented?—I think so. I gather from your question that you assume that through some of the slots the bolt is not true, that it is rugged, we will say, and that there is only a very small amount of bearing, those small bearings would be crushed.

15,324. Before the cotter was at all injured?—Yes, before the cotter was at all injured.

15,325. And even before the bolts gave way?—Probably even before the bolts bent.

15,326. At any rate, there are these two things which would tend to cause the ties to lose?—Certainly.

15,327. Now I want to know this for my own information, as there seems still to be some little doubt about it; supposing that as Mr. Bidder was good enough to begin at the top, we begin at the bottom; and supposing that all the ties on one side were loose to such an extent as to allow the top of a column to go over half an inch, taking the lower ones, first, say that the dark lines on this drawing (showing a diagram to the witness) were as they were in position, and the dotted lines as they are when they go over half an inch, then the bottom of the columns immediately below them would have gone over half an inch?—Certainly.
15,338. Supposing that the tie above that had given way, then the dotted line would indicate how it would have gone over; that would be an inch altogether, would it not?—Yes, it would cumulate.

15,339. Consequently, when you got to the top it would be 34 inches, or seven times half an inch, would it not?—Yes, it would certainly.

15,340. On the assumption that they had all given way to the same extent?—Yes, you would really have more.

15,331. But supposing that they did not all give way—supposing that the ties in only some of the panels were loose, then you might have the lower part bending one way and one or two of the panels upright, and others bending the other way, might you not?—That is supposing the bolts did not bend correspondingly.

15,332. You would not consider that to be very secure?—No.

15,333. You must probably have it all the same way, would you not?—Yes, I think so.

15,334. With respect to the connection of the girders, the dotted lines are where they might be supposed to be afterwards; you said the connection of the girders you thought was defective?—The connection between the girders and the piers.

15,335. You said that having five of the spans connected, having the five girders continuous. I think that under the circumstances of the structure, it did not add to the strength, but that it weakened it.

15,336. Would you have had each span separate?—I would have had each span separate.

15,337. Then how would you have connected it with the pier?—I would have had a collar joint.

15,338. You would have made the attachment in a different way from that which Mr. Bidder suggested?—I would have had as perfect an attachment as I could have got.

15,339. You said that you think it would have been exceedingly doubtful whether any investigation could have discovered the bending of the bolts after that jingling noise was heard?—Yes.

15,340. But at any rate I suppose the fact of that jingling being heard would be a sufficient indication to you as an engineer that something or other was loose?—Certainly.

15,341. And until you had discovered that something or other was loose, I suppose you would hardly have been satisfied?—I should not; I should have had the bar out.

15,342. Then you would have seen whether the bolts were bent or not?—Certainly I should.

15,343. Having seen that, you would have taken the proper measures?—Yes, I would have taken some measures to have remedied the defect.

15,344. The measures that were taken of putting in these packing pieces would not remedy any defects of that bending of the bolts, but it was due to some extraordinary cause; was it not?—It might have been due to that, or it might have been due only to the bending of the bolt; and the putting in of that packing piece would to that extent bring the bar again into play to be doing its duty, but it would be doing its duty with the bolt bent instead of being straight.

15,345. And in a distorted position, not vertical?—That would be right.

15,346. But, would the pillar be out of position then?—Yes, I think it would be to a certain extent.

15,347. And it would not be restored to its position?—No; it would not be restored to its position.

15,348. Would not the column be out of position—would the mere putting in of a packing piece be sufficient strain to bring the column back to its position.

(Mr. Bidder.) The view that we take is this: that if a severe strain has caused this slackness by pushing the head of the column out of position, and so bringing the strain on the bolt, when the strain is taken away the head of the column will go back into position of itself, otherwise the bar would not be loose. That is our view, although it may be an entirely fallacious one.

15,349. (The Commissioner.) The bar might be loose, I suppose, under the action of a passing train, from the head of the column, having a slight movement backwards and forwards, and others bending the other way, might you not?—I do not think it would cause the tie to rattle unless the tie was loose. If it was loose before, the train went over, then the bar would cause the base to come together, and the two bars coming together would make a noise which would be heard.

(Mr. Bidder.) Does not the fact of the tie-bar being loose, if it was occasioned in the way you suggest, imply that the column-head to which it was fastened had been pushed on one side and had returned?

15,350. (The Commissioner.) Does not the fact of its rattling show that the top of the column has a certain motion?—Certainly, it must have had motion.

15,351. But whether or not it is out of line at the time when the packing piece is put in, or whether it is returned to its line, is a mere chance, I suppose?—I should apprehend that after the strain was removed, the column would come back to its vertical position, and therefore that the bar would be quite loose, and that it would be necessary to put a packing piece in to get it tight. If it did not come back to its original position, I think the structure would very soon be over.

15,352. (Mr. Barlow.) You assume a condition of perfect elasticity in the pier?—Yes.

15,353. In that case the tie-bar which was strained would be the loose tie-bar which had to be keyed?—Yes.

15,354. But supposing, on the other hand, it was blown out of the vertical, and so received a certain amount of permanent set, then it would be the opposite tie-bar?—Yes.

15,355. And in keying that you would key it into its altered position?—Unquestionably.

15,356. So that it might happen both ways?—It might happen both ways.

15,357. (Mr. Bidder.) If you observed a tie-bar chattering during a storm, so Mr. Barlow says, it would be the tie-bar that was not doing duty?—It might be.

15,358. And if you observed a chattering when the storm was over, it would probably be the tie-bar that had too much duty cast upon it?—It might or might not.

15,359. Would not the probability of which tie-bar it was, depend upon whether you observed the chattering during the time of the strain or after the strain was over?—I do not think you could say that.

15,359a. (The Commissioner.) The diameter of the caisson is 31 feet, is it not?—Yes.

15,360. You will see that the distance between the two centres of the 16-inch columns is 21 feet 10 inches?—Yes.

15,361. Can you or can you not get two columns on the outside, taking the secant of the circle?—You could not get the whole of that base, but you could get very near to the whole of the base.

15,362. On to what?—Within the 31 feet.

15,363. Would that very much weaken it or not?—I do not think it would weaken it much.

15,364. (Mr. Bidder.) The diameter of the caisson is 31 feet, but the outside 18 inches cannot be looked upon as part of the frame. I am told that practically,
MINUTES OF EVIDENCE.

Further examined by Mr. Webster.

15,387. I do not know whether you have heard any evidence, given by Mr. Law with regard to the slots, the tie bars, and the slings?—I have not heard Mr. Law’s evidence.

15,388. I want that bit of sling produced. I think you may remember, Sir, that what was produced was not a slot in a tie bar, but a slot in a sling.

15,389. (Mr. Webster to the witness.) Will you tell me while that is being looked for where the tie bars were punched?—They were slotted in Middlesbrough.

15,390. Were they punched with a slotting machine, as far as you recollect when you saw the tie bars, how were the slots punched?—Wore they clean or ragged, or what?—They were clean, those that I saw.

15,391. That is a slot in a sling (handing it to the witness); that has not been cut with a slotting machine?—No, it has not, that is punched.

15,392. Do you remember how the slots in the slings were made?—Was there any difference between some and others?—Yes, the majority of them came from Middlesbrough ready slotted, almost all in fact. Some of them were prepared at the bridge works in order to make up for the want of some slings or to make some slightly longer slings so as to be used with shorter tie bars, being the only ones which had been left over. Perhaps, in some cases, they have been used slightly too long, as I explained the other day. Those were made at the bridge.

15,393. I want to ask your opinion about this; would the roughnesses on that slot in the sling, in your opinion, have any injurious effect upon the action of the cotter which passed through the tie-bar?—If the ends are fair, certainly not.

15,394. Are the ends there fair, or not?—Yes, they are tolerably fair.

15,395. With regard to what you told us about the slots being cut in the tie bar by a slotting machine at Middlesbrough, when the tie bar was sent to you, and the gib and the cotter passing through it, in your opinion was any practical defect occasioned by the roughness in those sides of the slot in the sling?—1t would only then have been the case when the hole had been considerably wider. This does not look pretty, but it cannot be a real defect.

15,396. I think you said very fairly to the Court, if I may say so, that the day you went to the bridge it was wet?—Yes, it was.

15,397. Did anybody point out anything to you?—Yes.

15,398. Who?—Mr. Campbuhl was with me.

15,399. I do not know whether you know if Mr. Campbuhl went over with Mr. Law or not?—I have heard about it.

15,400. Did you see any slot torn out, either in the tie bar or in the sling, or in any part of the bridge that you saw?—I saw not one torn out.
15.401. As far as you know have any torn out once been discovered?—I have not heard that there have.

15.402. Now then I will go to the gib and cotters. You know that the gib and cotters used in this part of the work would be in that from the gib and cotters put up in some parts by Mr. de Bergue on the northern portion?—Yes.

15.403. We have had the reason of that explained. You know the reason of the alteration yourself?—Yes.

15.404. Were these cotters driven tight so far as you know?—They were driven tight, but when I left the bridge I intended at any rate to go over them again.

15.405. When did you leave the bridge?—I left the bridge at the end of the month of November, 1877.

15.406. It had been your intention to go through the bridge again with reference to the tightening up of the tie-bars?—Yes.

15.407. Had trains been running over the bridge before you left?—Ballast trains had.

15.408. For how long,— For two months.

15.409. Constructed as this bridge was, would you expect that these cotters would require any attention from time to time?—I think they would. It is true that the ends were opened up, split ends; but a very small motion of the ridge of the cotter might produce an appreciable slackening in the bars, and that small motion might cause a considerable slackening in the tie.

15.410. Is that a matter to which you should have paid attention if you had been at the bridge after its completion?—Yes.

15.411. Attention has been called to a greater dimension of metal shown upon this drawing (producing a diagram) as compared with the actual size; do you know where that piece comes from (showing it to the witness)?—Yes, it is part of a quadrant serving to fix the horizontal diagonal braceings between the four 18-inch columns.

15.412. Will you point to the place where it is suggested by Mr. Law that there is a deficiency of iron, and therefore a deficiency of strength?—Here, and here (pointing to the model).

15.413. Do you know what these were constructed from: did you ever see the drawings yourself?—Yes.

15.414. Have you got them here with you?—No.

15.415. Were they made at Wormit or at Middlebrooke?—These were made at Wornit.

15.416. Would you just explain in your own way to the Court whether in your opinion that deficiency of thickness causes any weakness or not?—The object of the quadrant was to fix the horizontal diagonal braceings, being a round bar. It only touched the legs at the sides bare (pointing to the drawing). The fixing of this quadrant took place by these bolts (pointing them out). The strain which would come upon them would be in the direction of this bar (pointing to it); it would not be in any other. Therefore their weak point would be in this corner here (pointing to the drawing). Supposing the casting itself to be perfectly rigid, then the pull given by the bar would be in that direction (describing the same) and sheering on the bolts; and if the bolts did hold there was a tendency to break through that metal and through this metal, and not to break through that metal and through this metal (pointing to different parts of the drawing). Now, the thinness of the metal here (pointing it out) had nothing to do with this (describing the same); it would break-through here and there (pointing to the drawing).

15.417. (Mr. Barlow.) It does not seem to be broken there?—No, because there has been, perhaps, a wrenching motion on it, which wrenched this off. Against that particular mode of straining there would be an additional strength no doubt, but not against the direct pull; because if these two holes were put too near the edge it would leave more metal in between, which, for the direct pull, would answer the purpose as well.

15.418. (Colonel Yolland.) Is there any evidence of any blow?—I should imagine that this had been like this (describing the same), or it may also have been on the other side like this (describing the same). It depends upon where it was put.

15.419. Is there any evidence of any blow?—Yes, I would not expect the blow to have taken place exactly in that part (pointing to the model), but I should have expected the blow to have taken place, and then this would be the weakest section certainly.

15.420. (Mr. Webster.) Having described what you say was the position of the strain with reference to the section of iron upon that piece of the quadrant, I understand you to express an opinion, rightly or wrongly, that the thickness or thinness of iron there did not affect the strain, what, in your judgment, caused the fracture or breaking of that and similar pieces?—This, as well as similar pieces, has been, no doubt, broken by parts of the column falling upon it.

15.421. What was their position, standing horizontally out from the side of the column?—They stood horizontally out from the side of the column.

15.422. Do you know whether you know that it has been said that in one instance (I will not give you the number now) there are eight bolts to attach the top of one of the 18-inch columns to the under side of the L girder; you know the place?—Yes.

15.423. Up to the time of your leaving the bridge, had all those girders been fixed or not?—I think there may have been some bolts wanting.

15.424. So far as they had been completed, before you left had the eight been put in or not?—When I left there may have been some that had not received the eight bolts, but I am not positive about it.

15.425. In any completed column which you had actually finished off were eight or four bolts put in?—There were generally eight put in.

15.426. Do you know when you left whether or not there remained to be put in any more of those bolts?—No, I do not; only I know that in several places bolts had still to be put in, and that provision was made to get that done.

15.427. Do you know of any column to which no more bolting was to be done, which had been left and was intended to be permanently left, with only four bolts in it?—No, I do not.

15.428. You know the channel irons and their bearing against the legs?—Yes.

15.429. Was there any difficulty in screwing up those channel irons?—Certainly not.

15.430. Was it necessary to cut away any iron to screw up those channel irons?—No; it was necessary sometimes to make a key for the purpose, but it was not necessary to cut away any iron.

15.431. (Mr. Barlow.) You say sometimes; were they not all alike?—Yes, they were. All those bolts placed in the same position were alike; but when I say sometimes, I mean for particular bolts for particular positions.

15.432. (Mr. Webster.) As a matter of fact, could or could not those channel irons be tightly screwed up?—They all could.

15.433. Was there sufficient friction, in your opinion, between the channel irons and the legs to act as an efficient strut?—Yes, with the bolts properly tightened.

15.434. Do I not know that it is necessary to put it to you now, but you are aware there being brackets underneath the flanges, if I may use that expression, at either end of the pipe?—Yes.

15.435. It was part of the original design to put those brackets on?—Yes.

15.436. Could you have turned the under-side of these flanges so long as the brackets were on?—Not so long as the brackets were on.

15.437. (The Commissioner.) There would have been no difficulty in turning the flax?—None whatever.
15,453. (Mr. Webster.) If you remember, Sir, I am on a specific answer as to what ought to have been done to the under-side of the flanges (to the witness) : what was done to the faces of the columns ?—They were tarred.

15,456. (Mr. Webster.) How long was the cement put in before the bolt would be screwed up, that is to say, how long did the bolt remain ?—They differed a good deal, but, certainly, generally works at any rate.

15,457. You told us, I think, on the last occasion, that the order in which you went round was a regular programme ?—Yes.

15,458. Mr. Trayer, I think, did not quite understand one of your answers. At the time of putting on the bolt, that is to say, the bolt coming up through the hole in the column and at the time of putting on the nut, did you ever see a bolt raised or drawn up through its hole ?—No.

15,459. Or hear of such a thing ?—No.

15,460. When you spoke doubtfully about it what were you referring to ?—Mr. Trayer asked me whether I had seen during my inspection of the ruin any bases which had actually been pulled up.

15,461. (Mr. Trayer.) I meant, did you ever see any bolt which had been drawn up by the screwing of the nut at the time of the erection ?—No.

15,462. I asked you directly about the L girder, if that was not done by piece-work. Are you aware that a great part of the erection of the work, apart from its manufacture, was done by piece-work ?—Yes, I am aware that parts were done by piece-work.

15,463. What parts ?—One of the parts done by piece-work was the putting in at first of these lattice-bars without screwing them up, simply putting them in place. Putting them permanently in their places, but not fixing them permanently—going over them again afterwards.

15,464. Was any other thing in connection with the pieces done by piece-work?—Not that I recollect.

15,465. Were the columns placed by piece-work ?—I cannot recollect.

15,466. Was there a good deal of work done in the erection of the structure proper by piece-work ?—No, there was not.

15,467. Your recollection seems to be imperfect upon it, and I do not wonder. You could not approximate to the proportion of it that was done by piece-work ?—No.

15,468. (Mr. Barlow.) Were the gibs and cotters made by piece-work ?—All the gibs and cotters came from Middlesbrough.

15,469. (The Commissioner.) Where did the holding-down bolts come from ?—They came from Middlesbrough also.

15,470. Were they all made on the same pattern ?—Yes, or approximately.

15,471. Then how is it that one of them would be standing up so much higher than another ?—In putting it down, if the hole were not quite wide enough, it might stick half way. Of course, that is rather exaggerated, but it might stick at some distance from the very bottom.

15,472. Did you not make the hole at the bottom rather larger than up above ?—The hole was made about cylindrical, it was intended to be cylindrical.

15,473. Not cylindrical, not conical.

15,474. It was not larger at the bottom than it was at the top ?—No, it was not.

15,475. Then it was only made just about the size of the bolt ?—There was not very much to spare, and these bolts were forged, and I dare say some of them were a little wider below, because it was not a very material thing whether they were so or not.

15,476. We have had evidence to-day from a gentleman who has had great experience in building with ironwork, and he tells us that when bolt holes are cast they almost always, owing to the mould being put in, come out conical; if they did I suppose the bolt then would hold either at one end or the other ?—It would.

15,477. I think the holes in the lugs were all cast, were they not ?—They were all cast.
15,478. Were any means taken to make the sides of the bolt holes parallel?—The core was made parallel. I only heard this to-day for the first time.
15,479. But you never heard that any means had been so taken?—No.
15,480. Were you or were you not aware that the bolts were originally ordered of an 14 inch in diameter, and that they were afterwards altered to 14th inch?—Yes, I knew of that.
15,481. Do you know why that was?—Yes.
15,482. Why?—The first arrangement was to have three channel bars and the diagonal bars all running in the same line, and for that afterwards we substituted three 14inch bolts.
15,483. Then how was it that the same number of bolts were ordered if you wanted three times the number?—We did not order the whole number of bolts necessary at once, but ordered them in quantities as we needed them.
15,484. Was it in consequence of a suggestion by you or by Sir Thomas Bouch that the alteration was made?—I think it was on our suggestion.
15,485. Without any communication with Sir Thomas Bouch?—Yes.
(Mr. Webster.) May I remind you that in the letter to those very Cleveland people which Mr. Trayner put in, there is a postponing of the delivery of some of these bolts because they were not wanted so rapidly.
15,486. (The Commissioner.) I recollect that. (To the Witness.) I think it was done on your suggestion by the order of Sir Thomas Bouch?—Yes, with the consent of Sir Thomas Bouch.
15,487. What did then was to have three bolts instead of one?—Yes, three for one, or three for two, I do not know which.
15,488. You know, of course, that according to the specification the bolts were to be made to fill the bolt holes?—Yes.
15,489. And the rivet holes were to be made perfectly true and fair; but that does not seem to have been done?—I suppose that means practically true and fair—not theoretically.
(Mr. Trayner.) There are a number of drawings referred to in the specification upon which they were manufactured at Middlesbrough.
(Mr. Webster.) Any drawings that my friend wants, and that can be obtained, Mr. Gilkes will be happy to produce. I do not know whether he has the actual working drawings, but he has a great many drawings.
(Mr. Trayner.) They are enumerated in the specification.
(Mr. Webster.) I do not know, Mr. Gilkes, whether you have got them all?
(Mr. Gilkes.) I have not got them all here, but I can produce them.
(Mr. Webster.) Would you show me the list?
(Mr. Trayner.) It is on the second page of the specification.
(Mr. Webster.) I think I can get them for you. Do you want the details of the caissons, and things of that kind? You want all that we can find on page 2.
(Mr. Trayner.) If you please.
(The Commissioner.) Now, Mr. Trayner, whom do you intend to go on with?
(Mr. Trayner.) I have another practical witness, Sir, but I scarcely know at present whether I should examine him only generally, or in detail, and perhaps it would be more convenient that I should proceed with his examination to-morrow morning.
(Mr. Halfour.) The North British Company, as they promised, have brought Mr. Reeves from Spain, but he is very anxious to get back to his employment there, and I should be desirous to know whether anybody wants to examine him.
(The Commissioner.) We should like to examine him to-morrow.
(Mr. Webster.) I should certainly like to put some questions to Mr. Reeves.

**SEVENTEENTH DAY.**

Wednesday, 28th April 1880.

Mr. James Brunel's sword.

Examined by Mr. Trayner.

15,490. You are a civil engineer?—Yes.
15,491. In Westminster?—Yes.
15,492. You were requested, I believe, to visit the Tay Bridge along with Mr. Cochrane, who was examined yesterday?—I was.
15,493. For the purpose, as was explained by him, of examining both the quality of the material used and the workmanship, and also to give an opinion as to the probable cause of the disaster?—That is so.
15,494. You went to the bridge, I believe, along with Mr. Cochrane?—Yes.
15,495. On the last occasion you were with him?—On the first occasion as well. Two days on the first occasion, and two days on the last.
15,496. Will you tell me, before I go any further, something about your experience in the building of bridges and viaducts; you have had considerable experience, I think?—Yes, I have had what may be called large experience, I think, in the building of bridges with cast-iron piers and wrought-iron superstructures.
15,497. Extending over the last 27 years?—Yes, and during that time the bridges and piers I have erected would altogether amount to a little over four miles in length.
15,498. The Tay viaduct was one of your works?—Yes, it was; that is a mile and a quarter, or nearly a mile and a quarter in length, and in a very exposed position.
15,499. You also erected two viaducts in Morcunb Beach, I Bay, I think?—Yes. They are about 500 yards each, and they have been standing for the last 27 years.
15,500. You have also built some railway bridges. I need not go through them, but you have had a large experience?—Yes, I have built a great many, I do not know how many, both at home and abroad.
15,501. On both your visits to Dundee did you go over the ruins of the bridge in company with Mr. Cochrane?—Yes, and Mr. Peddie was there also.
15,502. He was Sir Thomas Bouch's assistant?—Yes.
15,503. And you made your inspections together?—We did on the four days that we were together.
15,504. I do not propose to take you in detail over this, you heard Mr. Cochrane's evidence yesterday?—I did.
15,505. Do you concur with him?—I do.
15,506. Both as to the result of observations, and in the opinions expressed?—Yes. I may say also that Mr. Noble was with us throughout the examination, and also Sir James Falsaw, one of the directors of the company.

Examined by Mr. Biddell.

15,507. When you say you concur with Mr. Cochrane, do you mean you agree with him in reference to the
15,508. I want to get that particularly, do you concern with him, that this design, if properly carried out, was the strength that would come upon it? I believe it was, without an excessive wind.

15,509. I did not say without an excessive wind, but with any wind that could be expected to come upon it, do you say that it properly executed was sufficient?—It was sufficient as long as, as I have said, there was no excessive wind, I cannot say that it was designed to meet the strength wind; but I can say that it was designed to meet 40 lbs. of pressure, that is what I make out it would take to overturn one of the piers.

15,511. You believe it would take 40 lbs. pressure to upset it?—Yes, to upset one of the piers.

15,512. With the train upon it?—With the train upon it.

15,513. Is that adopting Mr. Law's figures?—That is adopting Mr. Law's surfaces and weights, and working it out.

15,514. I will take that for the moment: what is your judgment, according to your experience, is the bearing capacity of wind that you would expect to have to provide against a large surface? I do not mean what you would get on the register of an anemometer—I could not tell. I could not possibly answer that question. I believe there is this which has not been taken into consideration by anyone, and that is the bearing capacity of the platform, I think that ought to have been taken into account in the calculations, which it has not.

15,515. Have you ever, in the course of your experience, had any experience which leads you to believe that such a pressure as 40 lbs. of wind over a structure of the size of this has ever been observed, or could be expected?—It would not be necessary that the wind should extend over the whole of this part of the bridge which has fallen, it would probably be quite sufficient that the wind was partially upon it, upon some part of the high girders.

15,516. When you say that, are you speaking from experience?—Mr. Law gave us certain calculations assuming a pressure of wind over every square foot of the girder, and of the pier and the train?—That is one span with a train upon it; I think very likely a high wind would at least reach to that extent; that is to the extent of a span of the girders.

15,517. Have you any experience or observation to support that view?—I have noticed that in cases of very high wind, plantations, that is to say woods, have been blown down, but not to any very great extent in width. I have seen an avenue of trees blown down, not extending for any very great width, and there the wind pressure must have been confined to the height which the trees had fallen.

15,518. But a good deal less than 40 lbs. of wind would blow a tree down, would it not?—It depends very much upon the tree, and upon the soil into which the tree is rooted.

15,519. Therefore I am afraid the mere fact of a great height of plantation being blown down will not help us much, unless we know that there was the tensile strength of those trees and their roots; there are trees which will come down with a very moderate pressure of wind, are there not?—Yes; trees that are planted upon a shallow soil are more likely to be uprooted than those rooted in a deep soil.

15,520. Have you any experience, or have you made any observations, that would lead you to believe that anything approaching 40 lbs. of wind has been experienced over a surface so large as one of these spans?—No. I cannot give you any instances of that sort.

15,521. What has been hitherto the outside wind provide for?—In my experience, for the roofs of buildings, I have taken 30 lbs.

15,522. As to your Solway viaduct, that you spoke of, did you make any special allowance for wind there?—No, that viaduct was constructed at a very low elevation as compared to this, and with very small spans, 30 feet spans—you do not require in that case to take any notice of the wind at all, the girders are so small; they are only 2 feet 6 inches.

15,523. In other cases in which you have constructed bridges, or girders of large span, have you made special provision for the wind?—I constructed one viaduct in Brazil 170 feet high—that is about twice the height of this, and there I had no occasion to reckon anything for the wind, because the viaduct is placed on a small ravine running into the main valley; and in that case I had the wind coming end on to the viaduct, and I did not require to make any allowance for wind pressure in that case.

15,524. In point of fact you have never had occasion, in your experience, to consider what would be the allowance for wind that you must provide for in the case of a structure like this?—No, I have not.

15,525. With regard to your 40 lbs. of wind pressure to overturn a bridge, it should like to understand whether that was upon the same data, and the same bases, as Mr. Law's, or not?—I do not know whether it is, but the result is very nearly the same.

15,526. What is the ultimate tension that that assumes upon the tie-bars?—I have not gone into that.

15,527. Do not you consider the overturning force without ascertaining what the ultimate tension upon the tie-bars is?—I take it merely upon the one pier—upon the whole pier without going into it further.

15,528. You could not take it upon the one pier without calculating the tension of the tie-bars, could you?—Yes.

15,529. Surely the tie-bars are an essential part of the structure in maintaining it against a lateral strain?—I have not the details with me to refer to; I can only give you the result that I have given.

15,530. I must ask you this question, because Mr. Law gave a figure which he afterwards considerably modified, and therefore I am bound to ask you upon what basis have you arrived at the 40 lbs. of wind as the pressure that would overturn the bridge?—I cannot give you the result. I have not the figures here.

15,531. You cannot tell me whether it was assuming a tension of one ton, or five tons, or ten tons, on the tie-bars?—No, I cannot tell you that.

15,532. You did not assume any particular ultimate tension upon the tie-bars in arriving at that conclusion?—I have not the figures here.

15,533. It places me in great difficulty, because I do not like to have your evidence against me without testing it.

(Mr. Barlow.) What I understand Mr. Brunlees to say is, that he assumed the tie-bars to be efficient, and that pier turned over as one complete structure.

(The Witness.) That is how I have taken it.

15,534. (The Commissioner.) As a rigid structure?—As a rigid structure, without going into minor details at all, for I have not gone into them.

15,535. It places me in great difficulty, because I do not like to have your evidence against me without testing it.

(Mr. Barlow.) What I understand Mr. Brunlees to say is, that he assumed the tie-bars to be efficient, and that pier turned over as one complete structure.

(The Commissioner.) That is how I have taken it.

15,536. (Mr. Bidder.) You do not agree with Mr. Law, because if I recollect rightly upon that hypothesis, Mr. Law has shown us in his report that it would take a much higher pressure of wind. Let me draw your attention to this in Mr. Law's report, if you look at page 28 of his report you will see that he came to there was, that treating it as a question of overturning, it would take 64-39 lbs. treating the pier as rigid, and the columns as bolted down, that is at page 28, paragraph C. "Pressure of wind required to overturn the pier with the train and with the columns bolted down 64-39 lbs., which would suffice to overturn the structure, supposing the pier to be rigid and the columns bolted down," a very different result, you see, from yours?—That is taking the bolts into account.

15,537. Did you not take the bolts into account?
15,537. I am glad to understand that. You are aware that the holding-down power of the bolts, if you treat the pier as rigid, is a not unimportant factor in the question? In my opinion the holding-down bolts were never called into action.

15,538. Let us deal with one thing at a time. I am now dealing with the evidence you have given regarding the pier as rigid, and without going into details of the failure of parts of the pier. Regarding the pier as rigid, the overturning force would be 40 lbs. to the foot, you say, surely if you are dealing with that hypothesis, the pier being treated as rigid, the power of the holding-down bolts becomes not unimportant. In my opinion those bolts were never called into play, they were no doubt disturbed in the failing of the structure.

15,539. Possibly so; our hypothesis as to what happened is different from yours. I am dealing at present simply with your evidence and your hypothesis. Regarding it as a rigid pier, the be overturned, it is not obvious that the fact of its being anchored by bolts, or anything else, on the windward side, is not to be neglected in considering what would overturn it. That is a force which Mr. Law shows amounts to a considerable factor. May I put it in this way, that whatever amounts to be added to your 40 lbs.? Yes, 15,540. I am quite content to leave it in that way, that to your 40 lbs. to be added whatever is the power of the holding-down bolts in resisting the overturning of the structure? At the same time I believed that those bolts were never called into play, but the bridge was overturned at a higher level, than that those bolts were simply disturbed by the falling of the columns and the girders.

15,541. Then you do not agree with Mr. Law, because he thinks that the tension upon those bolts was so great that it split some of the stone?—That, I apprehend, was in the failing of the structure.

15,542. Be that so, that only removes the question to another tier, so to speak, because there are bolts between each tier of columns; and if it turned over at a higher pier, still you have got to overturn the anchoring power of the bolts, whether it be at the first, second, or fourth tier, or any other tier?—Yes, that would have been so if those bolts had been retained. It would be the lowest tier of bolts that would give way first.

15,543. Therefore their resistance must be taken into account?—Yes.

15,544. I may fairly put it as a qualification of your evidence; that whatever that amounts to should be added to the 40 lbs.?—Yes.

15,545. Have you considered the question that I discussed with Mr. Cochrane yesterday, as to whether in point of fact the last two carriages of the train did not come in collision with the girder?—I have seen the whole of what remains of the wrecked train, but I have not seen anything that would lead me to think that any of the carriages got off the rail. I have examined them most carefully, and I have not been able to observe anything that would lead me for a moment to suppose that any of the carriages were thrown off the rail.

15,546. I do not know whether you heard me draw Mr. Cochrane's attention to this. You are aware that the two last carriages are smashed up in a way that the others are not?—Yes, the carriages are, no doubt—the second-class carriage especially is very severely smashed, but then it must be borne in mind that those carriages were very much smashed in the lifting.

15,547. That is not in evidence, I think, yet—it is possible that it was so?—I have no doubt it was so.

15,548. The two last carriages, as I pointed out to Mr. Cochrane yesterday, are much more destroyed than the former ones?—No doubt they are.

15,549. And, as I am reminded, it appears in the diver's evidence that they were in that smashed condition before they were lifted?—I believe they were.

15,550. I drew the attention of Mr. Cochrane yesterday to the way in which the back end of the second-class carriage, on its western side, is smashed—That might have resulted from the van running into the second-class carriage.

15,551. That is the very thing I suggest it did result from?—But that might happen without the second-class carriage having run into the girder.

15,552. It could not happen unless the second-class carriage was stopped before the van was stopped?—Yes, I believe it must have been stopped by something—not necessarily by the girder.

15,553. It was not stopped by the fore part of the train?—No, I do not think it was.

15,554. If it was not stopped by the fore part of the train, it was stopped by a part of the bridge, there is nothing that would stop the last carriages, I found that the footboards were knocked off, and the irons that supported the footboards are all bent towards the tall end of the train on the eastern side. Then, going round to the west side, I found exactly the same thing, namely, that the irons are bent back towards the tall of the train precisely in the same way as on the east side.

15,555. If those two last carriages had come into collision with the east girder you would expect to find any projections bent towards the tail of the train on that side, the western side,—I am not so clear about it. I cannot account for the bending on the western side, and the footboard is not so complete on the western side as on the eastern side in some of the carriages.

15,556. Did you notice another fact which I do not think I put to Mr. Cochrane, namely, that not only is the western side of the second-class carriage smashed up at the end, but the high pair of wheels has been swept away, and that it is the only case in which the wheels are gone. I am speaking of the back end of the second-class carriage.

15,557. (Mr. Trayer.) Is it the fact that those hind-wheels are off? (looking at the photograph)?

15,558. (Mr. Bidder.) If you will look at the photograph you will see at the hind end of the second-class carriage there are no wheels, as it is supported upon some sort of framework on the truck.

15,559. (Mr. Trayer.) I am not sure whether the wheels are not concealed.

15,560. (Mr. Bidder.) They are so effectually concealed that they become invisible and transparent. (To the witness.) Look at the left-hand picture, and you will see that the hind part of the carriage has no wheels?—There are no wheels here; but they would not be in the photograph.

15,561. (Mr. Bidder.) There are no wheels there.

15,562. (Mr. Trayer.) You are right.

15,563. (Mr. Bidder.) Who is Mr. Drummond? (Mr. Trayas.) That may be a side issue.

15,564. (Mr. Bidder.) His report of the second-class carriage is: “One pair of wheels gone, and one pair left with axle bent.”—Yes, all the axles are bent so far as I noticed.

15,565. The point I am drawing your attention to is, that the wheels of that second-class carriage are gone; and I think I am right in saying that is the ease with no other wheel in the train.

15,566. (Mr. Trayer.) I think that is a mistake. if you will pardon me. Have you got Mr. Drummond’s report?

15,567. (Mr. Bidder.) Yes, I have it. Do not let me say what is not right. It says a pair of wheels is missing.

15,568. (Mr. Trayer.) Then with regard to the first-class carriage, he says there are only the centre wheels remaining—that is a six-wheeled carriage—there are two pairs gone.

15,569. (Mr. Bidder.) I will wait until I have some more evidence about that. I think it will appear that those wheels came off in the process of lifting.

15,570. (The Witness.) You are more correct from the photograph because the wheels may be outside it.

15,571. Suppose it turns out that the position of the girders opposite the second-class carriage, and the guard’s van is very much more destroyed than any other part of the girder on the eastern side, does that raise any suggestion in your mind of a collision?—I do not quite understand your question.

15,572. (Mr. Bidder.) Suppose it appears that a portion of the girder on the eastern side opposite the second-class carriage and the guard’s van was much more destroyed?
sue ete than any other part ot the girder on the eastern side, does not that raise in your mind any inference that a collision took place there between those carriages and the girder?—That might be done by getting the guard’s van knocked off.

15,662. If the other girders fell intact it would be

at least a remarkable coincidence of this particular coincidence of this particular portion of the lattice girder is broken and torn about?—It would depend upon the nature of the belt of the river where the girder fell. If it fell upon a high part of the river it would knock the van.

15,663. But it would not necessarily turn and twist about individual lattices?—Not necessarily, but the lattices, so far as I could see, were very much knocked about by the dynamite and by the lifting operations.

15,664. Supposing that the second-class carriage was so that its wind

ward pair of wheels were raised clear of the rail, and the carriage was poised upon the two leeward wheels, and tilted over until the front corner of the roof came in contact with the lattice. would not that, in your judgment, in all probability turn the carriage off the line?—I hardly think it, because the carriage is on the side of the bridge and all the other carriage in front of it would knock the van.

15,665. Take the case of a railway carriage running along balanced on two wheels, like Inflödian on his high rope, with a tremendous wind blowing, is it in a condition of very stable equilibrium?—I should say not.

15,666. Does it occur to you, under those circumstances, that if you gave it a sharp blow on the front corner of the roof, with something on the leeward of it, it would be very apt to turn it off the rails?—No. I do not think it would.

15,667. Still it would it would be very easy to poise and keep it in equilibrium in its proper place?—If the framing of the carriage had struck any part of the girder above the level of the carriage, it might have been thrown off the rails, not the body.

15,668. You do not think that any blow that you could give upon the body of a carriage poised upon two wheels would turn it off the rails?—I think not.

15,669. Would it have any tendency to lift the front corner of the roof?—I do not think it would.

15,670. The framing of the carriage is not what you may call a strong thing to resist a blow.

15,671. Still a blow is a blow, and a blow has a certain momentum, whatever its effect may be in regard to destroying the body of the carriage?—Yes, but the carriage would very soon fall to pieces with the blow.

15,672. Have you put to you several suggestions; can you account for the cause of a collision?—No. I cannot think of any that would.

15,673. Suppose it appears that the guard’s van was brought by the diver resting on the end of the second-class carriage, that is to say, above it?—It is a likely enough thing to happen in a collision where cases in contact were.

15,674. Does it not suggest collision to your mind?—In fact, the question is answered, for it seems that it has suggested collision to your mind?—You must take into account that the guard’s van is very much heavier than the second-class carriage, and would be very likely to knock it into it and knock it about a good deal.

15,675. I have no way between the guard’s van and the second-class carriage in front of it, unless the velocity of the second-class carriage is arrested before that of the guard’s van?—No, the second-class carriage must of necessity have been arrested.

15,676. First?—By some means or other what means we cannot tell— the guard’s van being much heavier than the second-class carriage would, no doubt, pitch into it.

15,677. But the guard’s van was not going faster than the second-class carriage?—The second-class carriage, or the frames of the second-class carriage, were broken on each side, showing that something had gone into it, and pitched very violently against it.

15,678. I agree with you there, but just follow me. I want to lead you a little further. The two carriages were part of the train going with a certain indefinite velocity; there are facts that indicate to your mind, as they do to my mind, that the guard’s van has smacked into the second-class carriage?—I think it has; there is no doubt about it.

15,679. As I understand you, you agree with me that that necessarily involves that the speed of the second-class carriage has been somehow arrested before that of the guard’s van?—Yes, the guard’s van, being heavier, would go further.

15,680. It is not a question of one being heavier than the other, it is a question of speed; two things running at the same speed will not collide unless the one in front has its velocity reduced first, whether it be heavy or light in comparison with the one after it?

15,681. That is so. (Mr. Bidder.) That is a proposition nobody would dispute. (To the witness.) If you will follow me you will see that that does not bear upon the question that I am putting to you. You have two carriages moving with equal velocity, and you agree with me in thinking that the second class would knock the first the carriage in front has its velocity reduced, and the one in front must have been reduced, must it not?

15,682. Either reduced or arrested by something.

15,683. That something could only be one of two things, either the portion of the train in front of it, or some part of the bridge?—Yes, it would be I have no doubt either the one or the other.

15,684. Is there the slightest indication that it was the portion of the train in front of it?—No, I do not think you can possibly tell what took place.

15,685. Will you just look at this photograph of the end of the carriage next to the guard’s van (handing a photograph to the witness), you can see that it was either the portion of the train or it was the bridge.

15,686. That is so. (Mr. Bidder.) That is something or other.

15,687. I said also that it must have been either the one or the other—either the train or the girder.

15,688. (Colonel Yolland.) Or the falling?

15,689. (The Witness.) Well, we cannot tell; it is all conjecture, as I said before; there is nothing that I have seen on the ground that would lead me to suppose that any of the carriages had gone off the line and struck the girder. I have not seen anything to lead me to that conclusion.

15,690. (Mr. Bidder.) Do you draw any conclusion from the fact that those two carriages are found on their sides, and all the other carriages are upright?—I think that the whole of the carriages were found upright.

15,691. You must take the evidence, if you please; you must not think about it. There is distinct evidence that those two carriages were lying upon their side, and all the rest were upright?—I may be wrong there, but that is how I have seen them.

15,692. All the other carriages in front were found upright, standing in their proper position, and these were lying on their sides?—As I have seen them they were upright.

15,693. Did you see them under water?—No.

15,694. You must take it for me, that as found under water the other carriages were all upright, and these were lying on their sides; does that suggest to you anything?—No. I cannot say that it does.
You said if it turned out that that girder was all destroyed, it would not impress your mind any better or worse. I have not seen that part of the girder.

But supposing that was so?—I have not seen it.

I say, suppose that is so—supposing we actually find marks upon the lattice of the girder of the roof of the bridge, would that affect your mind at all?—I have not seen that part of the girder.

But supposing that was so?—I have not seen it.

I say, suppose that is so—supposing we actually find marks upon the lattice of the girder of the roof of the bridge, would that affect your mind?—The marks might have been made by the falling of the bridge—yes, you cannot really tell—it is all conjecture.

Even that would not raise any suggestion in your mind?—It is all conjecture, you cannot possibly tell.

You cannot suggest anything that would carry any conviction into your mind?—No. You must bear this in mind, that I am here to give information, if I can, and I am willing to do it, but I cannot go beyond what I have seen and what I believe.

Examined by Mr. Macrory.

You told my friend, Mr. Trayner, in your last answer, that you concurred generally with the opinions' that were expressed by Mr. Cochrane yesterday?—Yes.

With regard to the quality of the materials, did you examine the materials of which the bridge was composed?—Yes, on the first occasion when I visited the fallen piers I took a sample from every pier, from the remains that I found, a sample of the iron, and in almost every case I found the iron of very good quality.

Examined by Mr. Balfour.

You have had great experience of the use of cast-iron in columns in such structures as this actually?—Yes, I have.

And in the case of structures which have stood as long as 27 years?—Yes, some of them.

What is your opinion as to the fitness of cast-iron columns for such structures, if well designed and well executed?—Of course, I have the utmost confidence in the use of cast-iron.

And that is founded not only upon theoretical opinion, but upon large and long practical experience?—Yes.

You have told us something about the height of this bridge, and also about the height of other, which you have been concerned with. Would it be very much more easy to construct such a bridge as this, perfectly stable and perfectly safe, if it were made of a less height?—No doubt, the less height, he easier the construction and the safer.

If, for instance, it was lowered by such a measure as 20 or 30 feet, would that render the work of reconstruction very easy and safe?—It would make it its easier and safer.

There is one question I should like to ask Mr. Brunlces upon another matter. (To the witness.) If you found a vertical crack in any of these columns would that be a matter of any very great moment in affecting the stability of the bridge, in your opinion?—No; there are vertical cracks in some of the columns on the north side.

It is, that if such a thing would occur, and which you could hardly help occurring in any case?—I have not had it occurring in any case, excepting in the Solway, and there out of about nearly 4,000 columns I had 33 cracked.

What did you do with them?—Hooped them; those that came immediately under the rails I had replaced—taken out and renewed—but those that were only used as rakers I had hoops put round.

Hoops put round and then screwed up?—Yes.

Re-examined by Mr. Trayner.

In the Solway, did you understand you to say that those columns were to bear weight?—Yes.

(The Commissioner.) In the Solway they were replaced?—The cracked ones.

I understood you to say that those that came immediately under the rails I had replaced—taken out and renewed—but those that were only used as rakers I had hoops put round.

And the others were hooped?—Those that were rakers were hooped.

You think that cast-iron columns form a satisfactory pier for a structure of this kind, and that the safety and stability of the structure would be increased by their being less in height than the old columns?—Yes, I think so.

I should like to ask you this: Would you prefer in the matter of safety the cast-iron columns to brick piers? (Mr. Balfour.) How does that arise out of my cross-examination? (Mr. Trayner.) It arises out of Mr. Balfour's last question.

I avoided discussing the question of brick piers.

My friend, Mr. Balfour, asked Mr. Brunlces if the use of iron columns was a matter he approved of, and with a view to the future report of the Commissioners upon the future state of the bridge, I am merely asking him to say now whether he prefers brick to iron. If the Court will determine whether or not the question may be asked we need not discuss it further. If the Court does not wish the question to be put I will withdraw it, but if the Court thinks it material with a view to their report as to the future bridge, I will put it, if not, I do not care to put it.

There is no doubt that this question might have been put in the examination-in-chief, and if the question is put, Mr. Balfour will have a right to put other questions upon it.

The Court will quite understand that I do not in the least desire to go into this question unless the Court thinks it is desirable: to have this gentleman's opinion upon the value of a brick structure, as against iron columns, with a view to the future bridge.

It is not a mere question upon the admission of this particular evidence. Of course, if you think it is a matter that should be gone into, you will undoubtedly give Mr. Trayner permission to ask the question, and allow me to ask questions upon it; but it raises a further and a wider question in this way: I am here representing Sir Thomas Bouch, and my learned friend beside me represents the contractors, who are here to defend the question whether this bridge. Sir Thomas Bouch is responsible for the design of the bridge and the supervision of the structure. He has, according to his lights and experience, designed a bridge in a certain way and the bridge has fallen. Now, of course, it seems to me that the question really is whether that thing as it was was sufficient for its purpose, and what are the causes of its failure; but to open up a question of this kind and how that bridge might have been built and what other different designs might have been made is a question without limit, and to my mind I doubt whether it is a question that I ought to be called upon to meet. There is no limit to the suggestions that may be made of alternatives. Assume, for a moment that brick piers would have been, strong enough, or that a suspension bridge would have been strong enough, or you may go further still and say, assuming that a tunnel underneath the Tay would have been sufficient, what has that to do with the question whether this bridge as it was destroyed and as it has been built was sufficient and ample for the purpose, and what are the causes of its failure.

The Court, on a previous occasion, permitted me to go into a question which bore upon the report of the Court might feel bound to make with reference to the reconstruction of the bridge. I do not want to go into any argument upon it, but if it will be in the memory of the Court, as originally designed by Sir Thomas Bouch, the piers were to be brick piers. My learned friend, Mr. Balfour, says it is not a question that he need go into. Perhaps in that he is right, and probably the course that Mr. Balfour will follow, in the event of my being allowed to put the question, will be that he will not go into
put to the witness, with a view of aiding the Court, for what the Court have to get at is not only what was the cause, if there was anything wrong, but what is best for the future if the bridge is to have a future, and it was with a view of aiding the Court in its report upon that matter that I put the question, but I say again at once that if the Court does not desire to have any information upon that particular matter then I do not want to press the question.

(The Commissioner.) I understand, think we need trouble you any further. I think we have already decided this question. Our report in this case cannot be limited simply to the question whether or not this bridge was right in construction, or whether the workmanship was good. We must see whether or not, if it is put up again in the same form, it will be a safter proper bridge; and the public will not be satisfied, unless we express some opinion upon the remainder of the bridge as it now stands, and certainly I think a very serious responsibility would rest upon us if we were entirely silent with respect to the remainder which still remains, and a bridge was thereupon to be reconstructed upon that portion which still remains, and the bridge were to fall down in two months afterwards. Moreover, if this question is not to be gone into I should have stopped Mr. Balloun in the question he asked, namely, whether or not the bridge were stronger it it was built 20 or 30 feet lower. I mean to say that that seems to me to be quite the same question as that which Mr. Trayer is putting, and I think that although we should not go into the question as to whether it would be better to make a tunnel, as Mr. Bidder has suggested, underneath the river, we really must inquire into all the circumstances connected with the reconstruction of this bridge, therefore, I think Mr. Trayer may proceed with his question.

15,612. (Mr. Trayer to the witness.) As a question of safety, would you prefer cast-iron columns to brick piers?—All other things being equal I would prefer the cast-iron as I would brick, and in saying that I would add that although some of the columns have cracked in the Solway Viaduct, at the same time, I have now found out a perfect cure against any cracking, and that is by introducing small holes in the columns, a little above low water, so as to let the water out in frosty weather.

15,613. (Mr. Walter.) Are the columns hollow?—Yes, they are hollow.

15,614. (The Commissioner.) They are not filled with cement?—They are not filled with anything at all.

15,615. And you say that is a perfect cure?—Yes; I have had no splitting since I did that. In the heavy frost of 1874 and 1875 83 columns altogether were split, but since I have taken that precaution none have gone.

15,617. I suppose the mortar does steady the piers; it does not give any strength to them but it steadies the weight?—It gives strength too; there is strength in concrete, a good deal of strength. You get the binding effect of all of the weight, and you get the benefit of the strength in the iron which goes in.

15,618. If you will look at that paper which you have before you of the Tay Bridge you will observe that the four carriages which are immediately before the second-class carriage are now on their wheels standing upright; the girder has been thrown upon the rails. No doubt.

15,619. Consequently those carriages must have turned round?—They have turned up and righted themselves just because the air and the water would float them up?—The wheels and axles acted as ballast.

15,620. And they would rise up against the girder?—With doubt they would.

15,621. So that you would not be very much surprised to find that the top of those carriages might have come in contact with the girder?—I noticed on the top of the girder that the carriage had struck the top of the girder.

15,622. Quite the top of the girder which now lies up on its side?—Just so.

15,623. Then I suppose if the train got off the line before the bridge was disturbed, the top of the engine and tender the girder is described as being very much broken?—You will see immediately above the engine and tender the words are written, "the girder is very much broken here"?—Yes, I see that.

15,625. You observe that in red ink, about the engine altogether, there is "81 feet of the girder lifted and taken; the top portion can only be seen at low water, and is very much broken"; that is quite another aspect of the train altogether; is it not?—Yes.

15,626. The top part that would be the western girder, would it not?—It would.

15,627. And not the eastern girder with which it is supposed that the after part of the train came into collision?—That is so.

15,628. You said that a vertical crack would not be of very great importance; it would be of great importance, I suppose, if it were weight, and was not hooped?—No doubt; the cure for it is to hoop it.

15,629. But if it were left unhooped it would be a very serious thing, would it not?—It might get worse.

15,630. I suppose if one of these 18-inch columns on the outside had given way it would have come down?—No doubt.

15,631. And if it was cracked it would have a great tendency to give way?—It might grow worse by degrees, or it might suddenly fall.

(Mr. Bidder.) Supposing it was cracked from end to end, how would that weaken it with regard to tensile strength?

(The Commissioner.) It is the crushing strength I was speaking of, not the tensile strength.

(Mr. Bidder.) I will take the crushing strength, if you please; whichever you like.

15,632. (The Commissioner to the witness.) Now how would it weaken it?—No doubt it would weaken it, but not to a very great extent, I think, not under a crushing strain.

15,633. The crack would have a tendency to open, would it not?—With a very great weight, no doubt, it would.

15,634. With a great pressure?—Yes.

15,635. Therefore it would be weaker?—Yes.

15,637. And less able to resist a great pressure?—No doubt it would.

15,638. Will you turn to Mr. Law's paper, to which you were referred by Mr. Bidder, at page 28. Mr. Law altered that 32-69 lbs. to 34 lbs. I am referring to the middle of the page under lead B: "Pressure of wind required to overturn the pier with the train, but without any holding-down bolts"?—Yes, I see that.

15,639. You said you took Mr. Law's figures, and you found them correct, that is to say, you found that 34 lbs. would be about correct, not the 40 lbs.?—In the rough calculation I made it 40 lbs.

15,640. Without holding-down bolts?—Without holding-down bolts, without bolts at all.

15,641. I will ask you upon that this—in building that bridge in the Brazils, with a height of 170 feet, I think you said it did enter into your calculation whether or not it would be subjected to a wind pressure?—It entered into my mind but not into the calculations.

15,642. Because the prevailing wind was in the same direction as the structure?—The wind came end on to the structure.

15,643. That is the ordinary wind?—The ordinary wind from the sea coming up the valley, and it being a narrow valley there was no possibility of the wind coming across the viaduct.

15,644. But supposing it had come across, then, I suppose you would have taken the wind pressure into calculation?—No doubt I should.

15,645. Can you tell me as an engineer of large experience, what you would have allowed?—No, I cannot. I can hardly say; it is quite possible that
TAY BRIDGE DISASTER

J. Brunlees.
28 April 1890.

I might have taken 30 lbs. to the foot. I think so.
That is with the knowledge that I had at that time.
I am speaking of 20 years ago.

15,646. Allowing 30 lbs. to the pressure of wind, would it then be sufficient to upset it, would you have built the bridge just of that strength that it would just upset with 31 lbs.?—No.

15,647. What margin would you have given if it would have overturned with a wind pressure of 31 lbs.?—Probably 4 or 5 times that.

15,648. That is to say would have allowed a pressure of something like 120 lbs. we will suppose?
That is quite possible.

15,649. Yes; would certainly not have built your bridge so that it would have upset with an extra pound?—No, certainly not.

(Mr. Bidder.) Will you be kind enough to ask him whether he would not have allowed a factor, or margin of strength, in the iron.

(The witnesses.) That would have come into the calculation; the iron would have been made of a strength of four or five times.

15,650. You would have got your factor there?—Yes.
15,651. You would not have made the allowance twice over?—No.
The calculation would resolve itself ultimately into the strength of the iron.

15,652. (The Commissioner.) Do you say that 40 lbs., without holding-down bolts, would not, in your opinion, have upset the structure, but that it would require four or five times 40 lbs. to upset it?
No; in this case would upset the pier?

15,653. Even allowing for the strength of the iron?
Taking the iron as it is.

(Mr. Bidder.) I think there is some misunderstanding or mistake here, because Mr. Brunlees has not gone into the tensile strength of the iron, and therefore he cannot have taken the iron as it is.

(The Commissioner.) We must take his answer as he gives it.

(Mr. Bidder.)—Forgive me. I am sure that you will not take an answer that he has given under a mistake.
I am quite sure that Mr. Brunlees did not mean to say that he had taken the tensile strength of the iron as it is because he said he had taken it as a whole.

15,654. (The Commissioner.) Do you say that the lateral strain of 40 lbs. upon that, without holding down bolts, would be sufficient to overturn it?
That is so.

15,655. Whatever the tensile strain and whatever the height of the iron had been?—Yes.

15,656. Without holding down bolts?—Without holding down bolts.

15,657. 40 lbs. would have been quite sufficient?
Yes.

15,658. Assuming there were no holding down bolts, you would say that 40 lbs. would have upset the structure?—Yes.

An adjournment took place in consequence of Colonel Yolland being required to give evidence in one of the courts.

On re-assembling—

(Mr. Bidder.) There is one question which I should like to ask the witnesses.

(The Commissioner.) Very well, put it to him.

15,660. (Mr. Bidder.) Assuming that the strongest wind you would have to contend with would be 30 lbs. to the foot would you allow the margin which you would get by a multiple of 5, that is to say 150 lbs. to the foot—what you would do, as I understand, would be to take the wind pressure that the bridge had to meet, and you would have a margin by limiting the strains in your iron?—The strains upon the iron I take at 5 tons.

15,661. Knowing that iron would not break to about 30?—About 20 tons.

(Mr. Bidder.) The question we were asking you about was this—quite apart from the tensile strength of the iron, what strength of wind would be sufficient to overturn the pier, assuming the pier to have been rigid, and assuming the erection to have been well constructed, when would there be a tensile strain brought upon the bottom of the western bars and a compressive strain upon the eastern bars— at 40 lbs., did not you say?—Yes, I said 40 lbs.

15,663. Quite independently of the tensile strength, without holding down bolts?—Yes.

15,664. And therefore in that 40 lbs. you did not make allowance for a margin of 4 or 5 times?—Not in that case.

15,665. You assume that 40 lbs. pressure of wind would overturn the pier?—Yes.

15,666. Do you concur with Mr. Cochrane in thinking that the flange ought to have been faced over the whole surface?—I do not think I do quite. If I get a surface faced to the extent of the thickness of the iron in the column then I am satisfied.

15,667. You do not object to the channel inside?—I do not.

15,668. Do you object to the lugs being cast on the columns?—After a certain height of the structure I object to lugs; for low structures I do not object to lugs. The strain upon them is light so long as the structure is low, but when the structure becomes high, then I object to them.

15,669. Do you object also to the bolts in the lugs being cast so that the sides are not parallel?—They are much better bored, in my opinion.

15,670. If they are cast ought to beried out?—They ought to be bored out.

15,671. You agree with Mr. Cochrane in all that?

15,672. I think I understood you to say that you still are of opinion that the train did not have the rails till the bridge began to give way?—I think not.

15,673. You saw nothing to show that it did?—I saw nothing to show that it did.

15,674. Even if there was any indication upon the lattice of either of the carriages having come into collision with it, you would not draw the inference that they must necessarily have come into collision with it before the bridge gave way?—It is impossible to say—it is all conjecture.

15,675. You mentioned just now that taking a pressure of 40 lbs. of wind, you would take a multiple of four of that as a factor of safety; when you say that, I presume it applies to strains upon the metal?—It applies to strains upon the metal.

15,677. Taking 20 tons to the inch, 10 tons would be the limit of elasticity of the metal?—Yes.

15,678. And you take five tons, so as to provide against any imperfection that there may be in the metal?—Yes.

15,679. That is the Board of Trade rule?—I believe it is.

15,680. When you come to the question of overturning a pier, it is not a question of strain upon the ironwork, but it is a question of the width of the base, is it not?—No doubt.

15,681. Are we to understand that if you were called upon to reconstruct this bridge you would make the base of these piers four times as much as they are now?—Certainly, not so much as that.

15,682. Do you consider that the width of the base as it stands would be sufficient if there were strong holding down bolts?—I hardly like to give an opinion upon that point without a little more consideration. I think I should like a little more base.

15,683. (The Commissioner.) Do you mean in length?—In width.

(Mr. Balfour.) A little more base for the same height.

15,684. (Mr. Barlow.) Do you know Crumlin Viaduct?—Yes.

15,685. Do you know what wind pressure it would take to turn that over, assuming it had no holding down bolts?—No.

15,686. Do you know what the height of that Crumlin Viaduct is?—I believe 100 feet.

15,687. It is 195 feet?—200 feet I should have said.

15,688. You mentioned having made a viaduct in
Mr. Truesdell. 22.4. It is very different in height from the frame. That is not entirely different — structure to this. The cylinders there are filled with concrete; concrete adds to the stiffness.

15,729. What is the width of the base of the pier of the Severn Bridge? — It would be 30 feet at the bottom being 45 feet? — Yes, that might be varied a little by making the rakers stronger and having less base. You might have less base and have the rakers stronger.

15,714. Would you have two rakers or one raker outside? — Always two.

15,715. You think that is a defect in having only one raker outside? — It would have been better with two, I think.

15,716. (Mr. Barlow.) Your raker did not bear weight unless it was weight produced by lateral action? — Yes, I never put cast iron to take an indirect strain, if I can possibly avoid it.

15,717. What was the span of your viaduct in Brazil, which you said was 170 feet high? — Sixty-six feet.

15,718. And how many piers had you to form your piers? — Eight columns.

15,719. (The Commissioner.) Were the four minor ones under the railway? — Yes.

15,720. And the others were rakers? — The other four were rakers.

15,721. (Mr. Bidder.) In that case you were unlimited as regards base; you were on dry land? — Yes, as I have said there are cases where you could strengthen the raker with a narrower base.

15,722. In that case you had no object in contracting your base? — No.

15,723. (The Commissioner.) It was a viaduct over dry ground? — There was a stream through the valley, but the piers were all on dry ground.

15,724. (Mr. Bidder.) Will you look at that drawing (handing Mr. Low's drawing to the witness), would that be a sort of pier that would satisfy your engineer? — It is two cylindrical piers of brickwork 18 inches thick, with a diameter of 15 feet at the bottom, and 9 feet at the top, would that commend itself to your judgment as a proper sort of pier for a structure of this width and height, with ten spans of 245 feet exposed to these winds? — I do not know where slabs of 15 feet are to be got.

15,725. (Mr. Barlow.) Would you not commit yourself to that? — I do not think it would be so strong as the iron.

15,726. (The Commissioner.) Instead of stone slabs you might have iron discs of 16 feet, might you not? — That might be done. Then that would be very expensive. Then, when you came to the top of the piers, the 18-inch brickwork would have to carry all the superstructure. Without going into any calculation, I have no hesitation in saying that the brickwork would crush, at least I think so.

15,727. (Mr. Barlow.) Do you know the Severn Bridge? — Yes.

15,728. Do you know the height of that bridge as compared with the height of this? — I do not think it is very different in height; I think it is about the same. That is an entirely different structure to this. The cylinders there are filled with concrete; concrete adds to the stiffness.

15,729. What is the width of the base of the piers of the Severn Bridge? — It would be 50 feet at the bottom.

15,730. It would be 30 feet where this is 30 feet? — Yes.

15,731. It narrows after that? — Yes.

(Mr. Webster.) I have been asked if I would bring up the contract drawings. I have them here, and they are a complete set at originally signed. I have identified the numbers; they are the drawings signed by both parties.

(Mr. Trayner.) I do not think the Court need
take notice of them, unless we want to refer to them.

(Mr. Webster.) Duplicates have been already before you. Then there is one other matter which I should like to mention to the Court. You will remember that the witness said in his evidence that at the top of one of the 18-inch columns, where the drawings would show that there should be eight rivets, he believed there had been only four put in. You will remember the questions put to him and the answers he gave with regard to the suggestion as to that being or not the cause of this disaster. I am not very anxious about it, because in the view which I shall have to present to you it will be immaterial, but that being on the evidence I should like to call your attention to it. I was not at Dundee, nor were the contractors represented at Dundee, but I observe that Mr. Macbeath, who was the inspector of the Tay Bridge during the time when these bolts would have been put in, was called before you at Dundee, and I find that no suggestion was made to him as to the absence of those four bolts. I do not know whether the Court would like to put any questions to Mr. Macbeath as to the absence of those four bolts.

(The Commissioner.) Is Mr. Macbeath here? (Mr. Webster.) I do not know. (Mr. Balfour.) I have told he is here. (Mr. Webster.) I only call the attention of the Court to the fact that this question was not put to Mr. Macbeath. His evidence is at page 122. (The Commissioner.) Is there much turn upon this? (Mr. Trayner.) I should not like to offer an opinion. If the Court think it necessary to call Mr. Macbeath he can be ordered to be here.

Mr. Macbeath called again.

15,732. From what you said at Dundee, it appears that you examined these columns?—Yes.

15,733. Did you remember the bolts that fastened the Ledger to the 18-inch columns?—Yes.

15,736. Do you remember how many there were to be in the top of each of the 18-inch columns?—Eight.

15,737. As far as you know, can you say one way or the other whether those eight bolts were put in in every case?—As far as I could see, they were.

15,738. After the work was finished, did you see any vacant hole where a rivet-bolt should have gone in the top of any one of the 18-inch columns?—No.

Examined by Mr. Bidder.

15,739. During the time that you were engaged as inspector of the bridge did you go through the different columns of the bridge with a view of ascertaining whether the tie-bars were properly tightened up and the struts?—Yes.

15,740. Can you give us any idea how long you were occupied upon that work?—About two months previous upon the Government surveyor going over the work, and three months afterwards.

15,741. Two months before General Hutchinson's inspection and three months afterwards?—Yes.

15,742. During those five months that you employed in doing?—In examining the work, tightening up the gibs and coppers that were loose in any way—examining the bolts.

15,743. Were you acting under the instructions of Sir Thomas Bouch?—Yes.

15,744. Did you overhaul the piers of the bridge from end to end during those five months?—Yes.

15,745. Did you examine every strut and every tie-bar?—Every strut and every tie-bar from bottom to top.

15,746. Every strut and every tie-bar everywhere?—Yes.

15,747. The latter three months the contractors had left the work altogether; the work was delivered over, and you were acting under Sir Thomas Bouch?—Yes.

15,748. Can you say whether you made them all tight?—Yes.

15,749. (The Commissioner.) Are you satisfied that the ties and the struts were drawn up tight in every case?—Yes.

15,750. (Mr. Bidder.) Yes, we may say up to the beginning of June 1878. (To the witness.) I believe you reported the progress of your inspection from time to time to Sir Thomas Bouch?—Yes. I did not report it direct to Sir Thomas Bouch; it was reported through Mr. Noble.

Examined by Mr. Trayner.

15,751. How many of the tie-bars did you tighten up from first to last in the five months?—I could not exactly say how many; there were so many of them.

15,752. So many tightened up?—No, there were not very many tightened up.

15,753. Can you give me an idea of how many were tightened up; were there hundreds or tens of them?—There might be, perhaps, two in one pier and there might be ten in another.

15,754. Did you find them loose to the same extent on every pier from end to end?—No.
MINUTES OF EVIDENCE.

15,755. Were there many piers in which there were tie-bars loose, or only a few piers?—Very few.

15,756. Can you give me an idea of the total number of ties that were tightened?—On some of the piers there were none.

15,757. That being so, you would be able the more readily to answer my question. Give me an idea of how many altogether were tightened up?—That I could not give you exactly. There were so many of them.

15,758. How did you tighten them?—By driving in the cotters.

15,759. You had cases where cotters had given from where they had been originally left when put in at the construction?—Yes.

15,760. Can you recollect what was the greatest extent to which any of those cotters had given?—As far as I could see they might go a quarter of an inch.

15,761. Did a cotter leave the position in which it had been left at the construction to the extent of a quarter of an inch laterly?—Oh, no.

15,762. Was there any case in which it had come out of its place to that extent?—Oh, no.

15,763. What was the alteration in the position of the cotters that you remedied. (Mr. Bidder.) No did not say that there was any alteration in the position of the cotters.

15,764. (Mr. Trayner.) Had the cotters at all moved from the position in which they had been left?—Oh, no.

15,765. What was it you went to tighten up?—The broken bar.

15,766. Did you drive the cotter farther house than it had been driven home originally?—Yes.

15,767. To what extent do you think in the largest case did you drive the cotter farther home than it had been originally driven?—I perhaps would not move it but just with a little jar: the least tap in the world would do it.

15,768. What was the greatest extent to which you drove the cotter farther in?—I never actually measured it.

15,769. Did you drive both the cotters?—Yes.

15,770. They were setting in opposite directions, the heads were, the cotters; the different heads were on different sides?—Yes.

15,771. Were they all opened out at the wedge end, the thin end, by that time?—Yes.

15,772. At the time, you went to them were they holding by the spread out end?—I do not understand you.

15,773. You drive in the cotter and it is spread out?—Yes.

15,774. When you went to these cotters that had to be tightened up, was the cotter holding by this spread out end; was it catching?—Yes.

15,775. Then if you drove it farther in would not you have to do anything to the plate in which it was placed against?—No.

15,776. Did you put anything in besides the cotter in any place, any packing pieces—No.

15,777. Did you notice whether any of the bars were loose enough to shatter at a train went past at that time?—I do not understand what you mean by "shatter."

15,778. Shake and make a noise?—You must say so (shaking his hand); it must have been loose altogether before it was so.

15,779. You went over these and tightened them up; were there any of them so loose that a passing train would make: those two bars shake against each other?—No.

15,780. (The Commissioner.) You did not see any instance of that sort?—Not so loose as that; they would move like that (describing the motion with his hand).

15,781. Did you hear one bar upon the other at all as a train was passing?—No, I felt them as I was climbing up, as far as I could feel going up the piers with trains passing, I never felt the vibration in the piers.

15,782. You went up from tier to tier of each column?—Yes.

15,783. Did you climb up by those cross bracings?—Yes.

15,784. Did you go over the whole of the bridge in the course of that five months?—Yes.

15,785. Was it once that you went over the bridge in that five months, or more frequently than once?—I was several times over it.

15,786. In that five months they were still in progress of being put up?—Two months out of the five. (Mr. Webster.) The last three months were after the Government inspection.

15,787. (Mr. Trayner.) During the last three months did you go over the bridge more than once?—No.

15,788. Did you go over the whole of the bridge in that three months?—Yes.

15,789. And you went, as I understand, for the purpose of seeing that the tie-bars were right?—Yes, that the bolts and everything were complete.

15,790. (Mr. Bidder.) I understand you tried each tie-bar: you examined each tie-bar in turn, and hammered up the cotter until it was tight?—Yes.

15,791. You did not find any sign of a cotter having changed its position, but you found that some of the tie-bars were slack?—No slack. I will not say that they were slack, they were just loose.

15,792. Can you tell by your hammer when you drive the cotter when the bar is tight up?—Yes.

15,793. Does it give a different sound?—Quite a different sound altogether when it is tight.

15,794. You tried in every case, and in some cases you could move the cotter, and in some cases you could not?—Yes.

15,795. You were employed and engaged upon that special work during that time in examining and carefully overhauling the whole of the bridge to see that everything was right?—Yes.

15,796. And you reported through Mr. Noble to Sir Thomas Bouch?—Yes.

15,797. And you did your duty?—Yes.

15,798. (The Commissioner.) Mr. Noble was asked, "Did you discover whether any of the iron-work of the bridge was getting unstable or loose?" His answer was, "In taking these soundings that I have spoken of, I noticed or heard a chattering of the "bars." During the five months you were there, and during the three months subsequent to the inspection, you observed and you heard no chattering at all?—No, unless it was with the wind; the wind would chatter these bars, though they were as tight as a fiddle-string.

15,799. If they were as tight as a fiddle-string, they would not require to be tightened up?—No.

15,800. Then the chattering would be of no importance at all?—No, unless they were really loose.

15,801. But Mr. Noble goes on to say that when the went to examine them, he found they were loose; I suppose they had become loose since you had left?—They must have done.

15,802. Either by the action of the wind or the action of the trains?—Yes.

15,803. But you are quite sure that when you left there were none of those bars that were chattering?—No.

15,804. None of them?—No.

15,805. They were all tightened up?—They were all tightened up.

15,806. That was up to the beginning of June?—The latter end of May.
Examined by Mr. Traunter.

15,807. Your present residence is in Lisbon?—Yes.
15,808. And you have come from there to attend this inquiry?—I have.
15,809. At the request of the railway company?—Yes.
15,810. You were engaged on the Tay Bridge contract first under the employment of Messrs. De Bercue and Company?—Yes.
15,811. And you remained there after the contract passed out of their hands into the hands of Messrs. Hopkins, Gilkes, and Company?—I did.
15,812. When did you leave the bridge?—I left the bridge officially, that is to say, as far as the contractors were concerned, at the end of 1877. I think it was the 28th of December, either the 28th or the 29th.
15,813. Did you remain after that at the bridge in any other body's employment than the contractors?—No.
15,814. Is it the case that your connexion with the bridge ceased in December 1877?—It did.
15,815. (The Commissioner.) You had nothing to do with the bridge after that officially?—No.
15,816. (Mr. Traunter.) While you were there, which would be over a period of some years, just kindly tell me, as shortly as you can, what was your position?—I was engaged at the Tay Bridge works in the first instance when Messrs. De Bercue and Company had the contract as Mr. Groth's assistant.
15,817. And after the contract came into the hands of Messrs. Hopkins, Gilkes, and Company, did you remain in the same position?—In the same position.
15,818. (The Commissioner.) All along you were Mr. Groth's assistant?—Yes.
15,819. (Mr. Traunter.) Will you tell me further whether there was any particular part of the work you were more immediately connected with; for example, had you anything to do with the Worsmit Foundry?—I had not.
15,820. You were chiefly, I suppose, connected with the construction of the bridge?—Precisely so.
15,821. Was it part of your duty to inspect the masonic iron, the columns and other things as they came to the ground?—No.
15,822. You were simply to put them in position according to the plan?—Yes.
15,823. Who was there on behalf of the engineers, Sir Thomas Bouch, while you were acting with Mr. Groth?—There were several of Sir Thomas Bouch's employees at various times.
15,824. Was there no permanent engineer?—Yes, Mr. Paterson.
15,825. (Mr. Traunter.) That is the gentleman we have heard is unwell. (To the witness.) I have no doubt you gave your best attention to the performance of the work that was immediately under your charge?—Certainly I did.
15,826. Were the different parts of the bridge erected, so far as you saw and knew of them, conformation to the drawings that were provided?—Yes.
15,827. Is there anything you would like to say in addition?—There were some alterations.
15,828. Whether according to the original design, or according to the altered design, when a thing was to be done—It was done by you, according to the plan that had then been agreed on?—In every case so far as I know.
15,829. And, so far as you know, well done?—Yes.

Examined by Mr. Bidder.

15,830. Sir Thomas Bouch had assistants whose duty it was to inspect the erection of the bridge, had he not. Mr. Paterson was the chief, and there were others subordinate?—Mr. Paterson, I understand, was the resident engineer.
15,831. (The Commissioner.) For the railway company?—I cannot say who employed Mr. Paterson.

(Mr. Balfour.) You are quite right, Mr. Bidder.

(Mr. Bidder.) He was paid by Sir Thomas Bouch, and he was his representative.

(Mr. Balfour.) Yes.

15,832. (Mr. Bidder.) And there were other subordinates, besides?—Yes, there were two.
15,833. Were they regular in their inspection and careful in their inspection of the work as it proceeded?—It is difficult for me to answer that question, because this work was two miles in length, and very often I was engaged for some hours in one spot, and therefore they might be very busy a mile and a half off for all I could tell.
15,834. Latterly Mr. Macoboth had particularly to supervise the work you were doing?—He had; he was appointed inspector with a view of going over all the bridge.
15,835. You came more particularly into contact with him?—Latterly.
15,836. Was he careful in doing his duty and seeing that the work was properly done by you and those under you?—Yes, I thought he was rather extravagant in some particulars.
15,837. If he erred you think he erred on the side of over-carefulness and over-strictness?—That was my opinion.

Examined by Mr. Webster.

15,838. Do you remember the holding-down bolts, that is, the bolts that come up through the stonework, and go into the base pieces?—Yes.
15,839. Do you remember the way they were put in or fastened down?—They were put through the two upper courses of stone in the large piers, and there were four of those bolts to each of the bases.
15,840. You remember that?—Yes.
15,841. And do you remember how the bolts were left with regard to level ultimately?—They should have been all exactly of the same level, and I always endeavoured that that should be the case, but in one or two cases there was a slight difference in level which was not observed at the time they were cemented.
15,842. How long as a rule did the bolts remain after they had been cemented, before the base plates were put on and they were screwed up?—On some of the piers the base plates were put on the bolts before they were cemented that was latterly, but formerly I used templates for adjusting the bolts, in the usual way.
15,843. How long had the cement been put in in the cases where they were screwed up, before they came to be screwed up?—I should say on the average it would be at least a month or six weeks.
15,844. Do you remember any one bolt that stood up particularly high when the cementing had been finished?—Yes, there was one bolt, if not two. I think there were two.
15,845. Did you see any of the nuts put on and screwed down upon the top of the base pieces on the bolts that came up through them?—Latterly I did, but I did not see them all put on.
15,846. Did you in any instance see a bolt drawn up through its hole through the cement in the process of screwing up, or any fracture of the stone or anything of that kind?—No.
15,847. Do you believe that such a thing occurred?—I do not believe it would have been possible.
15,848. Looking at the way in which they were put in, in cement, and the way the nuts were screwed down, do you think it would have been possible for such a thing to have taken place?—Certainly not.
15,834. Was it ever necessary to put in extra washers in consequence of a bolt rising up?—Yes.

15,835. I am speaking of a bolt being drawn up?—The bolt was not drawn up.

15,851. I will ask you about the gibes and cotters; did you see the gibes and cotters that were used in the ties?—I did.

15,852. You left the bridge at the end of 1877. I did not quite understand whether you left the place altogether then, or whether you were about?—I was residing in Newport. I did not leave the neighbourhood for a week or a fortnight afterwards. I left the bridge as far as I was professionally concerned under contractors Messrs. Hopkins, Gilkes, and Company, on the 27th or 29th of December.

15,853. Had you any duty to do, or did you do anything with reference to the bridge during that fortnight?—No.

15,854. We will take it that your connexion with the bridge terminated on the 29th of December then. Did you see anything being done to the gibes and cotters during the last three months you were there?—More especially, during the last two months that I was in charge of the works. Mr. Grothe left early in the month of November, and Mr. Gilkes requested me to stay and see that every detail was finished about the bridge from top to bottom.

(The Commissioner.) When did Mr. Grothe leave?—15,835. (Mr. Webster.) I think it was the last day in the November statement. To the best of your recollection you think it was about the beginning of November 1877?—Yes.

15,856. You say that Mr. Gilkes, after Mr. Grothe left, asked you to assume the duties of going through the details to see that they were in order?—Yes.

15,857. Did you do so?—I did.

15,858. Will you tell us what you did, or what you saw done during those last two months, particularly with reference to the gibes and cotters?—When Mr. Macbeth went over the piers he discovered a few things that required, as he considered, to be altered.

15,859. Were you with him, did you see it yourself, did you call your attention to it afterwards?—Sometimes I was with him, and sometimes he went on his own account.

15,860. Sometimes you were with him, and sometimes it was a communication made to you by Mr. Macbeth after he had been over?—Yes, there was something to do on nearly all the piers: for instance, in some cases the bolts had two washers instead of one.

15,861. What bolts?—The bolts bolting the flanges and the columns together.

15,862. The column bolts?—Yes, and there were one or two of those horizontal tie-bars which were not screwed tight, and in some cases one or two of them had to be removed and more thread put on the bolt, in order to screw up the nut.

15,863. Was anything done with the gibes and cotters?—They were all gone over.

15,864. How were they gone over?—There were six or eight, and in some cases ten men put on each pier, and they had to continue working at that pier till Mr. Macbeth had gone over it carefully and stated that the work was completely finished.

15,865. What did they actually do to the coter to see if it was tight?—They would strike it with the hammer.

15,866. The examination would be by a stroke of the hammer?—Yes.

15,867. And it might give, or might not give, according to its degree of tightness?—They could tell pretty well.

15,868. I want you to follow me: you strike the coter with a hammer, and if it does not give it is passed, but if it is loose it will be driven further in?—Yes.

15,869. During the last two months did you go over, or see gone over, all the piers under the high part?—Yes.

15,870. As far as you believe, and from what you saw, I ask you distinctly this: Were there any loose cotters when you left the bridge in that high part?—No; to my knowledge there was not a single loose cotter.

15,871. (Mr. Harlow.) Were they all put in at that time?—I believe so.

15,872. (Mr. Webster.) Was the bridge supposed to be finished, as far as the contractor was concerned, before you left?—Yes.

15,873. It would have been part of your duty, under Mr. Macbeth's inspection, to see that cotters were put in if they had been absent?—It would.

15,874. I will ask you a question which was put by Court to the last witness. You have heard the expression used in this room that there was a chattering of the bars together, or some sound coming from the piers resembling rattling?—Yes.

15,875. Were trains passing over the bridge during that last two months?—Yes, ballast trains.

15,876. How frequently?—As frequently, I think, as four trains a day or five trains a day.

15,877. Did you ever hear during the time, before you left the bridge, anything that you would understand by a chattering of any parts of the ironwork?—Yes.

15,878. When was that?—Before the bars were perfectly tightened.

15,879. What would you describe it as?—I would rather you would convey to the Court what you think the noise?—Any of these tie-bars formed by two flat bars of iron are naturally, a little out of line, because they cross each other, and if they were loose, and if there was any vibration it would make one bar strike against the other, consequently you would have the noise of one piece of iron hitting against the other.

15,880. Do you know the bolts that fasten the top of the 18-inch columns to the L-girders?—I have seen those bolts in their place.

15,881. Was it part of your duty to examine and see whether those bolts were put in before leaving the bridge?—It was my duty to examine everything.

15,882. Can you tell me whether or not you did go over the bridge in order to see whether those bolts, as well as the other parts of the bridge, were in proper order?—I do not think I went outside and examined every bolt here, but I know that I was outside four or five of those L-girders with Mr. Macbeth, and one or two of the bolts were taken out that he objected to, and replaced by others.

15,883. Do you know whether Mr. Macbeth inspected those very bolts, pier by pier, to see whether they were properly put in?—I know he inspected some of them. I believe he inspected all.

15,884. He called your attention to instances in which some of the bolts in his judgment were not satisfactory?—Yes.

15,885. Were those bolts taken out and renewed?—Yes.

15,886. To the best of your belief, were there any of the 18-inch columns when you left with only four bolts instead of eight?—Not to my knowledge.

15,887. I am speaking of the L-girders?—Yes.

15,888. Do you think there could be only four of those bolts on the top of any one of those columns without it coming to your notice?—I do not think so, because I will not say that I saw every bolt, but I saw most of them. Mr. Macbeth, of course, was inspecting them.

15,889. You say that was a matter which you knew from the work you had to do, and Mr. Macbeth was also inspecting?—Yes.

After a short adjournment.

15,890. (Mr. Webster.) When we adjourned I had been talking about the gibes and cotters: do you remember the slots in the tie-bars?—Yes.

15,891. Do you know where they were made?—
The greater part of them were made at Middlesbrough.

15,892. Can you tell me whether the slots in the tie-bars were properly and regularly punched, or were they irregular?—Those that came from Middlesbrough I have often seen at the works, and they appeared to be well made.

15,893. Could you tell how they had been punched, whether with a slotting machine or not?—No, the sides were smooth, that is all I know.

15,894. There was a swing with a rough surface produced, in Court once or twice, did you see it?—I did.

15,895. In your judgment, had that rough surface any effect upon the holding or the security of the cotter or not?—There would be no strain sideways against the cotter, the strain would be applied at the end.

15,896. With regard to the channel iron, you have already said, with reference to my previous questions, that it had been your duty to, and that in fact you did examine the bridges during the last two months of your time there; had you to inspect the channel irons, and how they were with reference to the legs?—I had to inspect the work as it was then erected, to see that it was properly finished.

15,897. Are you able to tell the Court whether the channel irons had been properly screwed up?—The units were properly screwed up.

15,898. Certainly, otherwise it would not be properly finished. I understand you to say that you did in fact inspect the channel irons to see whether they were properly screwed up?—Yes.

15,899. Do you know the spot and facet?—Yes.

15,900. Did you see the erection of all the columns in the high girders?—No.

15,901. Do you remember which you did see erected?—I have seen a large number of columns go out from the jetty because I used to order them to be sent out as they were required.

15,902. Do you to this day with the erection of the column one on another?—Not in the case of the large piers.

15,903. Did you not inspect the work until the column was put upon the one below it?—I had not to inspect it, but I very often saw them.

15,904. I will not ask you as to matters which would not come within your regular duty. I think that is all I have to ask you.

( Mr. Dalby.) I have no questions to put to the witness.

Re-examined by Mr. Trayner.

15,905. There was a plate between the L-girder and the top of the column, was there not?—Yes, there was, a connecting plate.

15,906. Did I rightly understand you to say that these three things, the angle girders, the plate, and the columns were fastened together by a bolt which passed through the three?—Yes.

15,907. Now, the bolt-holes in the 18-inch column, I understand, were all cast?—I believe they were.

15,908. How were the holes in the plate made?—They could only be punched or drilled.

15,909. Do you know how they were done?—They were done, I feel almost certain, at Middlesbrough. I did not see them made.

15,910. But you saw them; can you form an opinion as to whether they were punched or drilled?—In that case I should imagine that they were punched.

15,911. How was the corresponding hole in the L-girder made?—That would, I think, be punched off.

15,912. I want to know whether in all cases you have found these three holes correspond exactly so as to permit of the bolt being put in and fastened up without any alteration being made in any of the three holes?—The bolts, I believe, were all in before I personally inspected any of them at the later stage. I have mentioned that one or two bolts were replaced, and that is all I can say.

15,913. Can you answer this question: in any of the high girders were any of these three holes in the different groups of them in a position not parallel or coincident with each other?—If the holes were not true, the bolts could not be put in.

15,914. Take the plate, for example—was there any alteration made in the hole in any of the plates to admit of the bolt being put in?—Not by my orders.

15,915. But within your knowledge?—Not to my knowledge.

15,916. Would you have permitted the extension or enlargement of the hole in the plate for the purpose of getting the bolt in, if you had known of it?—That would depend upon the extent of the alteration required; it might have required a slight amount of enlarging out.

15,917. In riving it out I suppose the alteration of the hole would have been a regular alteration in the circumference of the hole?—If it were rimed out, one of the holes would be a little out.

15,918. Did you see any of the bolts in the sides of which or the inner circumference of which was very irregular, being produced by just beating the hole and breaking it so as to be a little larger than it was when originally made?—No.

15,919. I wish you would not go away until I show you a plate that I have sent for, if you think it very good.

15,920. Your examination was made, Mr. Dalby, was it?—I understand, an examination on the part of the railway company's engineer before the work was taken off the hands of the contractors?—Yes, it was.

15,921. And I have no doubt that you and Mr. Macbeth made that examination very carefully?—As far as I was concerned I made it carefully, and I believe as far as he was concerned he did the same.

15,922. What I did not quite understand was this: did you examine yourself every place to see whether or not these tie-bars were correctly fastened?—No, I could not do so.

15,923. Then was the amount of your examination this: that where there was anything objected to, your attention was called to it, and you saw it?—No; the men that I had working there got their instructions, of course, from me and from the inspector, and where he saw that anything was wrong that had been passed and overlooked by the men he would then report that to me, and I would see that it was put right.

15,924. There were a number of men at each pier who were under your orders to do for Mr. Macbeth anything that Mr. Macbeth desired?—Precisely.

15,925. And if anything was done by them not quite correctly, or if anything was left undone that Mr. Macbeth had desired, that particular matter was brought to your notice?—It was.

15,926. And it was only in that case that your personal inspection was devoted to the work?—Quite so.

15,927. (The Commissioner.) You have not told us whether you are a civil engineer?—No.

15,928. And you examined this work on behalf of the contractors, and Mr. Macbeth on behalf of Sir Thomas Bouch?—It was not exactly that way. I was left in charge of the works after Mr. Grilie left them, before the entire completion of the works, and the men were under my orders.

15,929. But Mr. Macbeth was employed on behalf of Sir Thomas Bouch, I suppose?—Yes.

15,930. I think you told us that you were chiefly employed in the erection of this structure, were you not?—My personal attention, as I might say, was more devoted to the lower part of the work throughout, to this level (describing the same); the foundations and the floating of the caissons, and the floating of the girders, and other matters.

15,931. I think you stated that you had nothing whatever to do with the erection of these high piers?—No, I had nothing to do with their erection.

15,932. You did not see them erected?—Yes, I used to be frequently about in order to give directions.

15,933. But not to inspect it?—Not to inspect it.

15,934. Who did so, then?—There were several
people, but most of the work in the high girders was put together under the inspection of Mr. William Delpratt.

15,935. But there were different persons employed?—There were foremen, of course, but I thought you referred to the responsible assistants.

15,936. I did?—Mr. William Delpratt executed most of the work, and his brother had something to do with it as well.

15,937. When you left it, I think you said you saw that the ties—which came from Middle-rough were properly punched?—I did not see whether they were punched or slotted with a slotting machine.

15,938. At any rate, they were not properly cut?—Yes, I have inspected them several times.

15,939. Did you draw a distinction between those which came from Middle-rough and the others?—There were a few of these slung-bars that were made at the works.

15,940. Were those properly punched?—I think they were properly punched, but I think they were not as well finished as those that came from Middle-rough. We had no slotting machine at the works.

15,941. And therefore they were not so well done as those that came from Middle-rough?—Quite so.

15,942. You said that before you tightened it up you did have a chattering of the ties, did you not?—Yes.

15,943. But when you left it in December you heard none?—I never heard of these bars vibrating, or chattering, as it is called, after they were properly tightened. I have been down in different parts of the pier when trains have been passing, and my attention was particularly called to that, because I had heard them chattering on a previous occasion.

15,944. There we may take it that when you left at the end of December, 1877, you being responsible for the work, there was, so far as you know, no chattering of the ties and no loosening of them?—That is so.

15,945. And if any loosening did take place, it must have taken place subsequently to that?—I presume so.

15,946. (Colonel Yolland.) Were any packing pieces made use of for tightening up the tie-bars before you left?—Not to my knowledge.

15,947. (Mr. Harlow.) You heard, perhaps, the evidence given here that more than 100 packing pieces were used afterwards?—Yes, I did.

15,948. Therefore there must have been a considerable loosening after the work left your hands?—That is so.

15,949. To what do you attribute that loosening?—Something must have yielded.

15,950. In which direction; laterally?—In the direction in which the bar was placed.

15,951. What movement of the pier would be necessary to produce that; would it have to move over at the top?—If it moved over at the top of course it would bring strain on all the ties that were in the line of the force.

15,952. Was there any way in which those forces could have been brought into operation sufficient to elongate these bars, so as to allow the packing pieces to be stuffed in?—No, I think there must have been a horizontal movement of the column, decidedly.

15,953. (The Commissioner.) I think you are now engaged with Mr. Grithe?—No, I am engaged by the Royal Railway Company in Portugal.

15,954. In what capacity?—As an engineer in charge of some works, the construction of which they are at present undertaking.

15,955. A railway?—In connexion with a railway that is a deep water pier for loading ships at.

15,956. At Lisbon?—Yes, at Lisbon, and the reconstruction of some bridges on the line.

15,957. (Mr. Webster.) Iron bridges?—Yes, iron bridges.

The witness withdrew.

Major-General Charles Scrope Hutchinson, R.E., sworn.

Examin'd by Mr. Traxner.

15,958. You received instructions from the Board of Trade to inspect the Tay Bridge in the month of February, 1877, did you not?—Yes.

15,959. You went to the Tay Bridge accordingly, and you were there on the 25th, 26th, and 27th days of that month?—I was.

15,960. And you made a Report to the Board of Trade which is dated, Newcastle, 5th March 1878?—Yes.

(The Commissioner.) Will you put that in, so that it may appear upon the notes as an annex to General Hutchinson's evidence.

The Report was handed in, and is as follows:—

"North British Railway, Tay Bridge.

"Newcastle-on-Tyne.

"Sir,

"I have the honour to report, for the information of the Board of Trade, that in compliance with the instructions contained in your minute of the 15th ultimo, I have inspected the Tay Bridge, forming a portion of the Tay Bridge Railway of the North British system.

"The Tay Bridge Railway, in conjunction with the Perth Bridge Railway, for which an Act of Parliament has been obtained, will shorten the existing route between Edinburgh and Dundee (via Stirling) by 28 miles; and by means of these two railways and a new railway about to be constructed between Arbroath and Montrose, the journey between Edinburgh and Aberdeen will be reduced by 23 miles.

"In consequence of the magnitude of this bridge, of which T. Bouch, Esq., M.I.C.E., is the engineer, it was considered desirable to have it inspected before the lines north and south of it were ready for traffic."

The inspection of the bridge accordingly took place on the 25th, 26th, and 27th ultimo, the weather, fortunately, being favourable.

The Tay Bridge carries a single line of rail, in 3,430 yards in length, and consists of 85 spans of the following descriptions:

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In addition to which there are adjoining the north end of the bridge:

1 span of 100 feet bowstring girders.
3 spans of 29 plate girders.
In the 15 spans Act of 145 feet and with the 100 feet bowstring girders wrought-iron cross girders have been employed; for the other spans, cross girders of timber.
In the 13 spans of 227 feet and upwards, and in the bowstring girders spans the roadway is carried on the hottest portions of the girders; in the other spans on the tops of the girders.

The girders are arranged in continuous groups, generally of 4, 5, or 6 each, with proper provision for expansion.

3 A 3
They are supported on piers of varied construction, the foundation in all cases being formed of iron cylinders, lined with brickwork and concrete; counting from the south end.

Piers 1 to 14 are entirely of brick in cement.

Piers 15 to 26 are brick for 5 feet above high-water mark, finished with a stone belting, upon which are carried groups of cast-iron columns bridged together.

Piers 27 to 77 consist of groups of cast-iron cylinders brazed together, starting from the cylinders and encased in brickwork to a height of 30 feet above high-water mark.

Piers 78 and 79 are cast-iron cylinders throughout, finished with concrete.

Piers 80 to 84 are cast-iron columns.

Piers 85 to 90 are of brick in cement.

The greatest height from the level of the rails to high-water mark on the side is 92 feet. This occurs at the centre of the large space, whereas towards the north side there is a sharply falling gradient of 1 in 74, with a gentle fall towards the south end; at each end of the bridge there are curves of 20 chains radius.

The permanent way consists of double-headed rails, filled in, 24 feet, weighing 75 lbs. to the yard secured by oak keys in cast-iron chair, weighing 80 lbs. each, fixed at 3 feet average intervals to longitudinal timbers 17 inches wide, and varying in depth between 7 and 14 inches. There are 4 spikes in each chair. Throughout the length of the bridge each rail is provided with a guard rail.

The deflections of the bridge consist of 3-inch planking covered with a waterproof composition.

A substantial hand-rail is carried along each side of the bridge.

The deflections of the bridge are as follows:

- The 15 and 25 boxes varied between 13 inch and 12.1 inch.
- Various other variations are noted, with a general trend towards stability.

These results are, in my opinion, to be looked upon as satisfactory.

The lateral oscillation, as observed by the theodolite with the engines running over at speed, was very slight, and the structure altogether showed great stiffness.

The dimensions of the various parts of the girders have been carefully worked out, and the iron has in no case been submitted to a greater strain than 15 tons per square inch.

Upon a careful examination of the brickwork and masonry, they appear to be of a substantial character, and to be showing no signs of settlement. The ironwork has been well put together, both in the columns and girders.

The following are the only requirements that came under my notice:

1. Transoms and ties for preserving the gauge should be provided between the longitudinals.
2. The fireproof covering of the floor requires repair in several places.
3. Some slack places in the rails require adjusting.
4. The clearance as much as possible the expansion of the girders in hot weather, I should strongly recommend their being painted white.

It will not be desirable that trains should run over the bridge at a high rate of speed, and I would suggest 20 miles an hour as a limit which should not be exceeded.

A certificate will have, of course, to be given that the single line shall be worked with the train staff and block system.

Very careful attention will be required to ascertain from time to time that no scouring action is taking place in the foundations, particularly in the case of those piers which are subjected to a strong current.

When again visiting the spot I should wish, if possible, to have an opportunity of observing the effects of high wind when a train of carriages is running over the bridge.

Subject to the above requirements and remarks, I see no reason why, so soon as the adjoining railways are completed and inspected, the Board of Trade should object to the railway on the Tay Bridge being used for passenger traffic.

I have, &c.

C. S. Hutchinson.

The Secretary.

Railway Department.

Board of Trade.

15,964. (Mr. Trayner.) Would you tell me what in a general way were the instructions that you gave or what was the purpose for which you went to the bridge?—I was sent to the bridge to inspect it previously to the railways connected with the bridge being opened, because being a work of considerable magnitude, it was thought desirable, the bridge itself being completed, to get the inspection over before the railways north and south adjoining it were completed sufficiently to carry passengers.

15,962. The railways north and south of it being part of the system of which the bridge formed part?—Yes. Then, on receiving the instructions from the Board of Trade to inspect the bridge, I, at the same time, or shortly afterwards, received the drawings and the specifications accompanying the application of the company for the inspection, and my first duty was to examine those drawings.

15,963. Were those the drawings of Sir Thomas Bouch, the designer of the bridge, or did they include also the drawings under the specifications for the manufacture of the ironwork?—So far as I have seen, the drawings handed in this morning I think were copies of the contract drawings. I am not, of course, positive, but they were, more or less, no doubt, these are the drawings that were generally got copies of the working drawings furnished to the contractor. I examined those drawings as carefully as time and circumstances permitted. I gave them probably an extra thorough examination in consequence of the magnitude of the work, and satisfied myself that in all essential particulars the details showed sufficient strength theoretically.

15,964. Having done that you went and visited the erection itself?—Having done that, I went to Dundee. My memory may be a little defective on one or two points, but I believe that what I first did was to make a general examination of the whole of the bridge above and below (by water) I forget whether or not we went on to the bridge, but I think I did. I cannot quite remember that. Then, having made that general inspection of the whole of the structure, my next work was to test the bridge for deflection and oscillation. I do not know whether you wish me to enter into the description of it.

15,965. Did you do it by loading the bridge?—By loading the bridge with six engines, which rather more than covered one of the 245 feet spans. Each girders were tested separately, step by step, beginning, I think, at the south end and looking towards the north. I think that was the order of proceeding; then, when we came to the high girders, they were tested by placing upon them one engine, two engines, three engines, four engines, five engines, and six engines at a time, running them over in groups and altogether at various speeds.

15,966. As you have mentioned speeds, what was the highest speed that they ran across at?—I should
think probably 40 miles an hour, but I, of course, can only speak as to what it was probably. Then, that having been done, I, as well as I could, observed what lateral oscillation the high girders might have by stationsing myself some distance off. I think, on the one or more of the girders, and I think also on one of the tops of the columns, and observing what amount of lateral oscillation there might be with the engine running over it at speed. The result was very satisfactory. It seemed almost as if there were a very slight divergence from the perception of the sensation that I think that was on the third day, as far as I remember, under the bridge in a small steam launch, with a boat, and I floundered on a good many of the pillars, and clung about the columns, and at the same time that I think the engines were again running over to enable me to see what amount of vibration there was, and which kind of behaviour, in fact, the columns presented. I observed nothing at all to give me an uncomfortable impression about the stability of the columns. There was a slight vibration in the tie-bars as the engines ran over, but nothing more than you will always find in every structure. There was nothing at all excessive, as far as my judgment was concerned at the time, and I am not able to do the attachment of all the different parts, taking here and there one. Of course I do not mean to say that I looked at each bolt in each pier that would have taken far more time than I had at my disposal.

15,957. Your examination of the part of the bridge that you have just spoken to was enough, in your judgment, then, and now, to satisfy your own mind, and to enable you to make the report that you did make?—It was. I observed no symptoms of weakness which, to my judgment, gave any reason to doubt the stability, the structure, of course, always presupposing that the materials of which it was constructed were good, and that the workmanship was good, and that it was properly maintained.

15,958. Given, the bridge of which you had the drawings, well constructed both as regards materials and workmanship, you were satisfied.

(The Commissioner.) He added one other thing, that the materials were good, the workmanship good, and that it was kept in a proper state of maintenance.

15,959. (Mr. Trayner.) That is quite so, Sir. (To the witness.) In the maintenance of it what do you include?—Seeing that the bolting together of the pier was maintained tightly, that the holes were properly lined, and that all the different tension rods and struts were kept in a proper state of tension or compression, as the case may be.

15,960. You know how these tie-bars are fastened with jibs and cotters?—Yes.

15,961. Is that a matter which, in your opinion, required careful attention after the bridge was opened?—I think so; certainly. Of course the object of putting the cotters in was to have the means of tightening up as slacknesses occurred.

15,962. In a bridge of that construction tied together in that way, did you anticipate that that would be a matter, receiving careful attention from those in charge?—Certainly, it seemed a very important point.

15,963. At the time you examined it, they were tight enough to satisfy you?—Yes, I observed no instances of any more slackness than you would naturally meet with in any large structure of the kind.

15,964. Would the action of the trains passing over the bridge naturally tend to loosen these cotter pins to some extent?—I have no doubt that it would; and especially the higher the speed the more shaking motion, so to speak, would be produced on the structure.

15,965. Had you that in your mind at all when you suggested the limit of 25 miles an hour as a limit which should not be exceeded?—I had that in my mind; that it was not a structure with a wide base, and that therefore it was very desirable to limit the action of passing trains to as great an extent as was reasonable: and I therefore thought it prudent to suggest low speed. Because, of course, the higher the speed or the higher the momentum brought to bear upon the columns, the more tendency there would be to give them a rocking.

15,976. But even with that limit of speed uniformly observed, would there have been from natural action the probable result that I have pointed at of loosening the cotters?—There must have been a certain amount of vibration and oscillation introduced into the columns, and hence a tendency to loosen all the different joints of the structure.

15,977. Would the probability of that loosening be enhanced by the high winds blowing at one time from the east and at another time from the west?—Doubtless they would also tend to produce a rocking motion.

15,978. If you had found any of these cotters in a condition which would have admitted of the insertion of a packing-piece, would you have passed that as being sufficiently tight to warrant the bridge being used?—I should have called attention to it if I had seen it, and requested that the bar in question should be tightened or replaced by a proper one, but the presence of two or three loose bars, had I seen them, would not have led me to think that the bridge was an imperfect bridge, and could not be passed.

15,979. But supposing that you multiply two or three into 100?—It would have very much depended upon the amount of looseness which I found. So much depends upon what you see when you examine a structure.

15,980. It was necessary, I suppose, to the satisfying of your mind, that all these ties should, when passed by you, be as tight as they could be?—Certainly.

15,981. At the end of your Report there is this paragraph:—"When again visiting the spot I should wish, if possible, to have an opportunity of observing the effects of high wind when a train of carriages is running over the bridge." What induced you to make that observation, and what future opportunity had you in your mind at the time?—During the time that I was in the north of Scotland, at the end of February, it so happened that there was a high wind blowing, and I was, therefore, anxious in order to see what additional or what perceptible effect a high wind on a train of carriages might have had, to have another opportunity of observing that; but, unfortunately, I only got an opportunity of getting an inspection on the 8th February, when I might have had that opportunity, I was taken seriously ill, and the final inspection of the railways north and south of the bridge was abandoned upon another officer.

15,982. You anticipated when you were there in February that you would be back again to inspect the lines north and south—Yes, and then I meant to have spent some little time in Dundee with the idea of getting an opportunity of observing the effect of a gale upon the bridge.

15,983. That opportunity you did not get on account of your illness, and the consequent substitution of another officer to do that particular duty?—Quite so.

15,984. I will put this merely formal question: Are the statements in your report, so far as they are statements of facts, accurate?—So far as I am aware, I believe they are.

Examined by Mr. Bidder.

15,985. I think Sir Thomas Bouch was with you; was he not, during your inspection?—He was.

15,986. And I believe every facility was afforded to you to examine the bridge and the drawings?—Oh dear, yes, every facility.

15,987. Everything was done that you desired?—Yes, there was no failure in any respect.
You examined the drawings of the bridge as regards its design?—Yes.

And I think I gather that in your judgment, assuming it to be properly constructed, and the workmanship to be good, the design was unsatisfactory?—Yes, I would put it in this way: that the design was not unsatisfactory; there was nothing in the design, in my judgment, to warrant me in objecting in any way to it. Of course no one can say that a broader base would not have been a desirable thing.

The broader the base, of course, the stronger the bridge?—Yes.

But, as I understand you, so far as the design was concerned, the judgment that you came to was that it was sufficient for the purposes of the bridge?—It was sufficient for the purposes of the bridge, according to my judgment.

Of course you are quite aware that this was a case where you were not, so to speak, unrestricted as regards breadth of base?—Yes, I was informed of the reason of the adoption of this form of pier.

Did those reasons strike you as being satisfactory?—As far as I remember, I think they did; but of course it was a mere opinion. It was not part of my duty to go into that.

I think it was explained to you why that particular form of pier had been adopted that was adopted?—Yes, it was.

Now, with regard to the details of construction, I believe you took every precaution that you could at the time that you were underneath the bridge when the trains were passing over, by clamping the columns and by various experiments, to ascertain what amount of vibration or jar there was?—Yes, in a good many of them, not in all. I forget exactly what I did. I think I climbed up and held on to the columns and the braces when the engines were going over.

I think I am not wrong in saying that the conclusion you came to was that it was a remarkably stiff structure?—Yes, I think that was my impression at the time, that it was much stiffer than I had anticipated it would be.

Then may I take it that examining the condition and workmanship of the bridge as carefully and as minutely as a person in your position could do, the result and the conclusion arrived at in your mind were satisfactory?—Yes, that is so.

So far as you, with all the means in your power, could test and examine them, the workmanship of the bridge and the construction were good?—Yes, I should say so, in my judgment.

I think you explained amongst other things that you placed the theodolite at the top of one pier, with the view of observing the lateral oscillation?—I forget now where I placed the theodolite. I think it was on the stonework, and I observed what oscillation there might be at the top of some of the higher girders and piers.

Now more particularly with reference to those tie-bars; at the time of your inspection did they appear to be carefully tightened up?—So far as I saw.

I understand that your experience would lead you to expect in structures of this character that the use of the pier and the vibration of passing trains would in time slacken the tie-bars to some extent?—It would have that tendency, I should expect.

That is, what you would expect as an ordinary consequence of the use of the bridge?—Yes.

And if that slackening was watched, and the tie-bars were tightened up whenever any slackness appeared, you would not be apprehensive of any serious consequences, would you?—No, one would think that the structure would remain as it was at first, if those points were properly attended to.

It has been suggested to you that, if 100 tie-bars required packing, that would indicate looseness or inferiority in the construction of the bridge; I do not know whether you know how many tie-bars there were; I think there were something between eighty and ninety on every one of those piers; eighty-four being, I believe, the precise number?—I do not know. If at the period of my inspection I had found out or known that during the short time the trains had been running over the bridge, 100 of those tie-bars had required packing-pieces, it would have made me very sceptical about the ultimate stability of the bridge.

I think there are something like 5,000, and 100 out of 5,000 is only 2 per cent.?—No, but still it would have been unsatisfactory to my mind had I been aware of it.

At the time that you inspected the bridge there had only been ballast trains running for two months?—Yes.

But you would expect that with heavy gales and constant traffic more of the tie-bars would show slackness?—I should expect, of course, that there would be slackness occurring from the effect of the trains and the wind.

You would not be surprised, would you, if a year's work of the bridge in the first instance had shown slackness in about one hundred of those tie-bars?—It would depend upon the amount of slackness that was produced. A year is a very short time in the life of a bridge. I can very well understand the covers wanting tightening continually; but when you come to the introduction of packing pieces, it is a different matter.

If it was ¼ of an inch, would that be a very large amount?—I do not know that ¼ of an inch would be a very large amount, but ¼ of an inch would not require packing pieces, I apprehend; I do not know what the thickness of those packing pieces was.

I do not know whether you are able to answer this question. In considering structures of this kind have you adopted any rule or practice as to what wind pressure you ought to be prepared to provide for?—No, we have had no data whatever to go upon with regard to wind pressure.

So far as you know is there any guide on the subject known to engineers?—I have never heard of any number being adopted except in the case of the Forth Bridge, and there I have understood that upon the authority of the Astronomer Royal it was considered that 10 lbs. distributed over a large surface was the amount that might reasonably be expected in this country. But it has never been to my knowledge customary hitherto to take wind pressure into account in calculating the parts of bridges of this description.

According to your previous knowledge, and with all that you know on the subject, apart from anything that we have learnt from this actual disaster, what would you say would be necessary to provide for? I put it to you whether providing for 20 lbs. of wind pressure to the foot of one of the towers, or 20 lbs. to the very top, were you not?—Yes, I did not remember it before you mentioned it.

For the purpose of examining the condition of the ties from top to bottom?—Yes, and up here (pointing to the model).
16,017. (The Commissioner.) Under one of the high girders.—Yes.

16,018. (Mr. Webster.) You said that you did not recollect the exact speed at which the engines were run over the bridge, but you have no doubt that it was about 40 miles per hour?—Yes.

16,019. Do you remember when four engines were coupled, the contractor, Mr. Gilkes, suggested to you that they should run over the bridge at a speed of 40 miles an hour, and his timing it and finding that it was 52 seconds through the high girders?—I have no doubt that that is correct. I have a dim recollection of something of the kind.

16,020. You remember that they went over at high speed?—Yes.

16,021. And you also remember that you stood upon the pier inside the girders whilst engines were sent backwards and forwards?—Yes.

Examined by Mr. Balfour.

16,022. You said, in answer to Mr. Bidder, that any such defect as he described should have been observed and certain things done?—Yes.

16,023. Is it the duty of the engineer in charge of the bridge to give instructions for the observation of any such things as you have described, and then to direct what should be done upon them? (Mr. Bidder.) That is hardly a question for General Hutchinson.

(Mr. Balfour.) If the Court thinks so, I will not press it.

(The Commissioner.) I think you have got all that you want. General Hutchinson has stated that he thinks this required constant supervision; and we shall undoubtedly have other evidence as to the person by whom it should be done, because General Hutchinson only goes there to inspect the bridge.

(Mr. Balfour.) I am quite satisfied, sir.

Re-examined by Mr. Taynel.

16,024. You have told us that the use of the bridge and its subjection to lateral wind pressure on either side would produce slackness. Would the use of the bridge, and the vibration thereby occasioned, as well as the looming which would result from the lateral pressure that I have alluded to, if not observed and guarded against, result in slackness as, in your opinion, to threaten the stability of the bridge, that being used by constant traffic and being subjected to wind pressure sometimes on the east and sometimes on the west? If that slackness was not observed and remedied, but was allowed to go on, would it result in time in such a slackness as to threaten the stability of the structure?—I have no doubt it might if it was allowed to proceed to a sufficient extent.

16,025. If it were neglected for a long enough time, that looming would result in such a condition of the bridge as to make it unstable?—It would tend to take away from the idea of the pier, which is that it should be a solid structure.

16,026. And rigid?—And rigid, and it would of course tend to divide it into parts as it were.

16,027. If the slackness commenced, the slackness being possible, it was just a question of how long it was neglected, how long the bridge stood?—I wanted to get the precise facts from the Court what I have not yet got linked to this evidence (although it may have been), and that is with regard to the effect of the wind pressure upon girders. Supposing, for instance, that these five girders were really one girder 1,200 feet long, so that you may look upon it theoretically as one girder. Then, assuming (which, I think, may be assumed) that the wind in those parts acts in gusts and points; and that a point of wind—a high gust—takes the middle of the girder, or a certain part of the surface of the girder, it would have its impact distributed throughout the whole of the continuous girder, and its full force would not be felt upon this pier, and upon that (poking to the model) supporting the immediate bay upon which the thrust of the wind came. Of course, it would be a very difficult calculation to say what extent a high gust of wind of 40 or 50 lbs. to the foot would have to be reduced so as to arrive at its force on each of the pieces supporting the five bays.

16,028. (The Commissioner.) That would of course depend upon the width of the pier?—Quite so, but from what we know about the wind, or from what I have understood about the wind, even if you took a girder 245 feet long, you would hardly get a gust so long as that girder would be. Much less, therefore, would any gust of 40 or 50 lbs. to the foot extend with the same force over 1,200 or 1,000 feet.

16,029. Not talking of this country, have you ever heard of avenues of a considerable width being cut through the woods in America, the wind having pretty nearly the same force for a width of nearly a quarter of a mile?—No, I did not know that; that was the case. I have not heard of that, but I have seen the records of storms. What was in my mind was the diagrams of storms occurring in this country; where apparently you have the wind not acting along a long length of surface with the same force throughout that surface.

16,030. Those records are from an anemometer, are they not?—Yes, I suppose so.

16,031. They are only local?—Quite so, but I presume it is from some reasoning of that sort that the Astronomer Royal visited some time back that he thought that over a large surface the pressure would not extend beyond 10 lbs.

16,032. But that is merely assuming that a gust of wind has a pressure of a very limited extent, say of a few feet, then no doubt that force would be distributed along the whole length of the connected girders?—Of course it would be modified by circumstances.

16,033. (Mr. Bidder.) I understand General Hutchinson to go a little further than that, and to express an opinion that that was the condition of things;—Yes, I am assuming, of course, that the wind acts in points. Then I wish farther to say that that would be the state of things with no train upon the girders. If you assume a train to be upon the girder, and that a gust of wind comes, why, when the train in the middle of this girder, again the force of that gust upon the train would have to be distributed throughout the whole length of the continuous girders in order to get the pressure on the piers resulting from that gust. It is a difficult problem, but still I think it is fair to take it into account, and not to consider that any one pier would have to bear the full thrust of any particular point of the gust.

16,034. (The Commissioner.) When were these plans sent to you for inspection?—I cannot tell you exactly; some short time before I went down to inspect.

16,035. Would it be on the 13th of February?—It would certainly have been after that. We, as a rule, get the plans shortly after getting the order to inspect.

16,036. And that was the first you saw of the plans of this bridge?—Any of the detailed plans. I had been connected with the bridge before with regard to determining the height of the bridge.

16,037. But not the workmanship?—Not the workmanship.

16,038. Nor the construction?—Nor the construction; it was merely determining the height of the girders above high-water.

16,039. When you went down there it was all completed and painted and everything?—Everything done.

16,040. You could only see it, if I may say so, superficially?—That was all.

16,041. You could not test, I suppose, whether or not the bolts were sufficient?—No.

16,042. Nor whether the bolt-holes were of proper construction?—No, one could only judge by outside
appearances. If one had had any reason, of course, to suppose that anything was wrong—
16,043. Then you might have taken a tie-bar out and examined it?—Yes.
16,044. But that would not have been a portion of your duty?—No.
16,045. Therefore, when you said that you examined the attachment of the parts in their different places, you then mean so far as you could see it externally?—Yes, just as I could see this model.
16,046. You have stated that, having regard to the fact that these pier had, in your opinion, a narrow base for the height, and therefore would be liable, I suppose, to that rocking motion. You thought it prudent that the speed of the trains should be limited?—Yes.
16,047. And accordingly you entered in your report: "It will not be desirable that trains should run over the bridge at a high rate of speed; and I would suggest 25 miles an hour as a limit which "should not be exceeded"?—Yes.
16,048. When you stated that the trains should not exceed a velocity of 25 miles an hour, did you mean a velocity of 25 miles an hour from cabin to cabin, or that that should be the extreme velocity at any part?—I meant a maximum velocity at any part of their journey.
16,049. You did not mean that the train would be at liberty to go at the rate of 25 miles an hour from the south cabin to the north cabin?—No; that would of course, allow of any speed being run in the centre of the bridge. You might have 60 miles an hour at that rate.
16,050. You meant that 25 miles an hour should be the extreme speed at any part of the structure?—Certainly, because the object was to restrain the speed to a low limit in the centre of the bridge, where otherwise it would tend to be high.
16,051. You said that you could quite understand the c otters requiring tightening; do the c otters work loose in a structure of this kind?—It is my opinion that they cannot fail to do so. In a structure of this kind, with a number of joints and parts about it, there must be a little yielding and giving and taking.
16,052. By the c otters?—That is my opinion, but I cannot speak practically.
16,053. At any rate it would be only a loosening such as would require a tap of a hammer upon the c otters to bring it tight again; is that your idea?—Quite so.
16,054. But if a packing piece was put in you would consider that that was a structural defect?—It would show that there was too much action going on.
16,055. If the ties got loose, I suppose the columns would get out of their position?—It would permit that action to begin.
16,056. And if that derangement of the structure was neglected, the same force would tend to increase it, I suppose?—So I should think.
16,057. So that ultimately it must bring the structure down?—As I have said before, I think instead of the pieces working as a solid thing, or equal to a solid thing, it would tend to break it up into parts.
16,058. We are you quite satisfied with this examination that you made of the bridge on the 25th, 26th, and 27th of February, finding it a stiff structure?—Yes.
16,059. You considered that it was fit to open at that time?—At that time it was fit to open, with the exception of some details.
16,060. But at the same time you did not intend, did you, that it should not be examined again by you?—I intended only to examine it in the sense of trying to see the effect upon the stiffness of the pier of a train with wind on the bridge.
16,061. To take an analogy, such as occurs to me at the present time, you gave it a certificate for a certain time, just as they do in steamers?
16,062. (Mr. Bidder.) I do not gather General Hutchinson to have said that?—No, that was not my idea. There would have been no other certificate given with regard to the bridge, unless I had found out anything very unsatisfactory, had I had an opportunity of observing the effect of wind upon a train.
16,063. (The Commissioner.) Did you think, looking to its construction, apart from the wind, that it would have been your duty to have examined it subsequently, after the lapse of six or eight months?—No, that was not in my mind at all.
16,064. You considered that it was quite strong enough for the purpose for which it was intended, apart from wind pressure?—Yes.
16,065. But for wind pressure you thought it was desirable to examine it again?—I should have liked to have had the opportunity to have done so.
16,066. (Mr. Bidder.) I did not understand General Hutchinson to say that it would have been desirable, but that he wished to take the opportunity when he was there for another purpose. He says in his report that it would be interesting to observe it?—I do not say that it would be "interesting," I said, "I should wish, if possible to have an opportunity of observing."
16,067. (The Commissioner.) And you would have done so I suppose?—I would have done so if I could.
16,068. You consider that it would have been proper?—Proper if the opportunity occurred; but I should not have thought myself justified, if such an opportunity had not occurred when I was at Dundee, in recommending a postponement of the opening of the line for the purpose.
16,069. You thought the bridge sufficiently strong for the purpose?—I did.
16,070. Did you make any calculations at all when those plans were given to you as to what force of wind would be sufficient to overturn the bridge?—No, I did not. I made no calculations as regards the wind.
16,071. How did you judge then of the stability of the bridge if you made no calculations?—As I have already stated, the subject of wind pressure never entered into the calculations that I made, and never had done, I believe, in, I will not say, civil engineer's calculations, but as far as I know it has never been hitherto taken into account.
16,072. Do you know whether it is so in America or in France?—I cannot say. I believe that in France they have some rules, but it has never been hitherto customary in this country, as far as I am aware, to consider this question, especially in an open structure like this. Had the girders been plate girders, it would, of course, have struck me naturally that one ought to take very much into the wind.
16,073. (Colonel Volland.) When you inspected the bridge on the 25th, 26th, and 27th of February, during those three days did you at any time hear any chattering of the tie-bars?—No, I do not remember hearing chattering; there would be a slight vibration as the train was passing over, but not actual chattering that I remember.
16,074. Did you or did you not observe at that time that any packing pieces whatever besides the jibs and c otters had been introduced?—No, I do not see any; but then I do not pretend to say that I went over each joint. In the observation that I was enabled to make I did not see any packing pieces.
16,075. (Mr. Birkett.) I understood you to say that you subjected the bridge to a very strong test for vertical weights?—Yes.
16,076. And you found it perfectly satisfactory in regard to all those tests?—Yes, I found it so.
16,077. With regard to what you said as to the c otters, do you understand correctly that you consider it possible that tremor produced by trains might shake the c otters loose?—Yes.
16,078. But you do not, I presume, consider it possible that the tremor produced by trains should extend the ties and give them a permanent set so as to permit of the insertion of a packing piece of a quarter
of an inch or three-eighths?—No, not the tremor. It might result from other causes.

16,079. From strong lateral action?—From strong lateral action tending to some action upon the flanges.

16,080. Assuming such a thing as that to be known, do you think that the person who knew it should have communicated that knowledge to Sir Thomas Bouch?—I think so, undoubtedly. It was a most important matter.

16,081. I think you say that there is no data whatever for wind pressure in this country?—None.

16,082. You referred to the Forth Bridge and the Astronomer Royal's estimate of 10 lbs., but he admitted that in gust the pressure went up to 40 lbs.?—Yes.

16,083. Are you aware that in the case of the Tay Bridge that was applied three times over, making 30 lbs.?—Yes.

16,084. With regard to the width of base, if everything was made strong and good with proper holding-down bolts and with very sufficient wind ties, do you think that width of base insufficient?—No, I think that insufficient if everything was thoroughly good and made as solid and substantial as possible. There would be, I should imagine, quite 60 lbs. or 70 lbs. of stability against lateral pressure, supposing those pier walls were up, and the holding-down bolts good, I have not made the calculation with regard to the holding-down bolts; I have made it with regard to the piers standing on their legs, and I make it something over 40 lbs., without taking in the holding-down bolts.

16,085. And up to 60 lbs., or between that and 70 lbs., to the square foot of surface generally, if holding-down bolts were used; is that so?—I have not taken that into account. That is merely supposition; but with regard to the stability of the pier standing upon its legs, apart from the holding-down bolts, it is, I think, something over 40 lbs.

16,086. (The Commissioner.) In the calculation you made before you visited it?—No, I made no calculation; it is what I have done since; and that, as I have already stated, ought, I think, fairly to be reduced to some extent (I will not say to what extent), in view of the stability of the girders; and if it can be established that the wind acts in points and not over the whole of a large surface laterally—

16,087. (Mr. Bidder.) You do not mean reduced, do you?—I mean that the effect of the pressure would be reduced.

16,088. The ultimate pressure would be increased?

16,089. There would be the same pressure absorbed by the whole girders, only the moment of the pressure upon any particular column would have to be arrived at according to a certain law.

16,090. (Mr. Tayler.) I asked Mr. Reeves to stay here to show him one of the plates that were below the mitre girder, but I find it is so heavy that no cab would be induced to bring it up, and as there is no cart conveniently to be had, I cannot ask Mr. Reeves to wait for it.

16,091. (The Commissioner.) We saw it, I think, at Mr. Kirkaldy's.

16,092. (Mr. Tayler.) I have no other witness, Sir, to examine, except the witnesses whose attendance you desired to-morrow on the question of wind pressure.

16,093. (The Commissioner.) That is a separate subject altogether. Is there any other witness that any of the other gentlemen would like to produce now, because time is valuable?

16,094. (Mr. Bidder.) I am not ready to go on to-day, Sir. (The Commissioner.) Then we will go on with the wind pressure to-morrow.

Adjourned till to-morrow at 11 o'clock.

EIGHTEENTH DAY.

Thursday, 29th April 1880.


Examined by Mr. Tayler.

16,095. You are the Astronomer Royal?—I am.

16,096. Are all Greenwich?—Our present residence is at the Royal Observatory, Greenwich.

16,097. Have you at the Observatory instruments which enable you to tell the velocity and pressure of the wind?—We have the instruments which we have considered best for the purpose; that is to say, for the velocity of the wind we have Robinson's anemometer, and we have great, great care to make its precision, and for the pressure of the wind we have Osiër's anemometer, and I consider those two are the best instruments for the purpose.

16,098. And I suppose you have necessarily paid very great attention to both questions—the wind pressure and the velocity of the wind?—They come habitually before us, and every care is taken to be accurate upon both subjects.

16,099. Can you tell me what is the greatest known or the greatest recorded velocity of wind in this country within recent years?—I should have fixed upon one but for an unfortunate circumstance, that is to say, the heavy gale of December 5th, 1872; that is the heaviest gale I have known in the country. Unfortunately our recording pencil broke at a particular point, but still we have collateral evidence of the motion of the wind at that time, which induces me to say that that pressure, which I regard as the heaviest known in this country, may have amounted to 50 lbs. or nearly so.

16,100. What was the velocity of the wind on that occasion?—In that storm the velocity amounted to 70 miles in one hour, and in the course of the day it amounted to 918 miles.

16,101. That is a mean velocity of barely 40 miles an hour?—Perhaps a mean velocity of about 40 miles an hour.

16,102. The highest velocity in an hour was 57 miles, and over the 24 hours the mean velocity was something just under 40?—Yes, it was.

16,103. That, I understand you to say, is the greatest velocity recorded in this country with which you are acquainted?—It was not the greatest velocity over the whole day. There was one day not long since in which the wind was very steady, and, in which the whole day amounted to 954 miles.

16,104. That was on March 2nd, 1880?—That was on March 2nd of the present year; that was the greatest run in the course of a day that we have known.

16,105. That is a mean of under 40 miles an hour?
16,100. Will you kindly address yourself to the question, you were speaking to a little while ago, with regard to the greatest pressure of the wind that you have known, namely, in that storm of December 8th, 1872?—I have reason to think that the greatest pressure amounted to about 50 lbs. on the foot; but from the circumstance that our recording pencil of pressure broke at a critical time, I cannot say that 50 lbs. on the square foot is recorded; but pressures greater than that were recorded, and there is collateral evidence of the state of the wind from apparatus which registered the movement of the wind.

16,101. Will you kindly tell me what was the extreme pressure of wind on the 2nd of March 1880?—It was not great: it was about 30 lbs., I think.

16,102. With regard to the storm of March 1882, can you give me any particulars about it? I mean with regard to the state of the barometer during the course of it. The point I want to get at is this, while the storm was continuing or increasing, was the barometer constantly, falling, or were there variations of the barometer?—The barometer was continually falling until it was about 10 o'clock the next morning. I have not brought with me any farther records than those.

16,103. Did the storm begin to abate with the rising of the barometer?—The barometer rose so slowly that it is difficult to say.

16,104. Did the barometer reach its lowest point during the storm, or after the storm had obviously commenced to subside?—It reached its lowest point a little after the storm, after the fury of the storm had expired.

16,105. There was a storm, which you know as the "Eurydice" squall, on the 24th of March 1878, I believe: can you give me the velocity of the wind on that occasion?—The velocity of the wind was small, the highest pressure was 284, which would be a velocity of about 14 miles an hour: it increased when the gale came on, but not very much.

16,106. That squall was characterised, I think, by a sudden pressure, following immediately a sudden change in the direction that the wind was taking?—Yes; the wind changed its direction very suddenly, from nearly south-west to nearly north-west: but it changed 90 degrees, setting it generally as well as can be ascertained, and at the same instant the thermometer was falling, more rapidly than it had been before, and the squall came on instantly with a suddenness that I had not known in any other squall whatever.

16,107. Can you tell me the extreme pressure of the great gale under which the "Eurydice" founded?—It was not a high pressure; it did not exceed 10 lbs.

16,108. That was, of course, the pressure registered at Greenwich?—Yes; our distance from the sea might be 100 miles perhaps.

16,109. Now, with regard to the Tay Bridge storm on the 28th of December 1879, have you any records at Greenwich of that storm?—Our records are perfect, but they give very little information upon it. There was no more disturbance than there would be on any common blowing day.

16,110. You were out of the current or reach of that storm?—Yes; it will be remembered that our distance from the Tay Bridge was more than 400 miles.

16,111. Will you tell me, if you please, what was the pressure at Greenwich on the night of the 28th of December?—The highest pressure was 6 lbs. a single squall.

16,112. (Mr. Webster.) Seven and a half up to eight I see you say on page 4 of your paper.

16,113. (Mr. Frazer.) I see you say, "Soon after 8 p.m. the pressure rose to 7½ lbs. per square foot, and then these were the highest." I suppose that is accurate; that is your note?—Yes. I see 7½ lbs. to the square foot after 8 o'clock, and 8 lbs. to the square foot after 10 o'clock.

16,114. You know the site of the Tay Bridge?—I know its structure generally.

16,115. I say the site of it?—I know the site of the bridge very well; I know the valley of the Tay.

16,116. Do you think, from the conformation of the land there, that any structure across the Tay would be subjected to great pressure from storms coming down the river?—I have no doubt that if a westerly or nearly westerly wind was coming down the river the force of that wind would be much greater than there would be registered in any other place in the country.

16,117. Can you tell me whether there are any means which you are acquainted with of ascertaining the maximum velocity and pressure of the wind in sudden gusts?—No new ones that I know of. I am satisfied that with regard to the maximum pressure, we do get it; but with regard to the maximum velocity, I am not so certain; and I have been led generally to think that the information on the subject of velocity is much less to the point of the injury to the Tay Bridge than the maximum pressure.

16,118. As regards engineering purposes you think the pressure is a much more important thing to be kept in view than velocity?—Very much more important.

Examined by Mr. Rider.

16,119. May I take it that the maximum pressure that you have been able to record at Greenwich was 40 lbs. when the instrument gave way?—That is about the figure.

16,120. Your observations lead you to believe that the anemometer been incapable of recording it you would have registered 30 lbs.?—On that particular day I believe it would.

16,121. That is, of course, upon the area exposed by the anemometer at the particular point where the anemometer is situated?—Undoubtedly.

16,122. I would like to ask your opinion upon this question. Do you believe that any such pressure as 40 or 50 lbs. to the square foot ever obtains or over so large an extent of surface as is represented by a span of the Tay Bridge—that is to say, a length of 245 feet, and a height, including the pier, to the top of the girder, of 100 feet?—I have no means of knowing.

16,123. What is your judgment upon the point?—I conceive the course of the wind on these occasions to be almost as irregular as the course of streams in a river; there are some parts in which the pressure may much exceed that in others: in fact, the space through which the greatest force prevails is limited, I imagine.

16,124. Although you have observations which indicate so high a pressure as 40 or even 50 lbs. to the foot at a particular point, is it not, in your opinion, highly improbable that any such pressure has over obtained simultaneously over a large area?—I really cannot say that I have any very definite opinion upon that.

16,125. I observe, although you did not give it in evidence, that at the end of these notes of yours which have been printed, you make a recommendation that all calculations for the strength of a proposed structure, and especially for the spread of the base of the pier, should be based on the assumption of a pressure of 120 lbs. to the square foot?—That is an opinion that you have only very recently arrived at, is it not?—It is founded upon this rough kind of calculation. At Greenwich, I conceive, we have had pressure to the amount of 50 lbs. on the foot; that pressure I believe to be generally exceeded in Scotland, and in such a place as the Firth of Tay, I conceive it to have been much exceeded, on some particular occasions, amounting to something between 50 and 100 lbs. That is all I mean to say as my belief of what
prevalis, but as to my belief as to what ought to be done in respect of establishing a modulus of safety for an erection, I think we ought to go higher than 100 lbs.

16,126. May I not put it in this way; that, until within a very recent time, within the last year or two, the knowledge and experience of engineers, and of scientific men, did not suggest any such extreme provision for wind pressure as it is, but ideas do not always come into one's mind.

16,127. Do you happen to recollect that you yourself were consulted upon this very subject about seven years ago?—Not on the Tay Bridge, I think.

16,128. Not upon the Tay Bridge, but upon the Forth Bridge?—I was consulted upon the Forth Bridge; not with regard to pressure, I think.

16,129. With regard to the question in constructing a large bridge of that kind, what provision should be made for resisting the pressure of wind in extreme gusts. In (in your recollection that you were consulted?—It was.

16,130. May I refer to Sir Thomas Bouch's design?—Yes; but it was principally upon another point; namely, the combination of the means of suspension and of stiffening.

16,131. I will not trouble you about that. Do you happen to have a copy of your report?—No.

16,132. But I dare say you may recollect it. I will recall to your memory. Sir Thomas Bouch had prepared plans of the bridge over the Forth?

16,133. And those plans were submitted to several eminent engineers, of whom Mr. Barlow, who forms one of the tribunal here, was one, to report on to the North British Company; and those eminent engineers consulted you upon this point?—I do not remember anything with regard to the pressure.

16,134. Will you take this letter in your hand (handing the same to the witness); perhaps it will refresh your memory. You will remember that you wrote a letter to Mr. Barlow upon this subject?—I remember that I made a report upon some points, but I do not remember what they were.

16,135. Perhaps you will take it from me that that is a copy of your letter to Mr. Barlow. Will you kindly follow me through that. It is dated Royal Observa
tory, Greenwich, 9th April 1873, and it commences "Sir,—I have considered carefully the proposal of constructing the suspension bridge over the Forth; for carrying a railway in two spans of about 1,000 feet each, upon which I understand you wish that I should give you my opinion. First upon the liability of the bridge to suffer from the action of the wind; secondly, upon any points in the construction which might occur to me. I will advert here to both subjects." Then you say, "We know that upon very limited surfaces, and for very limited times, the pressure of the wind does amount sometimes to 40 lbs. per square foot, or in Scotland probably to more." That is to say, your knowledge upon that point seems to have been very much what it is now?—Yes.

16,136. Then you say, "So far as I am aware our "positive knowledge, as derived from instrumental "record, goes no further. But in studying the "registers it is impossible not to see that those high "pressures are occasional, and it seems most probable "that they arise from some irregular whirlings," of the air which extend to no great distance. I "should say certainly to no distance comparable with "the dimensions of the proposed bridge, and that the "fairest estimate of the pressures on the entire bridge "would be formed by taking the mean of the recorded "pressures at one point or space, representing the mean pressure upon a "moderate extent of space at one instant of time. "Adopting this consideration, I think we may say 
"that the greatest wind pressure to which a plane surface "like that of the bridge will be subjected on its "whole extent, is 10 lbs. per square foot." At the "time you wrote that report that was your judgment, based upon your scientific experience at that time, and with all the knowledge you had; and I am sure nobody had more knowledge or experience, or opportunity or ability to apply that experience to the subject in question. I may take it, may I not, that at the date of writing this report, in April 1873, your judgment was that 10 lbs. to the square foot was the greatest pressure of wind that you need provide for in the case of a large bridge like that?—I cannot say how large. If you will allow me to explain that the circumstances are very different. The point under consideration there was a span of 800 or 1,000 feet, I think; the pressure of 40 or 50 lbs. to the foot on a limited portion of that span of 800 or 1,000 feet would not be injuries to such a bridge, but it would be destruction to this bridge.

16,137. According to your letter of April 1873, in your judgment, in that case 10 lbs. to the foot was the outside that the engineer need provide for?—The outside of the main through the whole; there were parts upon it where the pressure might be expected to be about 40 lbs. or more.

16,138. I am quite aware that that was an exceptionally long bridge, but what has caused you to so far vary your opinion as to say in these notes that an engineer should provide for 120 lbs.?—I have endeavoured to state my reasons for that. The Forth Bridge was to be a suspended bridge, in which there was no question about any falling of supports, or the like, for a space of 1,000 or 1,200 feet, I forget which.

(The Commissioner.) One thousand six hundred feet was the length of the span.

(The Witness.) Upon a bridge of that sort, though there might be elements through a space of 100 or 200 feet pressure of 40 or 50 lbs. upon the square foot, it would do no hurt whatever, but it would ruin this bridge.

16,139. (Mr. Bidder.) Pardon me, that is not what you said in your report. These pressures of from 50 to 50 lbs. are attributed by you to irregular averagings of the air, and in your judgment the safest estimate of pressure for the entire bridge would be formed by taking the mean of recorded pressures over a moderate extent of time. I quite agree that this bridge, that is to say any particular span of this bridge, is not so long as the bridge that you were then discussing; but the same observation in principle applies here as it does there, does it not; that is to say, just as you were of opinion then that these pressures of 40 or 50 lbs. are pressures at a point, and cannot be regarded as obtaining over a large area, so it is true here, is it not.—I think most likely it is so here.

16,140. Of course, the particular section being considerably less, the space over which to take the mean, is not so extended; and therefore you may not get so true an average of the pressure. Are you aware that in the case of this bridge, although one particular span is not so great as that of the Forth Bridge, the girders were continuous girders in groups of four or five, so that the length of the bridge was not one continuous fabric here was not much less than that which you were discussing in the case of the Forth Bridge?—But I should conjecture that one span went first here.

16,141. I am afraid I have not made my question clear. Are you aware that the girders of this bridge were continuous for four or five spans, so that in fact it was a bridge of continuous girders from 1,000 to 1,200 feet?—I was not aware of that point in the construction.

16,142. Will you kindly take it from me as the fact that is so—that the spans were connected together, so as to give the benefit of a continuous girder, uniting in one case five spans in a group, and in other cases four?—That would contribute to the strength undoubtedly, but I cannot say how much.

16,145. But I am drawing your attention to this. For the purpose of considering the wind pressure, it would give an extent of surface very fairly com-
parable to that which you were discussing in the case of the Forth Bridge, because five spans of this bridge would be equal to 1,500 feet, and four spans would be equal to about 1,000 feet, so that the extent of surface, though not quite so great, is very fairly comparable with that which you were discussing in the case of the Forth Bridge. Unquestionably, if there were one division like this (pointing to the model) which was not connected with the others, a single gust upon this alone would be destructive, whereas if it were connected with the others it would not be so destructive.

At the time you were asked your opinion with reference to the Forth Bridge you had been asked to give your opinion as to the allowance for wind-pressure that should be made for a bridge of similar length in the Tay, you would probably have said about the same amount. There are circumstances in the construction of the bridge which might have modified my view. For instance, if a bridge like this, erected on piers, is subjected to a great pressure, it cannot recover from it; and it is necessary to make perfectly sure that it will bear the pressure which you consider to be likely to come upon it, and more; but in the case of a suspended bridge it is not so necessary, and I think it is very likely that that was in my mind at the time; a suspended bridge can be recoiled, and it will return.

16,146. I am not speaking so much upon that particular point; I rather want to confine my attention to your anticipations of the wind. I will turn your attention to another paragraph of your Report on that occasion. If you follow on, in the next paragraph you will see that in paragraph 3 of your Report you say this: "But if I rightly interpret the plan, the side of the bridge is not a plane, but a comparatively light lattice work. How much this will diminish the pressure of the wind I cannot pretend to estimate accurately. I should be quite satisfied with the assumption that it reduces the pressure to a 1/4 or 1/3 of 120, say to 24 lbs. per square foot." That, I take it, should be 21 lbs. Your language is a little ambiguous there; what I take it you meant was that the area of lattice work was probably the 1/4 of the full plane area, and that it would reduce it to 24 lbs. upon the whole area, if it had all been filled up.—Yes.

16,147. You say, "This will give you 1 ton for every 1,000 square feet in the side of the bridge or lattice work. Supposing the mean depth of the tube to be 20 feet, its length 1,600 feet, the number of square feet in the side is 64,000, and the lateral pressure may be 64 tons." If you will just bear those figures in your mind, your opinion was, that upon a lattice surface of 1,600 feet long and 40 feet high it was possible to get as a maximum 64 tons of wind pressure. —Yes, that appears to be so.

16,148. Let us compare that with one single span of this bridge of 245 feet long, that is about a sixth of the length of the Forth Bridge, and 27 feet high instead of 40; you would not expect to get anything like as much upon that area as you would on the other. I cannot undertake at this moment to compare the numbers. I have not seen this paper since I wrote my Report. —Yes.

16,149. In the case of 1,600 feet of length, and 40 feet of height, and in both cases there being lattice girders, you anticipated a maximum wind pressure of 64 tons?—Yes.

16,150. Suppose you would say that it would be impossible on an area of 4th of that to get the same pressure? —Do you mean the same pressure throughout?

16,151. I mean the same aggregate pressure. You have got upon 1,600 feet of length with 40 feet of height an aggregate pressure of 64 tons. If that was the maximum you could get for that length, you would expect nothing approaching that as the aggregate pressure upon a sixth of the length, and three-quarters of the height—but that is not the maximum pressure; that is the pressure taken upon the mean of the whole length.

16,152. I did not say the maximum; I said the maximum aggregate pressure. As I understand your process of reasoning was this: "I consider over the whole of this area the maximum mean pressure is 40 lbs. on a foot, and, as I have stated in my evidence-in-chief, I believe it to be greater in Scotland. I believe it would be greater, and especially in such a place as the locality of the Tay Bridge."—Yes.

16,153. In the case of the Forth Bridge, if you will allow me to remind you, it was not quite a mere tube, but there was a considerable structure in the middle of the stream, exposed to wind at a very great height?—Yes.

16,154. And supported by piers?—Yes, but I have not seen this plan before.

16,155. You have seen something purporting to represent the same thing? perhaps you will lay it before the Court?—(A plan was handed.)

16,156. (Mr. Bidder.) It is a long time ago, and perhaps you have forgotten it; but I think you will find that those plans were sent to you before you wrote your letter.—I have forgotten it.

16,157. I dare say you will remember that you made some very valuable suggestions as to the mode in which you would recommend the chains to be carried over the tops of the piers?—Yes, I remember that.

16,158. I see you concluded that Report by saying, "With attention to these principles" (that is to say, the principles you have enunciated), and with due attention to the details of its construction, I have no doubt of the perfect success of the bridge, and I should be proud to have my name associated with it."—Yes; I remember I was satisfied with the general safety of that bridge; and in regard to pressure, I believe my opinion was founded entirely upon the circumstances which I have detailed in the first page, that I believe the greatest pressure is limited in extent.

16,159. Taking such a limited surface as the side of a railway carriage, which, as compared with the side of one of these great girders, is a very small surface indeed, you would expect to have a much greater momentary pressure upon such a small surface than you ever could upon a girder?—Yes.

16,160. And from what you know of the storm of the 26th and 28th of December, would it be unreasonable to assume that upon the side of a carriage you may have had gusts of 40 or 50 lbs. to the foot?—Heavier; that is to say, from all the descriptions of the storm. The storm is described as having been a very heavy one, and no doubt there was a pressure greater than that.

16,161. Therefore a carriage whose momentum of stability was such that it would over-turn with a lateral pressure of 35 or 40 lbs. to the foot, might very well have been blown over on that occasion?—Yes, I should think so.

16,162. There was a matter referred to by some of the witnesses, with regard to which I think you can give us some valuable information, namely, as to the upward tendency of the wind?—I am unable to give any information upon that.

16,163. There is another matter I would ask you about, whether you have considered the effective pressure of the wind upon a body in motion transversely to it, as compared with the same pressure upon a body at rest. I do not mean the mere revolution of the
Examined by Mr. Balfour.

16,166. You were asked by my friend, Mr. Bidder, some questions relating to the Forth Bridge, as compared with this. Is it in your recollection that the Forth Bridge consists of two lines of railway with a space of about 100 feet interposed between them?—I remember generally that there are two lines.

16,167. Of course, the character of a bridge bearing two lines kept apart 100 feet must be very different to that of a bridge for bearing only one line?—I only remember generally the fact that there are two lines on the Forth Bridge.

16,168. And those two lines are kept apart at a distance of about 100 feet by cross-beam with a horizontal nature?—I have an idea that you will see by glancing at the plan whether it is not so?—It is.

(Mr. Bidder.) You may take it that the plan is before the Court.

16,169. (Mr. Balfour.) You see upon the plan the nature of that structure?—Yes.

(Mr. Bidder.) I do not know that my learned friend is entitled, upon my examination, to put these questions about the Forth Bridge. Of course I know that the character of the two bridges is as different as the character of any two bridges could be. My questions were not directed to a comparison of the bridges, but to a comparison of the pressures, and the relative power of the suspension bridge so much as the way in which you make your bridge will not make the wind blow less or stronger.

(The Commissioner.) The conclusion to which Mr. Bidder arrives was, as I understood, that it's pressure of 10 lbs. was good for the Forth Bridge it would be good for this bridge.

(Mr. Bidder.) No, Sir, I am very sorry that you should have misunderstood my question.

(Mr. Balfour.) I can only say that you have conveyed a common misapprehension, for everybody understood you in the way in which the Commissioner had.

(Mr. Bidder.) My questions pointed to this: that at the time the Forth Bridge was under discussion, the judgment of the Astronomer Royal, based upon all his knowledge and experience, was that the greatest pressure of wind per square foot over the whole surface that had to be encountered and dealt with was 10 lbs., to the foot. The mode of encountering that, the mode of giving stability to the bridge so that it was quite a different question.

(The Commissioner.) The Astronomer Royal's answer had reference to the different character of the structure of the Forth Bridge, because he said, in answer to your question, you must recollect that the construction is totally different: that the Forth Bridge is a suspension bridge.

(Mr. Balfour.) Surely it must be obvious that the mode of construction of the bridge does not alter the forces of nature; that the wind will not blow stronger upon the Tay because you build a stronger kind of bridge; and therefore I am fairly entitled, and at the proper time I shall observe upon it, to assume, or that what nature does in one place it will do in another.

(Mr. Balfour.) If I may say so, I think it is not only due to the railway company, but to the Astronomer Royal himself; that there should be no misapprehension upon this matter.

(The Commissioner.) You may proceed with your examination.

16,171. (Mr. Balfour, to the witness.) You recollect now the nature of the Forth Bridge with respect to which your opinion was invited, and with respect to which you were good enough to give it?—Yes.

16,172. Would the effect of wind upon a structure consisting of two lines of rails kept apart at such a distance, and thus creating such a broad floor, be materially different from its operation upon a narrow base such as that of the Tay Bridge?—The two lines of rails being tied together.

16,173. Kept apart, making a broad floor as compared with the narrow floor of about 14 feet, such as the width of the girder of the Tay Bridge?—As regarded the power of destroying the intermediate parts it would be much stronger; as regarded the power of pulling the piers down it would not be altered.

16,174. But as regards the power of destroying the intermediate parts it would be much stronger?—It would be very much stronger.

16,175. In the case of the Forth Bridge the piers are founded upon dry land, the main piers supporting the suspension bridge?—Yes.

(Mr. Bidder.) As you put that question, will you be kind enough to put this: whether, as a matter of fact, the ratio of width to the length was exactly the same as in the Forth Bridge?

(Mr. Balfour.) You may put that question by all means.

(The Commissioner.) I quite understand Mr. Bidder's question, namely, that these girders were connected.

(Mr. Bidder.) No, Sir, that is not what I meant.

(Mr. Balfour.) You had better put the question yourself.

(Mr. Bidder.) My friend has just asked a question whether the Astronomer Royal was aware that in the Forth Bridge there was a length of 1,600 feet with two girders 100 feet apart. What I desire the Astronomer Royal's attention to be called on, as a consequence of my friend's question, is this: that, taking any one span of this bridge, the ratio of span to width between the two girders is precisely the same, 16 to 1.

(Mr. Balfour.) That is not the point.

16,176. (Mr. Bidder.) Perhaps you will allow me to ask Sir George that question, whether he is aware that the ratio of width to length in the Tay Bridge was precisely the same as in the Forth Bridge. (To the witness): Were you aware of that?

—I was not.

16,177. (Mr. Balfour.) Do you consider that for the purposes of the questions put to you those two structures could be treated as absolutely and exactly comparable. I mean the Forth Bridge and the Tay Bridge?—There are considerations which affect our thought, without their always being put into distinct shape. There is one general thought which I have, no doubt operated upon my mind, and that is that a bridge which is suspended is much safer than a bridge which stands upon high stilts. I cannot say how far that applies, but still it does dominate in one's thoughts.

16,178. And that still in your mind is a material consideration?—A material consideration. The question of the Forth Bridge is perfectly new to me, because I have only had a day or two's notice of this matter, and I never thought of the Forth Bridge, but I may mention that after the experience we have had of the force of the wind, I should not trust to the pier of the Forth Bridge without some lateral support; it would be much easier to introduce them, I apprehend, for the principal piers of the Forth Bridge, than for the piers of the Tay Bridge, but I think it ought to be considered as a matter of course.

16,179. In your judgment, if provision be made for lateral support to the Forth Bridge, would the remainder of your calculations and recommendations given in 1873 continue good?—Yes, certainly, I have no doubt of it.

16,180. (The Commissioner.) Assuming additional lateral support to the piers, your calculations as given in 1873 for the Forth Bridge would still hold good?—Yes, I have no doubt they would.

16,181. (Mr. Balfour.) I think the last recommendation which you make in your notes relative to this bridge is quite in accordance with that idea, that is article 31. I will read the whole of it: "I recommend that all calculations for the strength of a proposed structure, and especially for the spread..."
"(transversely to the bridge, or longitudinally to the valley of the bridge) on the square foot."

What have you said just now is quite in accordance with what you say there?—Yes, everything depends upon this spread (pointing to the base of the model).

Further examined by Mr. Traynel.

16,182. You were asked by Mr. Bidder to consider this bridge as a bridge with continuous girders for four or five spans; that is to say, extending some 1,200 or 1,500 feet. Now, consider that at the end of one of these long girders there is that is called an expansion joint, which permits to a certain extent of longitudinal motion in the girder, and that there is no attachment proper between the girder and the pier at that particular point, but that it rests upon the top of the pier, and that resting is the only attachment there is. Assume these things; would you consider it safe to trust in reckoning the wind pressure power which such a bridge would resist.

(The Commissioner.) Before you go to that you also tell him that at the roller joints there is no attachment to the pier; that there is only a attachment at that point.

16,183. (Mr. Traynel.) I was going to take the things separately, first taking that continuous length of 1,200 or 1,300 feet. (To the witness): Would you think it safe to trust the bridge to the pressure of wind which you might expect fairly to come at the centre of the 1,250 feet?—It would require a very firm connection.

16,184. Given that there is no connection there between the pier and the girder, except that the girder rests upon the pier?—(Mr. Bidder.) Do not put the question in that way; that is not the fact.

16,185. (Mr. Traynel.) Insist upon being allowed to put my own questions; I am not going to be bid do everything I do here. (To the witness): Would a less pressure overthrow the bridge at that point than would, in your opinion, overthrow it 400 or 500 feet away?—Supposing the connection to be such that it would not slip off.

16,186. I am assuming that it could slip?—If it could cause a destructive force would act with the greatest disadvantage at that place.

16,187. The greatest disadvantage to the bridge?—Yes.

16,188. And it would have the greatest effect upon the structure?—It would have the greatest effect upon the bridge.

16,189. There are other places on this long continuous girder which have what is called a roller bearing, the rollers allowing a certain longitudinal motion, but there being no attachment except the flange of the roller. At that place would you consider it safe to leave the bridge subject to the wind pressure which you would consider it safe to subject it to if the girders had been absolutely continuous and were attached?—As regarded the bridge itself, everything would depend upon two circumstances; one is, whether the successive portions are really continuous; the other is, whether there would be any probability of the girder slipping sideways off the pier. Now, supposing the answer to those is satisfactory, I do not think there would be any particular danger introduced by the circumstance that you have mentioned.

16,190. You said that, assuming that there was a continuous girder of 1,250 feet long, it would require a greater pressure to upset or overturn that span than to a span of shorter dimensions?—Yes.

16,191. Would that opinion be modified, if in the course of the long girder of 1,250 feet you have, let us say, two points, at one of which there is no attachment to the bridge, and at the other of which there is only the attachment of the rollers, and that, except for that attachment, the girders are simply resting upon the pier?—Of course, if there was no power to resist a slipping, the safety of the bridge would lose one important point.

16,192. Do you know the site of the Forth Bridge as well as you know the site of the Tay Bridge?—I know it partially; I have been at Queensferry several times.

16,193. Do you think that there is the same probability of severe concentrated wind pressure coming westward at the Forth Bridge as there is at the Tay Bridge?—I should say certainly not; it is much more open land about the Forth than it is about the Tay.

Examined by the Commissioner.

16,194. Let me see if I clearly understand you. One of the continuous girders extends over five spans, giving a total length of 1,225 feet. It is rigidly connected at its centre point with a pier, and at the other four points it simply rests upon rollers, having flanges of three-quarters of an inch high. Should you consider that a span of that kind was in as good a condition to resist lateral wind pressure as the Forth Bridge, which was a suspension bridge rigidly connected at each end?—No, it seems to me that the whole resistance to what I call the slipping is at our point, if I understand it.

16,195. At the other points, where it rests upon the rollers, the only thing that prevents it from slipping off is a flange of three-quarters of an inch high, and the friction between the girder and the roller?—The question would be whether the bridge might not ride over that; I think that is not trustworthy.

16,196. You also stated that in the case of the Tay Bridge, to which your letter specially referred, it was a suspension bridge, which, when thrown out of the perpendicular, would readily return to its original position as soon as the pressure was taken off?—Yes.

16,197. But that in a construction of this kind, with rigid piers at its centre liable to overturn, and would not be so liable to return as in the case of a suspension bridge?—That was my view.

16,198. Then again you were asked whether or not a pressure of 40 lbs. upon the side of a carriage would not be likely to have a much greater effect upon this carriage than in overturning the bridge.

(Mr. Bidder.) I assure you, Sir, I did not ask that question; my question was whether you would not be much more likely to have such a pressure upon a limited area like a carriage than upon a big area like the bridge.

16,199. (The Commissioner.) Yes, that was your question. (To the witness): But you must remember that the carriage is between the girders?—Yes, the train is between the side girders.

16,200. Consequently in a very strong wind that might be blowing upon it, a portion of the wind would be impeded by the windward girder, would not it?—The whole area of the carriage would feel the wind.

16,201. Except so far as it was protected by the windward girder?—Then the girder would feel it. The whole aggregate pressure tending to injure the bridge would not be affected by the division of the pressure between the portion of the carriage and the portion of the lattice of the girder.

16,202. It is suggested that one of the carriages was overthrown, but with reference to the answer you gave as to the great force of the wind over a limited area, that force I suppose upon the carriage would be very much less, protected as the carriage would be by the girder, than it would be upon the windward girder itself?—Somewhat. Taking this (pointing to the model) as the proportion of lattice to that which is not lattice, I should think it would not make much difference.

16,203. When you said that those gussets had no great extent, you did not mean, I suppose, that the gussets had only an extent of two or three feet, did you?—No.
16.204. When you said no great extent, it was in general terms?—Yes, in general terms.

16.205. You mean extent equal say to the whole length of one of these spans?—Equal to one of those, or perhaps greater, I should judge; and I think all the unscientific report upon the gale seem to lead to the idea that there was a blowing hard all along the bridge.

16.206. When you said a gale, you did not mean a point?—I did not mean a point.

16.207. You meant a limited area?—Yes, I meant a limited area. In the case which I suppose of a great condensed storm coming down the valley, which I believe may be the state of things on the right in question, I think that would be felt as a condensed storm in every part of the bridge.

16.208. Over the whole extent of the bridge?—Over the whole extent of the bridge.

(Mr. Bidder.) I do not think Sir George can mean that, for if that were so, then upon a similar area in the case of the Forth Bridge it would have given a far greater total wind pressure than he assumes is the maximum-possible. If it were possible to have 40 lbs. to the foot for the area of one span of this bridge, it would throw a far greater wind pressure upon that area than Sir George has assumed possible as the total pressure upon nine times the area. Therefore, I think he can hardly have meant that. (To the witness): Perhaps you will just consider that for a moment. I may help you with the figures. Forty pounds of wind to the foot upon one of these spans would be 76 tons.

(The Commissioner.) When you say 76 tons, do you mean including the piers?

(Mr. Bidder.) Yes, inclusive of the piers.

(The Commissioner.) Inclusive also of the train.

16.209. (Mr. Bidder.) We had better say exclusive of the piers, 60 tons, if you please; 60 tons upon one of these spans. (To the witness): Your estimate on nine times the area was a total of 64 tons?—I expressly stated in the case of the Forth Bridge, that it took only a limited fraction of the pressure as pervading through the whole.

16.210. You estimated that on nine times this area 64 tons was the greatest pressure you could have; that being your figure in the case of the Forth Bridge, you could hardly have been under the belief that 60 tons could have been got on one ninth of it?—It would be better if I referred to a definite measure, namely, the square foot; and looking at my estimate for per square foot, it will be seen that there is no inconsistency.

16.211. (Mr. Barlow.) There is no inconsistency that I see. Sir George Airy says that is a mean pressure upon that large girder of 10 lbs. per square foot; and in his report he says you are liable to gusts of 40 lbs. or more. If the gust were of the breadth of 240 feet it would be 40 lbs. of pressure over this span; and to that extent I think the report is quite consistent.

But there is one question connected with this as to which I should be very glad if Sir George would tell us his real meaning. (To the witness): With regard to the 120 lbs. I take that to be including a factor of safety; that is to say, it would represent 30 lbs. of pressure with a factor of safety of four, or it would be a pressure of 40 lbs. with a factor of safety of three. It means the total result?—Yes, including a very large margin.

16.212. Whereas in regard to the statement with reference to the Forth Bridge, I took it, and my coadjutors took it, as representing the momenting to which a factor of safety had to be added, and which was brought in. Sir George the Astronomer Royal means this 120 lbs. to be treated in that way.

(Mr. Bidder.) I do not think I made myself quite clear; what I meant in putting my question to the Astronomer Royal was this. Taking the case of the Forth Bridge he was discussing an area nine times the area of one of these girders, and the conclusion he came to was, having regard to all the knowledge he had, and attributing the 40 lbs. to local pressure, that over the whole of that area the greatest aggregate pressure would be 64 tons. Then I was suggesting this: if over an area like one of these girders, you might have 40 lbs. to the foot, if there were a possible supposition, it would be, for or if—there would be nine times that area of 60 tons, and it is quite clear that if the Astronomer Royal had believed that upon that small area he would have had 60 tons; he never would have come to the conclusion that on nine times the area he could have no more than 64, because that would be assuming that 64 lbs. of the bridge would be to remain calm almost, while the rest was subject to severe pressure. If a pressure of 60 lbs. could fall upon this area in the one case, it could in the other, and it would be quite inconsistent to assume that if 4th of the area would have 60 tons of pressure, nine times the area would only have 64.

(The Witness.) I repeat that it would be better to confine our ideas to pressure on the square foot; that is a more definite standard to take. In what I said about the Forth Bridge I said that there would be pressures to the extent of 40 lbs. on a foot, but they would not apply to the whole extent, and therefore I took a limited part. In the present case I do not go much further with regard to the pressure per square foot, except that I say it may be 50 lbs. But I look upon the circumstances as different in this respect. In the first place, I think that in the Tay Valley the storm would come down more completely filling it, than in the more open valley of the Forth, for if this pressure of 50 lbs. were concentrated among one of these (pointing to the model), upon any one of these (pointing to the model), or upon more than one, they would be in very great danger, because it could not be very well distributed amongst the others. In the case of a suspension bridge it is distributed] laterally, that is to say, where there are only suspensions from two piers widely separated.

Professor George Gabriel Stokes spoke.

Examined by Mr. Traynor:

16.213. You are professor of mathematics at Cambridge?—Yes.

16.214. You were requested to direct your attention, I believe, to the relation between the velocity and the pressure of wind?—Yes.

16.215. Will you give us any information you can upon the relations between those two things?—I may mention that the subject of the motion of fluids is one to which I have paid a great deal of attention. I am not so well-acquainted with the results of various experiments which have been made by others in relation to the resistance of fluids, although I have attended, to a certain extent, to the subject. With regard to the relation between the pressure of wind and its velocity, I think we must, in the first instance, have a clear idea of what we understand by the pressure of wind per square foot. Now, there is one quantity which has, in a certain sense, an absolute value, which entitles it to be considered par excellence as the pressure per square foot, that is the pressure which is measured by the weight of a column of the fluid having a height equal to that due to the velocity. This, I believe, is the pressure which would be measured experimentally, by instruments depending upon the principle of presenting a tube with an open mouth to the wind, and measuring hydrostatically the pressure at the mouth of that tube by connecting it with a gauge in which liquid is used; for example, connecting that tube with an inverted siphon tube below, containing a measure of liquid, and measuring the pressure thereby. Now suppose that we were considering the question of pressure on a plate, a pressure plate for instance, it is by no means necessarily the case that the pressure per square foot so measured on a pressure plate should be equal to the pressure measured hydrostatically in the way that I have ex-
pressed. I imagine, but I do not know for certain, that there is rather a confusion upon this point, and persons in different ways of measuring one and the same thing, which ought to lead to the same result. According to the old theory of resistance, which is frequently given in books on hydrostatics and hydrodynamics, the two pressures ought to be the same thing; but that theory is founded on reasoning which is altogether apart from the practice of the mark; and though it may not be useless as a guide, provided it is accepted with caution, if trusted too implicitly it is merely misleading. In point of fact, the pressure experienced by a plate is a very complicated thing. Suppose the wind to strike fairly on the plate, it divides in front, goes right and left, and so down. According to the theory, we should expect that right in the centre of the plate the pressure on the face of the plate per square foot would be the same as the pressure measured hydrostatically in the manner that I have explained, which, for the sake of a name, I will call the standard pressure; but as you go off towards the side, the velocity of the wind at first increases, the wind begins to gush; the pressure diminishes, and towards the edge it may be actually negative, that is to say, the pressure may be less than the pressure as measured by the barometer. Away from the structure altogether, so that the face of the plate would be exposed only to the wind; and as the pressure in the wind is the same as the wind pressure, but in the wind there is an additional pressure due to the friction of the air. But then in the near there is a defect of pressure apparently arising from this: that the air in passing the edge breaks into eddies which with the still air behind, and tend to drag it along, thereby tending to produce a partial vacuum behind, and in the pressure as measured by a plate the two are necessarily included; the excess of pressure before and the defect of pressure behind are united. We cannot subject the theory of fluid to mathematical calculation; we must only trust to experiment to know what is the pressure per square foot experienced by a plate as related to the velocity or as related to the pressure measured hydrostatically. I have consulted to a certain extent the results given by different experimentalists as to the value of a pressure per square foot, supposed to be estimated by the pressure on a pressure plate. I find somewhat different results, but on the whole there is a fair amount of accordance. In some old experiment of Hutton, for instance, I find that the pressure was given as 1.44 to 1.46. It is an old book, Mr. Rothery was so kind as to furnish me with it, I find numbers which give it rather higher. For instance, taking a velocity of 20 miles per hour. I find 1.566 from the experiments of Rouse, and a rather larger figure from the experiments of Rea, and in it published by the late Sir Henry James: the pressure for 20 miles an hour is put down at 2-6 lbs. per square foot, that is to say, the pressure experienced by a plate. Mr. Scott Russell mentioned to me lately that he had been engaged in some experiments which were made, I may say, in a hydrostatic manner, and that he got out that 20 miles per hour gave a pressure of 1.3 lbs per square foot.

16,216. (Mr. Bidder). How does that agree with theory? I have calculated what it would be from theory for what I called the standard pressure, and it comes almost exactly the same; but, as I explained, the standard pressure is one thing, and the pressure which is given in the tables of the village can only be determined experimentally. With regard to a large structure, supposing even the side of it is flat, it is a question whether the value of the pressure determined by a pressure plate, supposing that you know the velocity of the wind, is the proper value to apply to such a structure, that is, taking the pressure per square foot over the same area in connection with the latter. So far as I know, experiments made on a small scale agree in showing that the pressure is pretty well in proportion to the surface, but I confess I should like to see experiments made, as I think they could be made, on a large surface, to see whether it would come to the same thing. Whether it would come to the same value per square foot, but as far as we know I think it would be to bring us nearly to the same thing.

16,217. That is to say, that the pressure would increase as the area directly?—Yes.

16,218. (The Commissioner). You think it would vary directly with the area?—I think it would, or nearly so. I do not think that we have had experiments on large areas, although I think they might be made in the hydrostatic method by piercing the area at different points and measuring it hydrostatically. I think it would be a valuable thing to make such experiments, but I do not think they have ever been made; I have never heard of them at least. I have no reason to doubt the accuracy of the records of pressure as given by the pressure-plate apparatus.

16,219. By Oster's apparatus?—Yes, by Oster's apparatus. But wind is more commonly measured with regard to the velocity than with regard to the pressure; at least, I imagine that anemometers which register the velocity are much more common than anemometers which register the pressure; but if that be the case, it is of importance to be able, if we can, to translate velocity into pressure. Of course the first point is to measure the velocity, and the second to translate it. Supposing we know the velocity, we can at once pass to what I call the standard pressure; and from that, and the velocity having been given, it becomes of importance to me that we may have a scale maintained by the plate. I should say on the average of the experimental results that I have seen, that you must add about perhaps 80 per cent. or so to what I call the standard pressure in order to get the pressure per square foot on the plate. The numbers as given by different experimentalists vary, and it is not a question on which I should wish to be compelled to speak with authority; but still, having looked rather lastly into the results of experimentalists, I find that Sir Henry James would make it 100 per cent.; other experimentalists make it lower; in one of Hutton's experiments it comes to a little more than 40 per cent.

16,220. (Mr. Bidder). Was Mr. Scott Russell's observation by what you call the standard?—Yes, by measuring the pressure hydrostatically, not by a pressure plate. I do not know whether engineers are generally aware that the two things are different, but I rather suspect that they have been misled by the old and I may almost say young theory of resistances, to suppose that they were the same, whereas they are entirely different. As I said, if we knew the velocity, we could pass through the standard pressure with a more or less close approximation to the pressure per square foot, but it is a difficult matter to determine what the velocity is. The instrument which is now generally employed for the measurement of velocity is Robinson's anemometer, and the difficulty of dealing with the velocities by the use of that instrument is twofold: first, we want to know what the relation between the velocity of the cups, which is the quantity measured, and the velocity of the wind is, by experiments made once for all. Secondly, we want to know what the registration of the velocity of the cups is on any particular occasion. I will take that second point first, because I have not much to say about it. The object of the instrument is to measure the mean velocity for a considerable length of time, and if I may call the total wind and the mean at any one time, how much wind blows in 24 hours or in one hour. The instrument is self-recording, and the time-scale commonly employed is such as would be convenient for that purpose. For instance, in the original time-scale used by Dr. Robinson, of which he was so good as to send me a specimen, an hour is represented by half an inch. In the instrument which I have here the Meteorological Office (I have a specimen of the time-scale here) it is represented by about three-eighths of an inch. The total wind which blows in an hour, assuming that you know the relation between the velocity of the cups and the velocity of the wind, is given easily enough in an hour or in half an hour; but when it comes to be a
question of two or three minutes, the time-scale is so constructed that the attempt to measure the velocity becomes precarious, because the trace of the recording pencil itself is a thing having a certain breadth; and though attempts have been made to measure the rate for a short space, they must be accepted with some hesitation. Mr. Scott, however, will be better able to speak to that subject than I can be. There is no inherent difficulty in the instrument itself to measure the velocity for a much shorter interval of time than even a quarter of an hour; and in view of this inquiry, I suggested to Dr. Robinson two or three weeks ago, if he would be interesting to connect the anemometer; on some occasion when the wind was blowing a gale, with a chronograph which he has used for his experiments, of which I shall have more to say presently, and he at once took the suggestion, but there was no gale for a good while. At last a moderate wind came, and only last night I received from the results which he had obtained by connecting the anemometer with the chronograph for about 45 minutes during which the wind was blowing pretty strong. I have here a table which he has given me, containing the velocity at different intervals of time extending over a few seconds, 7 seconds, 30 seconds, or 40 seconds, during which the record of the instrument was preserved, and these numbers show how very irregular the velocity is. The mean velocity registered during that time was 22.567 miles per hour; the individual velocities are all up and down. Omitting the decimals, I read here 17, 14, 12, 16, 15, 24, and so on.

16,224. Except that it varies between 24 and 3?—Yes. It would make a considerable difference in the pressure, as inferred from the velocity, whether you accepted one or the other; one would only give 64 per cent. of the other. It is remarkable that in a paper by Mr. Stokes, published in the first volume of the "Quarterly Journal of the Meteorological Society," devoted to a comparison between large and small anemometers, it is shown that if we strike out the light winds and attend only to the winds higher than such as to give a velocity of 20 miles an hour on the mean or the gale, the registration as given by the small pattern anemometers proceeds exactly according to the same law as is given by the Kew standard; but taking the average it comes to only about 76 per cent. of what would be registered by the Kew pattern with the factor 3. It is very curious that that agrees almost exactly with the result of Dr. Robinson's Dublin experiments; if you accept the factor published in the Philosophical Transactions of 1878, 33, which would make it 76.2. At the same time, I have already remarked that the more recent researches of Dr. Robinson led him to put the factor higher than that. In deducing the pressure from the velocity, there is the difficulty first of dealing with the velocity as for very short intervals of time—a difficulty which would easily be overcome if desired, but there exists a difficulty with reference to past results. Secondly, there is the difficulty of dealing with the proper factor as connecting the velocity of the cups with the velocity of the wind. I think now we cannot be very far off from meeting that difficulty. I believe, but I am not quite sure upon this point, that the anemometers with which Dr. H. Robinson formerly inferred 3 to be the factor, were of what you may call a small pattern; certainly that was the case with the anemometer used by Mr. Glazier, the cups of which were 3.75 inches in diameter, the radius of the arm being 6.72. Mr. Glazier's experiments are referred to the factor 3; and, according to Mr. Stokes's observations, we infer ought to be the factor for the large Kew pattern, as I said, we get almost the same figure that results from Dr. Robinson's Dublin experiments, which, however, he is disposed by his more recent investigations to increase. Then there is another point to consider, as to the exposure of an anemometer. Of course, at the time of the experiments which were carried out at Rathmines, just at the outskirts of Dublin, by means of a whirling machine in a large dome erected by Mr. Howard Grubb with a view to the great telescope which he has in hand. The result of those experiments led to a lower factor than should be in an open pattern with cups of 9 inches, and arms of 48 inches across. The figure which Dr. Robinson has given in the "Philosophical Transactions" for 1878, at page 816, is 2.286. That is given not absolutely, but as an approximation to what those experiments gave.

16,228. (The Commissioner.) And there were some disturbing forces there?—Yes, there were several disturbing forces there; but, making the best estimate he could, he arrived at that figure. It must be accepted of course, with some latitude for error in consequence of the disturbing forces. I should mention that the anemometer used was one which had flat arms specially adapted to cut the wind; and if the arms of the cups were round tubes, the factor ought to be slightly higher. I should think we should not be far out if we took it at 2.4 on the strength of those experiments. That would reduce the real velocity, as estimated by an anemometer of the Kew pattern, to 3. I suppose the factor 3. Since then, however, Dr. Robinson has been further carrying on his researches, and in letters to me, which I have recently received, he is disposed to put the factor higher than that resulting from the experiments in Dublin, more nearly approaching the old factor 3. But those more recent researches are still in progress, and I do not think that any figure can yet be given as final.
course of the wind by the cliff, so that that would not be a fair measure of the wind which we experience out at sea.

16,225. Except when you are close upon the edge of the cliff then you feel no wind?—When you are a little behind you are in a calm rush, but if you stand looking down you experience what I have mentioned; the wind glances off at the edge of the cliff.

16,226. (Mr. Trayner.) I think, if I have followed you right, I may take it from you in this way: the relation between the velocity and the pressure of the wind tested hydrostatically would be in the proportion of the wind, to a square foot, with a velocity of 20 miles. —In round numbers.

16,227. And that the pressure ascertained by a pressure plate would be with the same velocity; the pound you have previously given with 80 per cent. added according to Dr. Robinson’s experiments. —Dr. Robinson did not make any experiments upon that subject.

16,228. It was 80 per cent. according to some authority you gave, and 150 per cent. according to Sir Henry Hughes—I take 80 per cent. as a sort of average of different authorities.

16,229. And with the pressure plate you have with 20 miles of velocity one pound and 80 per cent. added? —Yes.

Examined by Mr. Biddler.

16,231. (Mr. Biddler.) I do not feel equal to measure swords with my old master, and I therefore ask questions as a learner as I have done in former years. I think I have followed your interesting explanation, and, so far as I understand it, it is this: the pressure upon a plate is greater than what you denominate the standard pressure, principally because of the absence, or rather the diminution of pressure at the back of the plate, there being a partial vacuum at the back of the plate?—Very much, and perhaps principally in consequence of that.

16,232. And that is attributable mainly to what you have described as the eddying action of the wind round the edges of the plate, sweeping on with it, as it were, the air at the back of the plate drawing it on or sucking it on with it? —That is the best explanation of it. I can give in my own mind. I do not say that I positively affirm that it is so.

16,233. That being so, would not you rather expect that an action of that kind diminishing the pressure at the back of the plate would not increase in proportion to an increase in the area of the plate? It is an interfering action at the edge of the plate, and it would only have effect for a certain distance; in; therefore if you took a much larger plate you would not get a proportionate loss of pressure over the whole back area of that large plate?—That is a point on which I should hardly like to express an opinion on theoretical grounds; it is a point with respect to which it is very desirable to make experiments; but, at the same time, this answer is to be remembered, that if you have a small plate you will have small eddies, if you have a large plate you will have corresponding large eddies.

16,234. Would that be quite so without limit. Suppose the wind is blowing past the edge of a wall, would the size of the eddies depend on the length of the wall? —I was rather considering the height of the wall.

16,235. I was considering the lateral eddy where the wall came to an end. Suppose it were blowing past the end of the wall, the size of the eddy would not depend on the length of that wall. It might within those limits, I agree?—No; but I suppose this book represented a very large pressure plate, and this piece of paper a comparatively small one, you would have eddies at the back in both cases. Here, no doubt, the derivation of the wind is very much greater, and the eddies would be formed on a much larger scale than they would be here; but whether they would be on so much larger a scale as to be in proportion to the larger size of the plate is a matter which we would hesitate to express any opinion about theoretically.

16,236. It is a matter upon which we have not sufficient observation to be able to form a definite opinion?—I am not aware that we have.

16,237. It is quite possible if we had extended observation we might find that the per-centages of increase over the standard pressure would become smaller as the area of plate increased?—It is conceivable that it might become smaller. If I were to speak at a guess, but it is little more than a guess; I should rather expect that it would become somewhat smaller. At the same time I must say that in some experiments that I was looking into last year a statement was made that on a larger plate the pressure per unit of surface was somewhat larger than on a small plate; it is the reverse of what I should have expected.

16,238. It sounds apocryphal?—It is the reverse of what I should have expected, but at the same time I feel that the subject of the formation of these eddies is one on which we can say we have very little a priori that we should have to appeal to experiment.

16,239. It is quite possible that the factor of increase may become smaller as the area increases, and in the limit, going to a plate of infinite area, may vanish altogether?—I should not think that.

16,240. I mean taking the comparison between the pressure on the plate and the standard pressure; the increase may become so much smaller as the area increases that in the limit with an infinite plate it might vanish so that the one was equal to the other? —Yes, the thing is conceivable; but the theory of these eddies is so very patent that I should not like to express any opinion upon that matter.

16,241. I think I correctly understand you that when you express an opinion that the pressure will approximately increase with the area that you are assuming that the wind itself is blowing uniformly over the whole area?—Yes.

16,242. You are not intending to express any opinion as to whether pressures observed locally do in fact exist simultaneously over large areas?—Quite so; I do not express any opinion upon that.

16,243. Have you formed any opinion upon the question which is touched upon in the Astronomer Royal’s Report which I read, as to how far you may safely infer from observed pressures that what we may call points for this purpose, the pressure that may be taken as the mean pressure extending over large surfaces?—I have no experimental evidence to bear upon the subject, but from general considerations I should imagine that in a clear open space these velocities would have a considerable lateral extent. Of course, in particular situations, you might have narrow gullies, where the wind was pent up, and a stream of wind comparatively narrow came out from that; or you might have a big rock, or a small abrupt hill, where there would be rapid eddies at the corners or edges; but in an open space I should not imagine (though I have unconvincing evidence upon which I rest my opinion upon the subject) that those high velocities would be found in portions of a very limited extent only.

16,244. I have no doubt you have observed, as we have all observed, if we have happened to be out on a lake in squally weather, little patches of violent agitation caused by the wind sweeping over a portion of the surface of the lake, covering only an area or a few square feet? —Yes, what we call cat’s paws.

16,245. If you watch the wind sweep across a cornfield you see the same thing?—Yes.

16,246. I take it that the anemometer in a plate on one of those cat’s paws would register much more highly than one out of it?—Of course, but those are good large gulls.

16,247. Sometimes they are large, and sometimes small?—You may have a little eddy on a small scale.
But, I should remark, as bearing on what I said just now, that very commonly a lake is in a mountainous country, the wind is rendered irregular by the hills and cliffs; of course that makes a difference.

16,248. I want to see how far your views are in accordance with those expressed by the Astronomer Royal. I will just read to you a paragraph from that letter which I quoted to him: "We know that upon the surfaces of the earth wind is limited by the boundary of the place or year, and that the presure of the wind does amount sometimes to 40 lbs. per square foot, or in Scotland probably to more. So far as I am aware, our positive knowledge of this is derived from instrument records, and goes to prove nothing further. But in studying the registers it is impossible to escape from the conclusion that there are exceptions. The moment I am certain that they arise from some irregular whirlings of the air which extend to no great distance." How far does your observation and judgment carry you along with those views of the Astronomer Royal?—The time scale of the ordinary pressure anemometer as a matter of convenience is so contracted that you cannot very well study the extent of time over which these high pressures are found to range. Mr. Oster was so kind as to show me last night some records which he has recently obtained with his pressure plate on a very open scale. Those, however, were made in only one or two columns. There he sees the great gale which with which to make experiments quite recently, and therefore I do not know how far they are applicable to the very heavy pressure belonging to a great gale. The pressure showed very considerable ups and downs even in the course of a short time. One can only judge, I think, in defult of experimental evidence, of the ordinary experience of guffs of wind. If you are in the open air, and you put out your hand, you have some idea of the way in which the velocity and pressure of the air vary. A very heavy gust will not be a mere momentary thing, though it will not be of any great duration ordinarily, but sometimes perhaps it will go on for two or three minutes blowing very heavily indeed.

16,249. We are accustomed to notice that it is very frequently very limited locally.—With regard to these very heavy gusts if you take the records which you read in the newspapers, and especially of the track of a storm through a wood, I think ordinary experience of guffs of wind. If you are in the open air, and you put out your hand, you have some idea of the way in which the velocity and pressure of the air vary. A very heavy gust will not be a mere momentary thing, though it will not be of any great duration ordinarily, but sometimes perhaps it will go on for two or three minutes blowing very heavily indeed.

16,250. (The Commissioner.) Some hundreds of yards?—Yes. (Dr. Bidder.) I am glad you have mentioned that, because allusion has been made to that before; you have seen accounts of such storms in this country and in Ireland.

16,252. Are not those storms in America of which we have heard, in the nature of storms, quite different from those with which we are discussing here? The same sort of thing on a big scale as we see on a small scale when the wind whirs up a column of dust, and sweeps it up in a straight line?—For all I know to the contrary they may be.

16,255. Is it probable that that is so, is not it?—I should suppose it is not unlikely it may be so, but I do not know.

16,256. If so, of course all the breadth of the track of devastation would be the breadth of the diameter of the rotating column of air?—The heaviest part of it, no doubt; but the breadth can only be inferred, in default of instrumental measure, by the breadth of the track of devastation. Those pressures of the maximum pressure which you mention, would depend on the length of time during which that high pressure lasted, which is a point respecting which I do not think at present we know very much, on account of the contracted time-scale of the anemometer.

16,257. Perhaps, if you can answer me another question, I might be in a position to answer you that question. Can you tell us what produces the violent fluctuations of wind which are exhibited within a few seconds, according to the results of the experiments that you gave us?—I should mention that those were selected seconds; they were not all continuous. Those variations from the mean apparently were but of brief duration, and they were produced, no doubt, by pressure and pressure changes, by the anemometer with which they were recorded. I should say, was erected on the roof of a house, though at some moderate height above the roof.

16,258. Bearing upon that there is another observation of the Astronomer Royal in his report which commanded itself to my mind; I do not know whether it commended itself to your mind; he says that these exceptional pressures he believes to be momentary and due to "irregular whirlings of the air which extend to no great distance. I should say certainly to no distance comparable with the dimensions of the proposed bridge," (that means no distance comparable with 1,600 feet); "and the fairest estimate of the pressure on the entire bridge would be formed by taking the mean of the recorded pressures at one point of space for a moderate extent of time as representing the mean pressure upon a moderate extent of space at one instant of time." I gather him to mean there that where you have rapid variations in velocity within a short space of time, you may infer rapid variations of velocity within a short interval of space also; to put it in other words, where from the anemometer that you know you have large variations of velocity longitudinally in space, you may infer that if you had a material change of velocity going on for so long as half a minute, it would extend over a considerable space laterally.

16,259. Mr. Bidder. I should like to know how far you agree with the Astronomer Royal when he says that 40 lbs., or possibly more, in Scotland is the extreme pressure. I suppose your experience is pretty much in accord with that so far as the fact is concerned.

(Mr. Barlow.) I take that to be at Greenwich.

(Mr. Bidder.) He says "40 lbs., or in Scotland "probably more." I infer he means 40 lbs. in England. He says, "Adopting this consideration, I think we may say that the greatest wind pressure to which a plane surface like that of the bridge will be subjected on its whole extent is 10 lbs. per square "foot." I will not trouble you about the capacity of that bridge to resist the pressure; that has nothing to do with the question; the opinion of the Astronomer Royal is, that, assuming you have a record of 40 lbs. per square foot (or possibly more in Scotland) at a given point, the greatest mean pressure you can have over a plane surface equal to the bridge he was discussing, which was 40 feet high, with two spans of about 1,800 feet each, is to be taken at 10 lbs. to the square foot, or a quarter of the maximum; do you agree with that?—Very much, no doubt; and I should think that it would depend on the length of time during which that high pressure lasted, which is a point respecting which I do not think at present we know very much, on account of the contracted time-scale of the anemometer.

16,260. The Astronomer Royal does not profess to know more than you do upon the subject, and he has given his reasons, and he says, "I know there are..."
such pressures as 40 lbs. and 50 lbs. to a foot. I believe those are due to momentary whirlings of the air, and that, taking a plane surface of the extent of 1,500 feet by 40 feet, I believe the greatest wind upon "that would be 10 lbs. to the foot." How far does your judgment go along with that?—That seems to me a low estimate, I must say. With regard to those squalls, I have no direct observations to furnish. I can only imagine myself looking at the surface of a sheet of water and watching the cat's-paws. I think that those cat's-paws, as I say, would be big paws, and would extend over a good portion of the structure of such a bridge as this which we have to deal with. I have 'no information but what is open to the public.

16,261. You think that the Astronomer Royal's estimate of the mean pressure is a little lower than you would have put it at yourself?—I should not have ventured to put it so low.

16,262. You would agree with me that any engineer is to be pardoned who regarded the opinion of the Astronomer Royal as of very great weight.

Mr. Balfour objected to the question.

Mr. Bidder withdrew the question.

(Mr. Bidder.) I suppose nobody is better able to form an opinion upon a question of that kind than the Astronomer Royal.

Mr. Tuenyer objected to the question.

The Commissioner intimated that the question might be put.

(The Witness.) The question, as I understand it, struck me as being one more appropriate for a jurymen than for a witness. Everybody knows that the Astronomer Royal's opinion upon such a subject is a very valuable one, and entitled to all due consideration.

16,263. One question upon another matter. I do not know whether your attention has been drawn to it, or whether you have had an opportunity of giving it considerable thought, as what relation, or what difference, if any, there is between the effective pressure of the wind upon the area of a surface travelling transversely to the direction of the wind as compared with its effective pressure on an equal area at rest. I do not mean the more question of resolution of the velocities, but whether the wind has more or less effect upon the area of the surface of a body in motion than it would have on the surface of a body in motion from the resolution of forces?—Let us take a simple case of wind blowing uniformly over a large extent of space, and let us take a body moving through it as against a body at rest.

16,264. A body moving transversely to the direction of the wind at right angles to it?—In such a case, of course, you may imagine a velocity equal and opposite to that of the travelling body, impressed both on the travelling body and on the wind; the relative velocity and the relative direction of the wind, of course, would be different from the absolute velocity and the absolute direction.

16,265. I was not desiring to trouble you with a matter so elementary as the resolution of velocities?—In anticipation of some such question as this, I prepared a diagram, drawn from a little roughly from data furnished by Mr. Hutton, as to the lateral pressure of the wind on a plane placed more or less obliquely to the direction of the wind. I take the case of wind blowing with a velocity of say 100 miles an hour, and a body, say a train, moving through it with a velocity of 40 miles an hour, and regarding the train as a flat plate exposed perpendicularly to the direction of the wind, which is here. Here are two ovals; the radius of this blue circle represents the pressure of the wind impinging obliquely upon the surface. This I suppose to be the direction in which the train is moving. The radii of these ovals represent what, according to Mr. Hutton, would be the relative pressure produced by the wind blowing in the direction of the radius of any point. The radius of these red ovals represents what would be the lateral pressure, supposing the relative velocity to be in the direction of the radius of one of these points. It turns out that the maximum increase of lateral pressure produced by the motion of the body is about 24 per cent.; that is, the force of the wind is blowing uniformly over as large an extent as you please.

16,266. I am not quite sure that I quite understand that 24 per cent. is the maximum increase of pressure upon a body in motion at the speed you mentioned?—Lateral pressure.

16,267. As compared with a body at rest—is it due simply to the resolution of the composition of velocities, or is it due to other causes?—It is due to the composition of the velocity.

16,268. And it is 24 per cent. more upon a body in motion?—Yes.

16,269. The point I was asking you to direct your attention to was another one. Apart from that, have you considered whether a body in motion is not subject to greater reflective pressure. I will put an illustration to show what I mean. When you expose an area to the wind, a plane surface, probably as we see in a stream of water where we can see what the fluid is doing, the air makes a bow, so to speak; there is a wedge-shape cushion of air in front of the surface which deflects the air on each side of the plate. I ask you whether that does not, at some extent, lessen the pressure, and whether that effect is not produced in the case of a body moving transversely to the motion of the wind?—It comes to much the same thing, as it seems to me, as if you had the wind impinging obliquely instead of directly.

16,270. It comes to no more than a resolution of the velocity?—I do not see that it does. I have not contemplated the case of an isolated stream of wind going through quiet air as a case.

16,271. One other matter with reference to observations taken by the cup anemometer. I gather from your evidence that they are not very reliable for extreme accuracy unless you know the whole history, so to speak, of the particular anemometer: that the factor varies from 2.29 to 3. In order to turn the velocity of the anemometer into that of the wind it depends upon the relations of the arms and ends of the anemometer and on the friction and various other matters, which may vary in one instance and another, and also upon the position?—Yes, I should say that the anemometers used in connection with the Meteorological Office are all of curious forms, and they are carefully made so as to have as little friction as may be. Of course if an anemometer has got friction which it ought not to have, the registered velocity would be under-estimated. I do not think there is any danger of its being over-estimated by the anemometer. If we take the lowest of those factors, which Dr. Robinson has given, it means that the anemometer is free, but it would not be over-estimated. Then, as I said, what you can get with certainty from the anemometer is the mean velocity over a time long enough to give you a space on your time-scale big enough to measure with certainty from.

16,272. What do you assume as the relation between the lateral force of the wind, that is, the normal force on a plate, and the angle at which the wind is incident?—I have taken what Mr. Hutton gives as the result of his experience, and worked the thing out graphically. I did not use a formula.

16,273. Can you tell us what observation shows to be the rule. Given a wind impinging not perpendicularly, but as at a certain angle, what is the relation between the angle of the wind, I have drawn a figure of the lateral force?—Mr. Hutton has given an empirical formula, which I have not in my head, connecting the two.

16,274. What does the red mean in your diagram?—The radius of the red line represents the lateral pressure for a wind blowing in such a direction that the relative velocity is the larger radius; so that the most formidable direction of the wind when the body is in motion is not exactly lateral, but in a certain degree, 10 or 15 degrees, inclining towards a head wind.

16,275. What do you assume the velocity of the
body to be.—Forty miles an hour, and the velocity of the wind I take at 100 miles an hour.

Further examined by Mr. Thayner.

16,276. The suggestion that is made is this: Given a fixed body against which the wind is blowing at right angles, having ascertained in the way you told us a little while ago the velocity of the wind, we then come to the question of the pressure per square foot. Given that fixed body, the suggestion is that there would be a certain recoil of the wind after it struck the fixed body, which might affect the further pressure of the on-coming wind on the fixed body originally struck. If the body, instead of being fixed, is in motion, then it is suggested that that recoil would not be there, but that there would be a series of impacts without recoil at all as the body advanced transversely through the stream of wind. Can you tell me whether the pressure on a body under those circumstances would be greater when moving than it would be when stationary?—The question is not, in my mind, cleared up by considering it as one of recoil; in fact, the wind impinging upon a body is not to be looked at in the same light as the gas resulting from an explosion of gunpowder fired out of a gun; we have a continuous flow; and it seems to me that the simplest mode of looking at it is to regard it as a continuous flow, and so regarding it the result of theory is what I have expressed upon that diagram.

16,277. As I understood your description, to which I was attending to the best of my power, the result you came to was rather that the pressure on the moving body would not be greater than the pressure upon the body when stationary. That it would be greater by about 34 per cent, is supposing the direction to be in both cases what is most favourable to the production of pressure; as regards a head pressure the difference would be very much larger.

16,278. Assuming that the pressure which is brought to bear upon the fixed body is at right angles, and assuming the wind to be pressing down in an equal strain as you have described it, upon that fixed body, say for a quarter of an hour, would there be less pressure at the end of any part of that quarter of an hour upon that fixed body than there was when the pressure began?—Do you mean that the pressure began quite suddenly as if the wind had been fired out of a gun?

16,279. I am assuming the uniform pressure over the whole of the fifteen minutes.—If the velocity is uniform, the pressure will be uniform. It is not the fact that the mere fact of the object that is pressed on being stationary does not, in your mind, reduce the pressure that is brought to bear upon it at any time within the period when the gust of wind that is bringing the pressure is uniform.—No.

Examined by the Commissioner.

16,281. Supposing, for instance, there is a stream uniform in velocity across its whole width, and you take a plate and sink it down in that stream, and you get a certain pressure upon one side of it by the force of the stream, is there any greater or less pressure upon that side if that plate is in motion? Would there be if it was moved right across the stream? Would there be any greater pressure upon the side of that plate if moved across the stream if it was held in the middle of the stream at rest?—There would be a greater pressure, as I explained, and as shown us in that diagram, in consequence of the resolution of the velocities.

16,282. But nothing else.—Nothing else, so far as I perceive.

16,283. Only from the resolution of forces?—Yes.

16,284. In fact, what they call in the navy bringing the wind about?—Yes, increasing the velocity in certain directions of the wind.

16,285. It is said in that memorandum of the Astronomer Royal's that the gusts are momentary and of very limited extent; by momentary do you understand that means that they only last for a moment or an instant of time?—Of course that means a certain definite time; but what he would consider momentary, is, of course, more than I can say.

16,286. You would not take it to be a simple instant of time. And I understand you to say you consider that the lateral extent of the storm would be in proportion to the duration of the gust?—Roughly.

16,287. Supposing as gust lasted for half a minute, then you could conceive that it would have a lateral extent in proportion?—Yes, I should consider it would not be very narrow in such a case as that.

16,288. Supposing, for instance, that the storm had a velocity of 120 miles an hour, or say 60 miles an hour, which is a considerable velocity, in half a minute it would go half a mile?—Yes.

16,289. Then you can imagine if it had a longitudinal extent of half a mile, it might have a lateral breadth of half a mile?—Of course it might, but it would not necessarily have it. I should compare it in my own mind to the eddies at the bottom of a stream; if these eddies are very narrow, as the stream flows they will last but for a short time over any point at rest; if they are of greater extent they last longer.

16,290. You instanced also the eddies that were made through woods of which we have heard, and you were asked whether or not that might be the result of cycloidal storms; but cycloidal storms may occur in this country, may they not?—Yes.

16,291. And they do occur?—And they do occur.

16,292. And we have got plenty of instances of them?—Yes.

16,293. (Mr. Bidder.) I was not aware of that.

(The Commissioner.) There are plenty of cycloidal.

(Mr. Bidder.) Every storm is a cycloidal storm in one sense.

16,294. (The Commissioner.) You said that 20 miles, you thought, would give an approximate pressure of 1 lb.?—What I called the standard pressure.

16,295. And you have assumed that, I suppose?—Yes.

16,296. Then what would be the relation between the velocity and the pressure?—I believe it is as the square of the velocity, a velocity of 60 instead of 20, that being three times as great, would give you a pressure nine times as great.

16,296. (Mr. Bidder.) 100 miles an hour would give you 25 lbs. to the foot?—For the standard pressure.

16,297. (Colonelolland.) That is rejecting Sir Henry James' formulas?—No. I explained that the standard pressure must not be confounded with the pressure per square foot on a plate, and it is that latter which Sir Henry James' formulas apply to.

16,298. You see no reason to doubt Sir Henry James' formulas?—I should suppose that it might be put a trifle too high, but that is all.

An adjournment took place for the usual period.

Mr. Robert Henry Scott, M.A., F.R.S., sworn.

16,301. And you have been desired to make up a statement of certain details which these registers so communicated to you afford?—Just so.

16,302. There is no anemometer at Dundee, is there?—No.

16,303. But you have one placed at Glasgow, and...
TAY BRIDGE DISASTER:

Mr. R. H. Scott.

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one at Aberdeen, from which you have regular reports?

—Yes.

16,304. With reference to the storm which took place on the 28th of December 1879, I want you to give me what has been communicated to the Council as the readings (if I may so call them) of the anemometer first at Glasgow and I have laid before the Meteorological Society in London a short report on that storm, which is printed in their Quarterly Journal, vol. vi. p. 98, and it may save the time of the Court if I simply quote from that report.

16,305. You have the results from Glasgow on the evening of the 28th of December; just tell me what results you have of the velocity of the wind at different hours as taken from the Glasgow instrument?—The greatest number of miles which were registered in any 60 consecutive minutes (which need not be exactly from one hour to another) was 71 miles at Glasgow, between 20 minutes past 6 and 20 minutes past 7. That being the time when the instrument had stopped for that time is here in my hand. I have also with me records of several other storms.

16,306. That is the greatest amount of velocity in any one hour during that storm?—During that storm.

16,307. Of course you have a greater velocity than 71 miles an hour at different periods shorter than an hour?—Certainly.

16,308. Will you look at the statements at the foot of the first page of your report, and let me get on the notes here the result of that. You estimate the hourly results for winds at different hours at Glasgow as follows:—From 6.25 to 6.30 p.m., 96 miles per hour; from 6.30 to 7, 72 miles per hour; from 7.15 to 7.18, 120 miles per hour; from 7.30 to 7.35, 84 miles per hour; from 7.45 to 7.50, 96 miles per hour; and from 8.45 to 9.45, 110 miles per hour?—That is so.

16,310. Can you give me the velocity at Aberdeen?—Between 7.15 and 7.20 eight miles of wind passed Aberdeen, giving a velocity of 96 miles per hour for those 5 minutes.

16,310. Is that the only record that you have from Aberdeen of the velocity on that night?—I have the entire records, and the tabulating scale from which those were obtained. The tabulating scales are glass, which the court may justify for themselves. I do not know whether I should be unduly taking up the time of the Court if I gave a description of the form of the instrument. Here is a tabulating scale for an hour, and here is also a tabulating scale for a five minutes interval. With reference to these very high velocities, I have expressly stated that I protest myself against its being supposed that I can absolutely swear to these, because any irregularity of the instrument for a minute might produce a similar disturbance to that due to a squall. There is a good deal of doubt about those.

16,311. I was not asking you whether they were accurate, but whether they were the records that were transmitted to you from Glasgow. Have you anything to indicate the wind pressure, or is there any other instrument under your control, or the result of which is communicated to you, showing the wind pressure?—No.

16,312. We have to gather that in the best way we can from the relation of wind pressure to wind velocity?—In the Meteorological Office we habitually use Sir Henry James's table.

16,313. What is the greatest known velocity of the wind registered in this country, of course within comparatively late years?—Am I to understand that you mean the greatest velocity of a gust, or the greatest mileage run over in 60 minutes, those 60 minutes being 60 minutes of an hour, and not any chance 90 minutes?—Yes.

16,314. I will take them both?—I can answer one, but not the other. I would give 83 to 84 or 85 miles as having been repeatedly reached during an hour.

16,315. (The Commissioner.) That is to say, from one definite hour to the next definite hour?—Yes.

16,316. (Mr. Frayne.) That is the highest recorded velocity of the wind over any consecutive 60 minutes?—Yes, within the last 13 years.

16,317. I see that you have in the report the velocity of the wind at Aberdeen from 7.15 to 7.20 on the night of the 28th of December, which was the time, I think, when the bridge went over; looking at what the velocity was at that time, and at what the velocity of the wind at Aberdeen was at that time, and looking to the geographical position of those two towns in relation to Dundee, can you form an opinion as to the rate at which the wind was travelling over the valley of the Tay at 7.15 or thereabouts that night?—I could not swear to that.

16,318. On the 18th December the wind was 71 miles an hour, at what place?—I know that on that night it blew hard in Scotland. I know from one or two reports which I have got (not from the neighbourhood of Dundee, but from the west coast of Scotland) the damage which the gale did; but I have no absolute statement from any person, and certainly no instrumental statement from any person actually in Dundee, as to what the force was. I could not estimate what the force was, without being at Dundee, and I have never been there.

16,319. Then you cannot answer the question, that I put to you?—No.

Examined by Mr. Bidder.

16,320. I should like to understand first how these records show the velocity of the wind?—If the Court will allow me, I will show the geographical lines, which are hour lines, and horizontal lines, which show mileage. If the trace travels from the top of the form to the bottom within the space of one hour, 50 miles will have been travelled within the hour. If it travels further, more than 50 miles will have been travelled in that hour. (The witness explained the record to the Court.)

16,321. So far as I follow your explanation of the mode in which the velocity is ascertained, I think it rather confirms what Professor Stokes told us before luncheon, viz., that for velocities travelled during short intervals, such as two or three minutes, you cannot rely upon the measurement for great accuracy?—That is what I have stated.

16,322. May I take it also that there is a good deal of ground to believe that the extreme velocities marked are very local and partial in their occurrence?—We have not evidence of that. We have no series of anemometers placed at 20 feet apart along a girt like this, which would enable us to state that.

16,323. It is quite clear that you have no evidence, of another kind. I see, for instance, in your report, a copy of which you have been good enough to furnish me with, that you point out that "On February 20th, 1777"—of course, that is not 'Tay Bridge one'—the Holyhead anemograph registered 92 miles an hour for two consecutive hours, and during the gust the velocity was at least 200 miles per hour. How do you know that?—By the same measure.

16,324. With the same inference from the short period?—Yes, and with the same doubt thrown upon it.

16,325. Then you say, "On November 16th, 1777, the Sandwick anemometer registered 88 miles in 60 minutes, and in this case also the gust must have been very heavy; a two minute trace gives an hourly rate of 180 miles, and a four minutes' trace, one of 120 miles." And then you add, "It is not a little remarkable that these very high velocities at Holyhead and Sandwick did not do material injury to buildings situated close to the respective anemometers"—it is perfectly true. The photograph of the Sandwick anemograph which stood that gust of wind, shows that it is an ordinary Scotch mason's house, and it was not particularly knocked about by the wind.

16,326. May I take it that it was a building which would literally have gone to the winds if a correspond-
ing pressure had been applied over the whole surface—
I have not calculated that, but I know that an ordinary
pane of window glass has been tried, and that that
will bear a pressure of 80 lbs. per square foot upon
it uniformly distributed. That was tried at the time of
the reasoning about the upsetting of Cleopatra's
Monument.

16,327. I should have thought by the look of the photograph that the building in which the anemometer
exists would not have had much chance. According to
Professor Stokes's formula, there must have been a
pressure of at least 80 lbs. to the foot upon that
building, and probably a good deal more. I see that
you have given us in this report an account of the discussion at the Meteorological Society which followed, and
I observe that there is an interesting fact mentioned
by Mr. Whipple in connection with this subject, which
seems to illustrate what I have been asking you about.
He says that, "As an example of the effects
"of gusts, he had recently upon the roof of the New
"Observatory a massive wooden tripod with heavy
"iron top, but loaded at the base with sufficient
"weight to keep it steady, and probably necessitate
"the strength of three men to overturn it. A gust
"of wind blew it down, although the anemometer,
"a few feet distant, failed to register a higher velocity
"than 30 miles in the hour in question."—I have
"read your statement to Mr. Whipple has not calculated
"from the record whether for two or three minutes
"there was a higher velocity; he has taken it over the
"whole hour in question; and such gusts as that for a
"short period, of course, as every one knows who has
"any experience, do occasionally occur on calm days.

16,328. I take it you can give me other instances where the same thing has happened in narrow widths, and
when it has been comparatively calm in the neigh-
bourhood?—I hand in photographs of the whirlwind
at Walmer, October 24th, 1875 (producing them).
Of course these whirlwinds are not very uncommon in
these islands, but they are not so common here, because
the contrasts of temperature are not so strongly marked as,
for instance, in the United States.

16,329. What was the whirlwind at Walmer?—A
whirlwind swept across inside Dover; it came over
the town of Walmer. Most of the things that were in
its way simply disappeared and were carried out to
sea, and half the houses were broken away. These
photographs give you a better idea what this sort of
thing can do.

(The Commissioner.) What was the lateral extent
of that?

16,330. (Mr. Bidder.) Judging by the picture it looks
to me about 60 feet?—The statement as to that made
by Mr. Symons in his Meteorological Magazine is that the breadth of the track was in no
place less than 450 feet, and in no place greater than
700 feet.

16,331. (The Commissioner.) It varied from 450
feet to 700 feet?—Yes. Copies of these photographs
can easily be procured, and I shall be very happy to
present them to some of your hon. friends.

(Mr. Bidder.) Have you formed any judgment
upon the question upon which I examined the
Astronomer Royal and Professor Stokes this morning; that
is to say, whether the opinion expressed by the
Astronomer Royal in his report of 1873 is not a well-
known one, that these very high pressures are due to whirlings of the atmosphere, and
are momentary, and cannot be taken as pressures that will exist simultaneously over an area of some hundreds
of feet?—I am disposed fully to agree with the
Astronomer Royal as to these pressures being momentary. As to their being whirlings the records do not
prove us in the case of such whirls as those of the
sea. Whirling implies change of direction, and there
is no change of direction.

16,332. And being momentary, they are also prob-
ably very local?—That may or may not be. I would
not say that they were always very local.

16,333. But the probabilities are in favour of their
being local, are they not?—I think I may very
probably be able to give the Court some information
about this identical storm from the west of Scotland.
What I should understand by its being local would
be that it was some hundred yards in width.

16,334. You were probably in the room this
morning when I read the report of the Astronomer
Royal in which he says that he considers that the
momentary (taking the word in its natural sense of
cause), and infer that they are local in extent, and that,
notwithstanding there are such pressures at
particular points, he does not anticipate that over an
area such as that of the Forth Bridge, which was
about 1,800 feet in span, you would expect a maximum
pressure of more than 10 lbs. to the foot. I am
perfectly unable to offer any opinion upon that subject.
I consider that the pressure would be over a consider-
able extent of the span, if not the whole of it. I
consider that an excessive pressure would be exerted
over a very considerable portion.

16,335. You would expect, would you not, that the
larger the area that you took, the less would be the
mean pressure over it, and that you would have a less
crude maximum?—I consider that the points for the
wind are not mathematical points, but areas of
considerable diameter.

16,336. The opinion of the Astronomer Royal, be
it a well founded one or not; is this: That although
you may have from 40 lbs. to 50 lbs. upon the
anemometer, yet, taking an area such as the Forth
Bridge, you cannot have over the whole of that an
aggregate pressure of more than 10 lbs. How far do
you agree with or differ from that view?—The state-
ment that I have myself published on the same subject
is in a paper which is inscribed in the second volume
of the "Quarterly Journal" of the Meteorological
Society, and it is this: "It appears to me that the
extravagant record of the pressure of 90 lbs. per
square foot recorded at Bulston, observed on the
9th of March 1871, may have been a correct indica-
tion of the force exerted on the plate, but not of
the "violence of the wind at a distance of only a few feet
from it."

16,337. That seems to be a valuable paper, because
I see you say that the pressure in storms is evidentlly
exerted in distant and separate gusts, each affecting a
limited superficial area?—Some of the records appear
to prove that.

16,338. Because you say it is inconceivable that if
the pressures which are sometimes recorded by our
instruments were felt over the surface of a wall or
chimney, the structure could stand?—That is what I
think.

16,339. When you say that these extreme pressures
are local, you mean that they may be felt on the instrument though they may not be acting upon chimneys
within a few feet of it?—That is as far as we
know; we cannot be sure.

16,340. You do not mean local in the sense of half
a mile in breadth, but local in the sense of a few feet
in breadth. I see you go on to add that you have been
yourself a witness of the way in which they may be
done in storms to individual trees or buildings, while
objects adjoining them escape comparatively uninjured;
that is a matter of common observation, is it not?—It
is. Certain trees are picked out, and others stand.

16,341. So that if the anemometer be in the beat of
the storm, so to speak, with all its facilities and high
pressures, these very high pressures do not exist except over an area of a few feet?—That
may be so, but it does not prove that the pressure a
few feet off may not be greater.

16,342. Then I see you quote a case which you
have already mentioned, that the extraordinary record
of a pressure of 90 lbs. per square foot recorded at
Bulston, observed on the 9th of March 1871, may have
been a correct indication of the force exerted on the
plate, but not of the violence of the wind at the
distance of even a few feet from it.

16,343. (Mr. Barlow.) Was that pressure of 90 lbs.
deduced from the velocity?—It is the actual instru-
mental record of the pencil of one of Mr. Oslter's
anemometers. The instrument was graduated up to
40 lbs., and the pencil was driven on beyond a distance that was estimated by Mr. Hartung, the average length of a 50 lbs. wind. 16,344. (Mr. Biddulph.) I see you also quote this pertinent fact: "This statement receives strong confirmation from the following remarks by Mr. Blanford: in a paper on the Climate of Bengal, just published, where he says, 'The highest (pressure) that has been registered in Calcutta by an Osler's anemometer is 60 lbs. to the square foot, but this was in a storm of no remarkable violence, and one which did but little injury in Calcutta.'" That is to say, an extraordinary pressure was registered at a time, when little sea was running, and when little damage was done.—The next sentence is more telling than that.

I can only deal with one at a time. Then Mr. Blanford goes on to say, "In the far more severe storms of the 2nd of November 1867, and the 5th of October 1864, the anemometer was blown away under a pressure of 36 lbs. to the square foot, so that no register of their maximum force was obtained."—Yes, Mr. Blanford states that.

16,346. That is to say, the very anemometer which had registered 50 lbs. and stood it, was blown away under a pressure of 36 lbs., record and all?—It is perfectly possible that a gust may have come of over 50 lba., and that the instrument may not have had time to record it.

16,347. Then you say, "I, for my own part, notwithstanding the remarks by the late Captain Donkin on the storm of November 22nd, 1872, am convinced that we do not feel the full violence of tropical cyclones in these islands; we never dream of building storm masts as a refuge when the rest of the house has vanished into thin air. Such a 'building storm' is or formerly was sometimes taken in the West Indies." And then you go on to quote the relation of velocities to pressure and force from certain authorities given in Spon's "Dictionary of Engineering," which gives 49 lbs. to the foot, as supposed to be the pressure of a hurricane that tears up trees and throws down buildings; and certain additional pressures as having been observed by Keochom; and you make the very pertinent observation that if it did more than throw down buildings it must have been very difficult to register its force.—Such is the state of information about pressure at present.

16,348. With all these facts in your mind will you still adhere to the opinion expressed by the Astronomer Royal in 1873 was far wrong when he said that, notwithstanding all those extreme pressures and velocities observed by the anemometer, he believed that the maximum pressure that you might expect ever to have over the whole of a surface, such as that of the Forth Bridge, some 1,600 feet in span, would be about 10 lbs. to the foot?—I am disposed to think that that figure is too low. My experience from the neighbourhood of London exactly confirms the Astronomer Royal's statement from Greenwich; but the comparison of the wind at all stations on the coast (and not only, as those in Scotland) shows that the wind at London gives no representation whatever of the force of the wind at coast stations. 16,349. (The Commissioner.) It is much higher, you mean, on the coast?—Yes, on the Atlantic coast. 16,350. (Mr. Biddulph.) The Astronomer Royal has allowed for that, because, whilst he fixed 40 lbs. as the maximum in England, he assumed that probably it was higher in Scotland. However, in his judgment, in fixing that 10 lbs. as over an area of the size of the Forth Bridge, you think he fixed it at rather a low figure?—I think he fixed it at rather a low figure.

16,351. Should you feel inclined to fix it at any higher figure?—I should not. I have no information that would enable me to do so. 16,352. I see that one gentleman who took part in the discussion dwelt on a good deal upon the possible upward action of the wind; have you anything to add upon that subject?—Nothing but my reply at the end of the report, in the very last sentence, is the following words: "As to Capt. Jimson's remarks on the importance of the wind in directions other than simply horizontal, I can only say that some experiments on this subject have been made in Italy, but I am not aware that any results have been published." 16,353. I suppose you would agree with Professor Airy in what I put to him, which was a little misprint, but that the result is that, upon an extreme pressure, such as 40 or 50 lbs. to the foot, you would be very much more likely to get that upon a small area, say such an area as the side of a railway carriage, than over an area of the size of these girders?—I merely say that there is no evidence one way or the other. I cannot express an opinion without facts.

16,354. But I thought you had facts enough for that. If I make my question intelligible, you say you frequently find these pressures extremely local?—In one or two cases we have found them local. This 50 lb. pressure was very local.

16,355. You have quoted other cases also. If that is so, the maxima are much more likely to obtain over a small area than over a large one, are they not?—It is more probable, but it appears to me that there is no sort of proof, in the absence of direct observation, what is the pressure upon this part of the girder (pointing to a point near the end), supposing it to be 40 lbs. per square foot at the centre.

16,356. That is not the point. It will take an area of 200 feet and an area of 2,000 feet; you would be more likely to get an extreme pressure of 40 lbs. over the whole of the 200 feet than over the whole of the 2,000 feet?—The evidence appears to point in that direction.

16,357. You showed us a photograph just now, illustrating what I was cross-examining you about with reference to Sandwick as to the buildings which stood uninjured during that remarkable velocity; have you also a photograph of the buildings at Holyhead which you refer to in your report?—I have not.

16,358. I see you say this: "We should also remark that neither the steamboat shed at Holyhead nor Sandwick have been blown away; so I presume that there was a certain steamboat shed at Holyhead, which would probably have vanished supposing that it had been subjected to a pressure such as was indicated by the anemometer?—The anemometer at Holyhead, is distant from the steamboat shed by the width of the main road; the pressure there was 90 lb. to the square foot, but the steamboat shed is a certain extent protected by the parapet of the old pier, which runs up about ten feet. Holyhead is by far the most stormy place in the British Islands from which we have any record.

16,359. I gather that, had such a pressure been acting upon the steamboat shed, you would have expected that the steamboat shed would have gone; but it did not?—Yes; had the pressure been exerted in the same way.

Re-examined by Mr. Trayner.

16,360. There is, no doubt, a good probability of a heavy wind pressure upon a small surface upon a very extended surface; but can you tell me whether a gust of wind coming with great force upon a plane of that kind, of, say, 250 feet in extent and width, is at all an unlikely or improbable thing in the north of Scotland?—I think it is certainly not so.

16,361. And, of course, coming down in that width, it would bear an equal force upon the 250 feet of surface of anything that was opposed to it, whereas there was 10 lbs. to the foot or 100 lbs. to the foot?—Yes.

16,362. You were asked about the Astronomer Royal's opinion upon another matter; I should like to put this to you: The Astronomer Royal says, "It is certain that the pressure at Greenwich may amount to 40 lbs., to the square foot," if that remark is well founded, the pressure may on the more level part of Scotland rise perhaps to 50 lbs. to the
square foot. I suppose you agree with him in that?—That may be so on the sea coast, but inland it will not follow. Close to the coast and in valleys it will follow.

16,583. He goes on to say, “During the effect of the contracted valley to which I have alluded in Article 27 (that is the contracted valley down which the Valley Tay runs), I have no doubt that the pressure may advance far towards 100 lbs. upon the square foot at the site of the Tay Bridge.” What do you think of that direct view? I should not like to express any opinion upon the subject. But I have said that one of the gusts in this gale did extend over considerably more than 300 feet in lateral width on the north-west coast of Scotland.

16,584. Where did that take place?—At a place called Strontian, on Loch Sunart, not far from Balachulish. The wind blew down a gully called Loodal, swept all the instruments that were available in the Loch, crossed the Loch, unroofed Sir Thomas Ruddell’s house (who is a friend of mine), carried the roof for about 200 yards and dropped it over a garden wall, unroofed also the tin, which is situated about 80 or 90 yards from this house. On the other hand, at the other side of the river is Sir Thomas’ factor’s house, and that was not damaged at all.

16,585. (Mr. Bidder.) Is that 80 or 90 yards in a transverse direction?—There are cross valleys, the valley of Loch Sunart runs east and west, and the valley of Strontian runs north and south; and this wind, unroofed by the hills of Morven, swept up this valley from south to north, and meeting these two houses in the way it took the roofs off.

16,586. (The Commissioner.) But what Mr. Bidder wants to know is, whether the houses were in a line south and north?—They were in a line east and west. That house was not touched.

16,587. (Mr. Fraser.) From your records you know, and we all know, that the storm of 28th December 1879 was a very severe one?—It was severe.

16,588. Is it the most severe within recent years?—Not nearly so severe as that which happened six years ago in Edinburgh, on the 24th of January 1869. That is the opinion of Mr. Buchanan, the Scottish meteorologist, and certainly the damage done during the Tay Bridge storm bears no comparison to that which was done in Edinburgh.

16,589. (The Commissioner.) Could you tell me what the direction of the wind was between 7.15 and 7.20?—It was between the 28th of December last at South-west and by west.

16,590. What was it at Aberdeen?—Between 7.15 and 7.20 it was between south-west and south-south-west, slightly more southerly.

16,591. Aberdeen is, as we all know, to the north?—Yes.

16,592. Would not that lead you to suppose that the direction of the wind had a certain approximate cyclonic tendency?—I consider that all winds have, and certainly this one had.

16,593. And that the Tay lying between the two places would probably be within the same area of action were there would be a strong presumption that it would be.

16,594. It could hardly avoid it, could it?—It would be very strong evidence that it would experience a very severe gale.

16,595. It would be within that cyclone?—Certainly it was part of the same storm.

16,596. Assumining the direction of the wind, we should naturally assume, from the form of the cyclone, would be something like west-south-west, would it not?—About west-south-west.

16,597. Assuming it to be an ordinary cyclonic storm, the force of the wind at Dundee would be very similar to the force of the wind at Aberdeen and at Glasgow, would it not?—It is very hard for me to express an opinion positively, because the force of the wind in a cyclone does not vary directly with the distance from the centre. There will be certain curves of the wind which will be stronger than wind adjacent; and so, although the wind may have been blowing hard at Aberdeen and at Glasgow, it is possible that at Dundee it might have been less, or it might have been more. I will produce for the Court the actual chart of the storm at 06 o’clock which has just come (producing the same). It does not show the storm at the time the train went over the bridge.

16,578. Judging from this, and seeing here as we can see where the centre of the storm was, the probability is that there would not have been very much difference in the ordinary force of the storm, at the Tay Bridge from where there was at Aberdeen and Glasgow?—It seems very likely that the strong gust that came over Aberdeen did pass near the Tay Bridge.

16,579. You said you believed that these gusts were momentary, and Mr. Bidder said that he took that in its natural sense; now will you kindly tell me what you meant by its natural sense?—The best explanation that I can give in answer to that question is by exhibiting the records of one of Mr. Osler’s anemometers.

16,580. There has been a question between us as to what “momentary” meant, Mr. Bidder said, “I take that in the natural sense;” and you assented to it. Now I want to know what you meant by “momentary”?—The records which Professor Stokes mentioned, and which Mr. Osler kindly showed to me, show that the gust of wind on the day that he measured them, and not last half a minute, that the waves of wind passing over did not last half a minute. The rate at which they succeeded each other was a different thing, but they certainly did not last half a minute, or anything like a minute.

16,581. When you said that they did not last half a minute, did you mean to convey to the Court that they lasted very nearly half a minute?—Some would last nearer half a minute.

16,582. And some more than that?—I have not seen any that lasted longer.

16,583. But, at any rate, there might be some that would last half a minute?—Yes, possibly.

16,584. You have given us several instances in which the effect of a gust has been seen, we will say, either upon a building or upon some object, and has not been felt to the same extent at only a few feet off. Did you, or did you not, mean to convey to the Court that there might be some of them have a small lateral extent.—I have said that there might be some of them have a very small lateral extent.

16,585. But are we to conclude that the impression upon your mind from the very large experience that you have had is that these gusts have a very small lateral extent?—I think some of them have a small lateral extent.

16,586. Do you mean to the extent of 80 or 90 yards, or only a few feet?—I should think that some of them have an extent of a good many feet, some 30 or 40 feet; but one cannot be sure. The only direct experiment that I have is mentioned in that paper which is in Mr. Bidder’s hands, but that was a gas explosion, which correspond with a shot from a gun.

16,587. But these storms of which you have told us, which came down across the valley near Balachulish, had certainly, I suppose, a lateral extension of from 80 to 90 yards?—The storm had; but we do not know that it was the same gust that unroofed the two houses at the same moment of time.

16,588. (Mr. Webster.) Where was the factor’s house?—Distant about a quarter of a mile to the west under the shade of a hill which broke the wind.

16,589. (The Commissioner.) Then you would consider that it was the projecting hill which sheltered it?—Yes.
16,390. I think you said that the track of the whirlwind at Walmer was certainly from 450 to 700 feet in width.—Yes.

16,391. (Mr. Bidder.) That is the track of the eye of the whirlwind.

16,392. That is a different thing from the gusts of a storm.

16,393. (The Commissioner.) What was the pressure of that whirlwind?—There is no measure of it; it carried everything but itself away.

16,394. But within the whole of that area there was a great pressure.—A tremendous pressure.

16,395. (Mr. Barlow.) I understand you to say that the diameter of the rotating mass of air, one side of which would give the pressure, and the other: would not?—Across that diameter everything was carried away.

16,396. (The Commissioner.) I understand you to say that for an area of from 450 to 700 feet everything was carried away.—Yes.

16,397. Therefore there must have been a very great pressure along the whole of that width.—Yes.

16,398. Were the objects carried in different directions?—I cannot say about the Walmer whirlwinds; in other whirlwinds they are.

16,399. But in the Walmer whirlwind there certainly was a width of 700 feet, and there was a great pressure of wind, which carried everything before it; is that so?—That is so.

16,400. (Mr. Barlow.) You have given us in the first part of your evidence some velocities per hour at Glasgow; were those velocities obtained upon the basis of multiplying the velocity of the anemometer by three?—Yes; they all require the correction of Dr. Robinson's recent experiments. In all the velocities I have taken Dr. Robinson's old figure of 3.

16,401. And they would be considerably altered if they were multiplied by the figure of 2.28 which we heard of this morning?—Yes.

16,402. You have also given us the pressure of 90 lbs. per square foot as the highest that you have ever heard of. Are there any other pressures recorded that approach that in degree?—I have no evidence to prove it. The other highest pressure recorded is this one at Calcutta of 50 lbs.

16,403. Have we no record in this country of a pressure of more than 50 lbs.?—There are, as far as I know, only three pressure anemometers in this country at all, and we have hardly any records from them.

16,404. I asked the question because in Professor Rankin's book, where he makes an estimate of the strength of those tall chimneys in Glasgow, he states that the greatest recorded pressure in this country has been 55 lbs. to the square foot.—With regard to the chimneys there is an excessively important and interesting observation which I have heard with reference to the greatest storm in this century, which was the storm of the 6th of January 1839, in Dublin. Mr. Robert Mallet, the engineer, had had a chimney totally built. That storm occurred a few days after the chimney had been placed. There was a lightning conductor on the chimney. In the morning after the storm, he got up and expected to see the chimney down. The chimney was standing, but the lightning conductor was sticking out like the gaff of a cutter. The chimney had been oscillating the whole night, and the bolts had been torn out, and the metal of the lightning conductor was actually blown off by the force of the wind, while the chimney had not been carried beyond what its elasticity would bear and stand still. Mr. Mallet is alive, and will be able to give me, the actual statement of that in writing, which could be put in evidence.

16,405. (Mr. Bidder.) Do you happen to recollect whether it was calculated what pressure would have overthrown it?—I do not know.

16,406. (Mr. Barlow.) Those two very tall chimneys at Glasgow I take it from Professor Rankin, would not bear more than 53 lbs. pressure, and yet they have been standing a great many years on a hill, in a very exposed position.—The only remark that I would make upon that is that they have not yet had a whirlwind like the Walmer whirlwind passing over them.

16,407. (The Commissioner.) With respect to those calculations that you have made, taking 3 as the factor in order to estimate the velocities, you have told us that Dr. Robinson made certain experiments, to which you referred in a paper, leading him to suppose that 2.286 was the proper factor?—Yes.

16,408. But since that you are aware that he has made other experiments which led him to think that that factor was too low?—Yes. He is not the only person who has made those experiments; there have been great experiments tried in Russia and elsewhere.

16,409. And you are aware that at present the factor which he would substitute for that would be about 2.46?—Say 2.5, roughly speaking.

16,410. (Mr. Travers.) What is Beaufort's scale from 1 to 12; what are the respective velocities represented?—Beaufort's scale was made when he was in command of a vessel, and he made a scale of twelve degrees according to the sailing powers of a ship. The scale is described in my paper in the 2nd vol. of the Quarterly Journal of the Meteorological Society, to which I have already referred (2, 1336).

16,411. (Mr. Travers.) I have not got the results of Mr. Kirkaldy's experiments, but I have applied to him for them, and we have been promised the results to-morrow morning. In that case I will put them in, and then, so far as I am concerned, I have nothing further to say before the Court. Mr. Law has spoken hitherto to the result of Kirkaldy's experiments, and I do not know whether the Counsel who are here would desire to have Mr. Kirkaldy himself put into the box merely for the purpose of swearing that these are true results.

16,412. (Mr. Webster.) No. We know Mr. Kirkaldy works very well; he is a most careful experimenter.

16,413. (The Commissioner.) You will accept them. I think everybody can rely upon them. I think they go very far to support your view, Mr. Webster, if I may say so, and therefore you would have no objection to them.

16,414. (Mr. Travers.) Putting in those will only occupy a few minutes unless there is cross-examination upon them by Counsel.

16,415. (Mr. Bidder.) I thought you were going to call Mr. Abercromby on the wind question.

16,416. (Mr. Travers.) The Court did not press me to call him, and Mr. Abercromby's health, I understand, is not good.

16,417. (The Commissioner.) Now, Mr. Balfour, do you produce any evidence on the part of the North British Company, or shall I ask one of the other learned Counsel to proceed?

16,418. (Mr. Balfour.) Probably, Sir, at the close I may produce a little evidence with regard to the question of inspection.

16,419. (The Commissioner.) Inspection subsequent to delivery?

16,420. (Mr. Balfour.) ChieflY; it would rather consist in the putting in of letters, but I might probably require to bring up the manager and examine him.

16,421. (The Commissioner.) Is he here?

16,422. (Mr. Balfour.) I showed my friends yesterday the letters that I propose to put in, and they can be here now. I do not want to take any explanations from the manager in regard to them, but I have rather assumed that the same order would be followed in leading the evidence as has been followed in pursuing the examination, and that Mr. Bidder would go on, and then Mr. Webster, and that then, if I have anything to say to the contrary, I should conclude with it, as I am not taking the main part in the contention between the Board of Trade and the constructors on the one part, and the designer on the other.

16,423. (Mr. Bidder.) I think I am entitled to hear what Mr. Balfour calls. Hitherto my friend,
Mr. Balfour, has not had much to do beyond watching the case, but now, when it comes to evidence, he may be going to call evidence that may be adverse to my client.

(Mr. Balfour.) I see no reason why the order which has been hitherto followed should be departed from. I should scarcely expect that my friend's client, Sir Thomas Bouch, who, I assume, he will examine, will dispute these letters. I should probably get from them all I want.

(Mr. Bidder.) I shall decline to call any evidence until the client, Mr. Balfour, has finished his.

(The Commissioner.) It rests entirely, of course, upon counsel whether they choose to call witnesses or not, or whether they wish us to form our opinion on the evidence as it stands.

(Mr. Bidder.) I am quite sure, Sir, you will see the reasonableness of what I was pointing out just now, that Mr. Balfour's evidence may, in fact, affect my client. I have no reason to suppose that it will, but it may, take the form of an accusation. That being so, I think it is only fair and reasonable, and common justice demands, that if Sir Thomas Bouch or the contractors should be called upon to defend themselves, they should know exactly what is laid to their charge.

(Mr. Webster.) May I say with regard to this matter, reminding you, Sir, of the practice in your own Court, that I am quite sure Mr. Balfour and those whom he represents would be the last persons to wish that any charges should be brought forward after Sir Thomas Bouch and Mr. Gilkes have been in the box, and I only ask that he will, to-morrow morning, let us have that correspondence, or else we cannot be prepared to meet it.

(Mr. Balfour.) I will let you have it now.

(The Commissioner.) The difficulty in which I feel myself is this: You know, or you will know at any rate by to-morrow morning, the purport of the evidence which Mr. Balfour is going to give. We have not the least idea, nor, I suppose, has Mr. Balfour, what evidence you are going to adduce.

(Mr. Balfour.) Not the slightest.

(The Commissioner.) Therefore I think we must consider to-morrow morning whether or not, after having seen the evidence, you are prepared to go on, and we will decide the question then. I do not think we can decide it now.

(Mr. Bidder.) I have handed to my friend, Mr. Balfour, the completed correspondence, and told him that so far as the letters are concerned there will not be the least difficulty, because they are all admitted letters that have passed between us, and I have furnished him with those he has not got.

(The Commissioner.) We know nothing about them at present. We must also recollect that Mr. Balfour represented your party, and also Mr. Webster's party for a considerable time.

(Mr. Balfour.) Perhaps I may be allowed to say something to-morrow morning about it.

(The Commissioner.) That will be the best plan, I think.

[Adjourned till to-morrow at half past 10 o'clock.]

NINETEENTH DAY.

Friday, 30th April 1880.

(The Commissioner to Mr. Trayer.) I understood you to say yesterday that you had no further witnesses to produce.

(Mr. Trayer.) That is so, and I was just going to say that I have heard that an application was made to Mr. Kirkaldy about the results of the experiments he has been making, and he said that he would send them direct to the Court. I do not know whether you have received them.

(The Commissioner.) We have not received them.

(Mr. Bidder.) I have had an opportunity of speaking to my friend, Mr. Balfour, since we met last evening, and I think there will be no difficulty between us as to my going first, because he has told me what it is he wants, and I think he will find that what he requires to bring out will all appear in the course of my evidence.

(The Commissioner.) I think you have taken quite the right course. It seems to me that the first thing in order of time is to see how this bridge was constructed, and of what materials it was made, and then subsequently, rests upon the company the onus of maintaining it after it was delivered over to them.

(Mr. Balfour.) That, sir, is our view, that we come third in order, that is to say, that maintenance comes third, and therefore it was that we thought yesterday we should not go on until the others had finished.

(Mr. Bidder.) I suppose it is quite understood that this case will proceed in accordance with what is the usual practice, namely, that we shall complete our evidence, and then that Mr. Trayer, for the Board of Trade, should address you and make his charge, and that we should then have an opportunity of addressing you upon it.

(The Commissioner.) I do not think there will be any charge to be made. I have refrained from using the word "charge." We must keep ourselves perfectly distinct from anything like charges. I think you will have observed that.

(Mr. Bidder.) I should not have used that phrase.

(The Commissioner.) I have especially avoided using it.

(Mr. Bidder.) Mr. Trayer, I presume, will state what the views of the Board of Trade are, and then we shall have an opportunity of stating our views.

(The Commissioner.) I understood that was Mr. Trayer's view of the course to be taken.

(Mr. Trayer.) With deference, I would say that I am not disposed to take that course. Of course I am subject to suggestions from the Court, which I would give every due consideration to, but it humbly appears to me that the course to be followed is this: The Board of Trade having submitted to you all the information it is possessed of, or which you desire to have laid before you, there is no matter upon which the Board of Trade has to argue. If there was a matter for argument proper I should certainly take the lead, but it does not occur to me that there is anything for the Board of Trade to argue. The course would be for those who represent the contractors and the designs and the railway company, if they have anything to say, to submit it to the Court, and then only if the Court desires to hear me in reply. I should be very happy to address myself to any matter that the Court desires to hear me upon. But to go over the whole case and present the views of the Board of Trade to the Court would be out of place, because the Board of Trade have no views upon the matter, except those which they have submitted through their witnesses to the Court for consideration.

(Mr. Bidder.) That is not altogether a convenient course. It is leaving us rather in the dark if we are not acquainted, before we address the Court, with the views which the Board of Trade desire to put before
30 April 1840.

you, as in their judgment the conclusions you ought to draw from the evidence that has been adduced. (The Commissioner.) We are not exactly in the same position in which we would be if I were sitting as Wreck Commissioner. I am sitting with two colleagues here, and not with two assessors, and we have to form our opinion quite independently of whatever opinion the Board of Trade may choose to form upon this point.

(Mr. Bidder.) No doubt.

(The Commissioner.) And the only use that the view of the Board of Trade would be to us would be this, that Mr. Trayner having followed the case throughout, and having heard the whole of the evidence, no doubt it would be very useful to have from a gentleman of Mr. Trayner's eminence his view of what the bearing of the evidence is, but I do not think it is essential to the decision of the case that that should be done.

(Mr. Bidder.) Only, of course, looking beyond the form of the proceedings to the substance, one cannot shut one's eye to the fact that Mr. Trayner, in the evidence he has called before you, has in reality very distinctly pointed to what his witnesses suggested to be defects in design and defects in workmanship; those suggestions being in point of fact, and they may be called in form to a certain extent, "charges," and in some respects very serious charges, affecting those whom my learned friend, Mr. Webster, and I represent. I think I may assume that, in many respects, those views that were originally held by those witnesses will probably be modified by other evidence that will be adduced, and under those circumstances it really seems to me to be a matter of reasonable convenience, and only-right and fair to us to know what further part my friend, Mr. Trayner, will take in the matter when the evidence has been concluded.

(The Commissioner.) In saying what I am about to say, I am expressing the opinion of my colleagues. If Mr. Trayner were now called upon to state what his views were upon the evidence, he would, of course, only present before us the views which he was to a certain extent instructed by those whom he represents to lay before us. There would be a little inconveniency in that, because we are not the judges, but we have to report to the Board of Trade, and if our report came in conflict with the opinion that they had formed and had expressed through Mr. Trayner, there would be an inconveniency. Of course, this is an entirely new proceeding, and we are feeling our way.

(Mr. Bidder.) I am quite content to leave it in that way.

(The Commissioner.) It seems to me under those circumstances it might be better, the evidence having been given in the way it has been, that we should hear any remarks that you will be good enough to address to us, and also any which Mr. Webster and Mr. Balfour may wish to address to us upon the several points, and then we shall be very glad if Mr. Trayner would say anything in reply upon any of the observations of counsel.

(Mr. Bidder.) It does occur to me that there would be the same inconveniency in Mr. Trayner speaking at that stage, because, as your report is a report to the Board of Trade, it would be Mr. Trayner, as the Board of Trade, finally dictating what you were to report to them.

(Mr. Webster.) There is just one word I should like to add. Of course, one has to be guided by the tribunal to a certain extent, but there are a number of allegations that have been shadowed forth in the course of this inquiry which, I think, have become immaterial, and on behalf of the contractors what they desire me to say is this. Of course, if we are going into a general examination of their conduct in the minutest details, I should be perfectly prepared to give the fullest possible explanation and any amount of evidence in the matter, but I do apprehend that it is either desirable or is it necessary that I should do so. Of course I should direct my observations and my evidence to such matters as really are material with regard to the construction of the bridge, and as regards the causes of its collapse.

(The Commissioner.) We may say this, that in the event of the bridge being any point which we think material, we will call your attention to them.

(Mr. Webster.) I am much obliged to you, sir.

(The Commissioner.) We shall not take you by surprise by our report.

T. Bouchier. Examined by Mr. Bidder.

16,411. You are a civil engineer?—I am.

16,412. In the course of your experience, have you built—many large bridges and viaducts?—A great number. I do not suppose anybody has built more, but of course the bulk of them have been ordinary viaducts, with stone piers and arches.

16,413. You had also, I believe, built previously to the Tay Bridge several iron viaducts and bridges of considerable size?—Yes, both iron girders and superstructure upon stone piers and brick piers, and also viaducts entirely of iron.

16,414. At the time of the question of the Tay Bridge coming under your notice, you had acquired considerable practical experience in the construction of iron bridges and viaducts?—I had.

16,415. I believe, amongst others, you constructed a bridge over the Tees, did you not?—Yes, that has stone piers and lattice girders.

16,416. Malleable iron lattice girders?—Yes. I may say that in the course of my practice I hit upon this system of bracing, and I followed it out. I was pleased with the results of it in all cases, the structure offering: less resistance to the wind, and it being altogether a simple form of girder; and this is what I followed in the course of my practice.

16,417. Your experience has led you to prefer the lattice form of girder as offering many advantages?—Yes.

16,418. What were the spans of the Tees Bridge?—There are seven spans of 120 feet each, the greatest height being 130 feet.

16,419. That is to say, the height above the river is 130 feet?—Yes.

16,420. And that, I think, as you have already said, was a simple lattice girder, somewhat similar in general design to that which we see in the case of the Tay Bridge?—It was upon the same principle as this.

16,421. It was a good many years ago that you constructed that bridge?—It must have been 22 years ago.

16,422. May I take it that ever since you have adopted the same form of girder in similar structures?—I have.

16,423. What has been your rule as regards the relation of the height to the span of your bridges?—As a rule I have almost always taken the depth of the girder an eighth of the span; and I was very much led into doing that from a conversation with Mr. Robert Stephenson. In adopting that proportion, the strain upon the top and bottom members is exactly equal to the distributed load, and it facilitated the calculations.

16,424. Amongst other works, I think you also constructed the Deepdale and Beela Viaducts?—Yes. The Beela Viaduct is more than double the height of the Tay Bridge.

16,425. How many spans are there in that viaduct, and what dimensions?—There are 16 spans of 60 feet each, the greatest height being 186, more than double the height of the Tay Bridge.

16,426. What were the dimensions of the Deepdale Viaduct?—The Deepdale Viaduct had 11 spans of 60 feet each, the greatest height being 160 feet; that
is rather less than double the height of the Tay Bridge.

16,427. In those cases, being viaducts on dry land, there was no object in having excessive spans?—No.

16,428. You have here a drawing of the Beethab Viaduct, showing the elevation of it?—Yes (produced).

16,429. (Mr. Barlow.) Are these six columns there?—Yes.

16,430. (The Commissioner.) There are two central columns and two raking columns?—Yes, two rakers on each side, and two centre ones.

16,431. (Mr. Bidder.) Those piers, I think, were built entirely of cast-iron columns, were they not?—Yes; they were built entirely of cast-iron columns.

16,432. What was their diameter? 12 inches.

16,433. (Mr. Wylie.) I think it is; the outside diameter?—Yes, 12 inches diameter outside, and the thickness varied from 1½ inch to 3½ in. at the top.

16,434. Another bridge, I believe, which you constructed of a similar character was the Redheugh Bridge?—Yes, but that is not a railway bridge.

16,435. (The Commissioner.) At Newcastle?—Yes. Of course it is not subject to the same strain, except as regards the wind, but it is subject to a great strain from the great crowd of people that go to witness the regatta there.

16,436. (Mr. Bidder.) What were the spans of the Redheugh Bridge?—Two spans of 260 feet, and two spans of 240 feet.

16,437. And the height above high-water level?—About 80 feet; the same as the High Level Bridge.

16,438. Was that a lattice-girder bridge?—Yes; it was a sort of compound bridge; there were some bars to it, making it a half suspension, a stiffened suspension.

16,439. Of what were the piers composed that you adopted in that bridge?—They were composed of six columns firmly-bonded together, just the same as here, horizontally with cast-iron girders and diagonal wrought-iron tie-bars, nearly in the same way as the Tay Bridge.

16,440. Are you quite sure about the six columns, because I have a note that they were four columns?—I have a recollection of four columns, but it is put six in my paper.

16,441. Your recollection is that there were four?—It is many years since I erected that bridge.

16,442. (Mr. Wylie.) My note is that it was four columns, and that agrees with your own recollection?—Yes, that is my recollection.

16,443. Those are larger columns?—They are 3 feet in thickness.

16,444. And the thickness of the metal is what?—Three-quarters of an inch.

16,445. Then again there is the Bilston Burn Viaduct, which is another that you constructed?—That is stone piers.

16,446. (Mr. Wylie.) And lattice girders again?—Lattice girders again of the same character as those.

16,447. (Mr. Barlow.) Before you leave the Redheugh Bridge, were these large cylinders filled with concrete?—No.

16,448. (Mr. Bidder.) What is the height of the Bilston Burn Viaduct?—150 feet. There are six spans of 70 feet each.

16,449. (The Commissioner.) Stone piers?—Yes.

16,450. (Mr. Bidder.) I will not go through any more of your works of this kind, but I will now ask you to go to the story of the Tay Bridge. I believe your attention has been drawn to the question of bridging both the Tay and the Forth for many years?—Yes.

16,451. (Mr. Bidder.) You were appointed engineer and manager of the Edinburgh, Perth, and Dundee at the beginning of 1849?—It was then the Edinburgh, Perth, and Dundee; it is now the North British.

16,452. And it was during your occupation of that post that you were led to study the question of bridging those two firths?—Yes. As manager I found great difficulty in conducting the traffic across the Forth, and nothing that I could devise could get over that, except I invented at the time and carried out a system of sending the goods bodily across on board ferry boats, and that has been in operation since.

16,453. So far back as 1864, I believe, you deposited plans for a railway which was to cross the Tay Bridge?—Yes. That system that I established of taking the trains across was a great relief, but I felt, as manager, that the railway could never accommodate the public without a bridge across the Tay, and another across the Forth. And as far back as 1864 I began to devise some means of bridging the two estuaries. The way in which the traffic had to be conveyed at that time was by going 30 or 40 miles round inwards, and I wanted to get right across.

16,454. You deposited plans in 1864 for a railway involving a bridge over the Tay?—Yes.

16,455. I think that scheme was withdrawn in Parliament?—Yes.

16,456. Again in November 1865 you deposited plans for a line promoted by the North British Railway Company?—Yes, a little west. About 300 yards west of the site of the present bridge.

16,457. A little further up the river?—Yes.

16,458. That scheme, I think, did not pass through Parliament, did it?—No; it was withdrawn when it was in Parliament.

16,459. In November 1869 did you for a third time deposit plans?—I was wrong with the other one. That was the first time we went to the length of depositing it.

16,460. I do not think you were wrong. First, it was an independent company, in 1864; secondly, in 1865, by the North British Company, which was withdrawn; and thirdly, in 1869, again by the North British Company?—Yes, that is so.

16,461. That was the scheme which included as part of it the present bridge?—Yes.

16,462. And that was sanctioned by an Act in 1870?—It was.

16,463. Before you deposited those Parliamentary plans in 1869 had you taken the precaution to have borings made in the bed of the river across the proposed site of the bridge?—Yes. The scheme being so exceptionally large, and with the objections made in Parliament, and also with the view of taking contracts before we came to Parliament, I had the river upon both occasions thoroughly bored by an experienced borer, a Mr. Wylie.

16,464. And I believe you took the trouble to prepare detailed drawings of the bridge, even before you went into Parliament?—I think on the last occasion we actually let the contract.

16,465. Did the journals of the borings which were taken for you on the site of the bridge-show that you had a rock foundation nearly the whole length of the bridge?—They did.

16,466. With the exception, I believe, of some 250 yards on the north shore?—Yes.

16,467. You produce a plan on which are plotted the results of the borings?—Yes (producing it, and explaining it to the Court).

16,468. I believe that that plan will show that the result of the boring was to represent rock as existing at depths below the bed of the river, varying from 9 feet to 24 feet?—Yes.

16,469. (The Commissioner.) Did you say was the borer you employed?—A Mr. Wylie, a man very largely employed in mineral borings in Scotland.

16,470. (Mr. Bidder.) You have, I believe, if it is desirable to refer to them, all the original journals of the borings?—Yes.

16,471. (Mr. Bidder.) You have an assistant of my own to take out the position of the bore-holes, and to register the borer's returns as they were drawing up the material.
Se T. Bish. 30th April 1860.

16,470. The Commissioner.) Who was your assistant?—Mr. Ower; he is an engineer at Dundee.

16,471. (Mr. Bidder.) You adopted generally the form of lattice-girders which you had used in other cases, some of which you have mentioned in your evidence;—Yes; and in a form. I think, that presents the least resistance to the wind, and which I had found from 20 years experience was the best.

16,472. I believe you engaged the services as your assistant and conductor, for calculating the details of the strains, Mr. Allan Stewart, also a civil engineer?—Yes. He had higher mathematical attainments than I had, and I was glad to get his assistance, only I had created a great many girders of that form before I knew Mr. Stewart.

16,473. He, I believe, went into the detailed calculations of the strains of all the parts of the girders for you?—He did. Of course he went into them according to my directions and orders as to the form of the thing; and under my supervision too.

16,474. I believe also, whilst you were finally determining on the plan you adopted, consulted other engineers of eminence?—Yes; Mr. Thomas Harrison. I talked it over with him, as it was a novelty. There was a good deal of talk about it, but the conversation with Mr. Thomas Harrison was not official.

16,475. With the assistance of Mr. Stewart you devised, and worked out in detail the designs for the girders and the bridge generally?—Yes. The first design was very simple; one; it was just brick piers with the same form of malleable iron girders that we have since adopted.

16,476. And you also, on one or two matters, in order to be quite clear, communicated with Colonel Yolland?—That was as to the initial live load. I suggested that I might take a ton and a quarter per foot for live load.

16,477. (Colonel Yolland.) That was the rolling load?—Yes.

16,478. (Mr. Bidder.) Have you got your correspondence upon that subject. You wrote this letter to Colonel Yolland on the 5th October 1879?—Yes.

16,479. Will you just follow me while I read it. My dear Sir,—In calculating the strains of malleable iron girders, will you kindly tell me what you take the live load at per running foot for spans over 200 feet, and is it necessary to take the pressure of the wind into account for spans not exceeding 200 feet span, the girders being open lattice work. My own opinion is that ½ tons per foot run for live load is sufficient for spans over 100 feet, and that it is not necessary to take the force of the wind into account where openwork girders are used and spans of less than 200 feet. I merely ask the information that I may act in accordance with the views of the Board of Trade. Then I see Colonel Yolland's answer is dated the 8th of October 1869. "Dear Sir,—A ton and a quarter per foot run will be sufficient for spans of over 100 feet, and we do not take the force of the wind into account when open lattice girders are used for spans not exceeding 200 feet. It is right to say that that letter refers to the girders only, and has not to do with the piers.

16,480. I believe, you took every opportunity you could to inform yourself on every matter relating to the bridge?—I believe I am right in saying that there were no observation on that day that caused a special calculation as to strains in respect of wind.

16,480A. Having completed the detailed drawings, I think that the piers were invited, were they not?—They were.

16,481. Perhaps before I go to that I ought to ask you another question. Did you satisfy yourself that the wind, which you finally worked out with the assistance of your conductors was simply and abundantly sufficient for all the load and strains that could be brought upon the structure?—I was perfectly satisfied; and if the foundations had turned out as shown by the drawings, the first contract drawings would have been carried out exactly as they were designed, and there would have been brick piers; there would have been no alteration, just a simple structure.

16,482. Were you also satisfied as to the strength of the bridge with regard to the wind?—I was. I may mention that when I built the bridge at Bencath, I used to have rather a high opinion of the force of the wind there, and the bracing there is somewhat different to what I adopted afterwards; but after the report upon the Forth Bridge, my opinion upon the force of the wind was entirely modified from Sir George Airy's report.

16,483. I will come to that presently; that is a little bit anticipating, because we are at present in the year 1870. At that time, believing that you had a rock foundation, you were proceeding to carry out the work with brick piers?—There could be no question as to the resistance of everything then, and I admit that I had a higher opinion of the force of the wind than I had afterwards.

16,484. This part of the matter I may take somewhat shortly. Originally the tender of Messrs. Butler and Pitts was accepted by the company?—Yes.

16,485. And I believe Mr. Pitts died before the Act was obtained?—Yes. He was the monied partner in the firm.

16,486. Consequently that acceptance fell through?—Yes.

16,487. Then in May 1871 was a contract entered into with Messrs. Charles de Berge and Company, of London and Cardiff?—Yes.

16,488. (Mr. Bidder.) That contract, sir, I believe you had had put in?—(The Commissioner.) We have it.

16,489. (Mr. Bidder.) Did they proceed in that year with the work of erecting the bridge?—They did; they commenced at the south end.

16,490. You have all the contract drawings, and I think they have been produced?

16,491. (Mr. Butler.) A whole set has been put in.

16,492. (Mr. Barlow.) Have you the drawings of the brick piers. (The evidence shows them to the Court, and they were afterwards handed to Mr. Trayer.)

16,493. (Mr. Bidder.) At that time, I think, the total number of spans was 82, was it not?—Yes.

16,494. I do not know that I need go through them all in detail, but I see that the 14 spans in the centre were of 200-feet each?—Yes.

16,495. And the other spans were of less dimensions?—Yes. For the purpose of free navigation through, those fourteen 200-feet spans were raised up, so that the railway ran along the bottom, so as to give height for the shipping; on all the rest of the smaller spans it ran along the top.

16,496. That was 200 feet clear in the waterway?—Yes.

16,497. But 216 feet from centre to centre of the piers?—Yes.

16,498. You appointed, I think, a representative and assistant as your resident engineer to superintend the contract, did you not?—I appointed Mr. Paterson.

16,499. Mr. William Paterson?—Yes. He was a man of very large experience, and I had a very high opinion of him, and he was well known to the directors of the North British Company.

16,500. He was the resident engineer of the Edinburgh, Leith, and Granton Railway?—Yes. He carried through a very difficult work there, called the Scotland-street tunnel; here they were very much troubled with water; and he was afterwards resident engineer of the Edinburgh, Perth, and Dundee, and he then became engineer of the Scottish Central Railway. From his own designs he built the bridge over the Forth at Stirling; at least, it was a timber bridge originally, and he altered it to a bridge with cast-iron arches.

16,501. Mr. Paterson was a man of whom you had, and of whom you still have, a high opinion as to his ability?—Yes.

16,502. (Mr. Trayer.) Did you say that it was...
under Mr. Paterson that the Scotland-street tunnel was made?—Yes, he was the resident engineer of it.

16,500. Will you kindly give us the year?

16,501. (Mr. Bidder.) If you happen to have the date of the Scotland-street tunnel, will you give it?—It was done before I went to Scotland; I was in the north of England before I went to Scotland, and it was done before I went to Scotland.

16,502. (The Commissioner.) We will take your evidence. At any rate, you had a very high opinion of Mr. Paterson?—I had, and had reason.

16,503. (Mr. Bidder.) And I believe Mr. Paterson was engaged in your service and pay as resident engineer, to devote himself exclusively to the work of superintending the Tay Bridge?—Yes.

16,504. (The Commissioner.) Have you told us when he was appointed?—He was appointed when the work commenced.

16,505. (Mr. Bidder.) I believe, unfortunately, Mr. Paterson is prostrated with illness?—With paralysis. When the bridge was approaching completion, or, at least, events near towards the end of it, he was struck with paralysis, and I believe it was very much from his attention and anxiety over the bridge; at that time, he is in that position now, or I would like to have had him here. Mentally he is all right, but it is impossible to get him up to London.

16,506. Had he also two assistants?—He had two assistants in his office at Dundee at the bridge; the one was his own appointing, and the other one I supplied him with out of my office.

16,507. (The Commissioner.) Who were they?—One was Mr. Ralph, and the other was Mr. Butlor—did not know him, but he had been an apprentice of Mr. Paterson before.

16,508. (Mr. Bidder.) I believe these assistant inspectors were paid by you, and were in your service?—Yes.

16,509. I am told that that is not the usual arrangement, because ordinarily the company would pay for the inspectors?—I do not call these inspectors.

16,510. They were assistants of Mr. Paterson?—They were engineer assistants.

16,511. And in addition to them, were inspectors employed for the different departments of the works?—Yes. At the first, of course, the work that the inspectors were required to inspect was the founding of these brick piers and the concrete—concrete was not much used in Scotland at that time, and, with a view of having somebody thoroughly conversant with it, I applied to the Metropolitan Board of Works, and Sir John was pleased to recommend Mr. Noble to me.

16,512. Any having special experience in concrete work?—Yes; and I gave him 200 a year.

16,513. And you had then, and you have still, every reason to believe that he was thoroughly efficient in that department?—He is one of the best examiners of concrete and Portland cement that I have come across in my experience, and most careful; but that was his sole duty to attend to that whilst the works were going on.

16,514. Subsequently, when the works advanced, and the ironwork was in progress, were other inspectors appointed?—Yes, I got a Mr. Wennyas, on the recommendation of Mr. Davison, who was a very good draughtsman, better educated than most inspectors.

16,515. And do you believe, from your own knowledge and experience of him, that he was an efficient man for his duties?—Yes; he was a little superior to any other work you were working at that time in the firm of Messrs. Hawthorne and Company, of Leith. He was strongly recommended to me by Mr. Davison.

16,516. He was engaged during the earlier part of the contract in preparing detailed drawings in connection with the ironwork?—Yes, he was backward and forward from my office to the bridge, and from my office to the Cardiff Works, and to other places; among others, to Middlesbrough, where the works were going on.

16,517. Mr. Wennyas, I believe, is in South Australia?—Yes; I am sorry to say he is, for I would have been glad to have produced him.

16,518. As regards the erection of the bridge, I believe you began at the south end?—Yes.

16,519. (Mr. Bidder.) Messrs. de Bergey's contract was in May 1871?—Yes.

16,520. The first four piers were on rock, I think, were they not?—Yes.

16,522. And piers Nos. 5 to 9 were founded on broken sandstone rock, with clay mixed with it?—Yes.

16,523. Piers Nos. 10 to 14 on hard red clay?—Yes.

16,524. So far, I think, the foundations were satisfactory and good?—They were, and had they continued in the same the bridge would have been carried out without the slightest alteration as originally designed.

16,525. It was when you were sinking the cylinders for pier No. 15 that you first were made aware that the borings had not correctly represented the state of things beneath the bed of the river?—It was.

16,526. And it was then that my attention was first drawn to the character of the foundation, and I then had borings taken again. I was dissatisfied with it, and I had fresh borings taken.

16,526. You found that the rock was disappearing, did you not?—It was practically gone. In sinking the cylinders we came down to a little bed of gravel, and I said "Go on with it," and we got through that gravel, and then there was no rock.

16,527. (Mr. Barlow.) What were you in then?—Sand again.

16,528. (Mr. Bidder.) In that particular case, I think, you adopted the precaution of putting two additional cylinders, and piling also the northernmost of them?—Yes, there were four cylinders there, and I piled the north one.

16,529. And I think, at the same time, your experience of No. 15 led you to adopt a similar precaution in pier No. 14?—Yes. Then there were No. 14 and put two more cylinders there. No. 14 was approaching the change of the character of the material. I thought it was well enough founded; but still, as an extra precaution, I put two more cylinders to it, and made four instead of two.

16,530. Was it in consequence of what you had discovered in that last pier that you ordered the bed of the river to be bored again systematically right through?—It was, and I sent the borers through this hard bed of gravel.

16,531. Was the result to show that what the former borers had taken for rock was a very hard bed of gravel, which was only three or four feet in thickness?—That was so; it was a compact bed, almost conglomerate, but they did not go through it. They supposed it was rock.

16,532. The result of those borings was to show you that beneath this gravel you had, instead of rock, an unknown depth of clay?—Yes, and sand.

16,533. Did that lead you to the conclusion that it was necessary that you should reconsider the design of the bridge?—It was clear that it was change necessary. I had no alternative. The foundation would not have carried those brick piers. The brick piers had a pressure of something like six tons per square foot at the bottom of the pier. That, of course, was not taking wind into account.

16,534. (The Commissioner.) The average downward pressure?—It was only fifteen tons per square foot on the pier above it.

16,535. (Mr. Bidder.) When was it that these second borings were taken which necessitated the alteration of the design?—I really forget the date.

16,536. Perhaps this will fix the date. You made a report on the 11th of December, 1873, to the Board of the North British Railway Company?—Yes. Of
16,537. We are now upon the foundations.—It had reference to what we must then do upon completion of the foundations.

16,538. That was your first report after you had discovered that the rock had gone?—Yes.

16,539. (Mr. Biddor) I think I may give you an earlier date still; for I see that there was a report on the 28th of May, which appears to be the first, and that is from Mr. Paterson, the resident engineer. Mr. Paterson appears to have made a report on the 29th of May to the chairman and directors of the North British Railway Company.—Yes.

16,540. He reports, "Of the contractors for the Tay Bridge, on the Fifeshire side, the land abutment and the first 10 piers finished, and the 11th and 12th piers only require the stone coping to be completed. The 13th, 14th, and 15th piers are built up to the height of 20 feet above high-water level. When the caissons for the foundations of the 16th and 17th piers were being sunk, about 3 feet of pretty firm stuff was gone through, a layer of soft muddy stuff was entered; the caissons then became a little unmanageable with the weight of the air-bells on their top. To prevent accident, the air-bells were taken off, and divers set to work to sink the caissons and bring them level, and when they are brought into that state the caissons will then be so deep in the ground that the air-bells may be put on again with safety, and the caissons sunk to the rock. The falling in with this soft bottom will naturally retard the work a little, but the contractors have undertaken to construct a malleable-iron staging, strong enough to carry the air-bells."

I do not think it appears that at that stage it had been realised that the rock was not there.

16,541. (Mr. Biddor) Then I must go to your report of the 16th September, your own report to the Board: "Gentlemen,—I have to report that the contractors for the Tay Bridge portion have, on the south side of the river, the land abutment and 12 piers completed, and 112 sets of girders laid thereon, piers 13, 14, and 15 with two sets of girders placed thereon, and built to the height of 66 feet above low-water line. Caissons for the foundations of other five piers are placed in position. The malleable-iron stowings that were being prepared for the sinking of the 16th and 17th caissons are now ready for use. At the north end of the 'straight portion' of the bridge, caissons for the foundations of 10 piers are placed in position. One is built up to the height of 20 feet above low-water line; two are sunk to the depth of about 35 feet."

Then he speaks of the extreme north end, and then comes the important part of that report. "The foundations on the north side, I regret to say, have turned out worse than I expected in the contract. "Underlying the bed of sand, which is dry and visible at low-water level, and which has an average depth of 25 feet, there exists a layer or bed of hard compact gravel and boulders. It appears the breakers, on reaching this bed, had found it so difficult to penetrate that they believed it to be rock, and reported accordingly. We now find in "sinking the piers 54 and 55 through it that this layer is only about 4 feet thick, and that there exists a subsoil about a depth yet unascertained, but which we have penetrated with boring tools 22 feet. There is no difficulty whatever in making a good foundation on this material, but it involves the necessity of considerably increasing the area of the base. From this cause the progress of the works during the last four months has not been equal to my expectations; now the contractors have got the enlarged base made for 15 additional piers, and I expect, notwithstanding the approach of winter, the progress will be much more rapid. It is with extreme regret that I have to report the distressing accident that is an accident to soothe the minds of those that were killed. I do not read that; it was an accident to the bridge itself."

16,542. Then the rest refers to other parts of the railway?—Yes.

16,543. Now I come to the report of the 11th of December 1875 from you to the chairman and directors of the North British Railway Company: "Gentlemen,—In my report of the 16th September last I stated that the foundations on the north side, I regret to say, have turned out worse than the boring led me to expect. Underlying the bed of sand, which is dry and visible at low-water level, and which has an average depth of 25 feet, there exists a layer or bed of hard compact gravel and boulders. It appears the breakers on reaching this bed found it so difficult to penetrate that they believed it to be rock, and reported accordingly.

We now find in sinking the piers 54 and 55 through it that the layer is only about 4 feet thick, and that under which there exists a clay of a depth of 3 feet not yet ascertaincd, but which we have penetrated with boring tools 22 feet."

That is a quotation from the former report, and then you go on after the quotation to say, 'The object of this enlargement of the base is to reduce the pressure per square foot of the foundations to a point at which experiences have shown the materials with which we are dealing will not yield. The greatest amount of this pressure is due, not to the weight of the superstructure and train, but to the weight of the brickwork in the pier itself. As an illustration, take the 200-foot spans for the Tay Bridge, and look at the foundations, as originally designed, the weight per square foot would have been 64 tons, of which 53 tons was due to the weight of the brickwork; so that it must have been much more solid brickwork than that proposed by Mr. Law.—Yes.

16,544. A very different kind of structure?—Yes.

16,545. Then you go on to say, "On the foundations, as proposed to be enlarged, the weight per square foot would be 34 tons, of which 34 tons is due to the weight of the brickwork in the pier alone." That, as I understand, is sticking to the original design with an enlargement of the base?

16,546. Then you go on—"Since I made my report I have had under consideration whether I could not still further reduce the pressure on the base by building the piers of strong iron columns, commencing the ironwork about 5 feet above high-water spring-tides, so as to place it beyond the corroding action of the salt water. Accompanying this report will be submitted a plan showing how this can be done. After the anxious consideration I have given the subject, I have thoroughly satisfied myself that it is the best thing to do, and confidently recommend its adoption for the following reasons:"

(1.) That in the event of the boring failing to reach the base, the pressure on the foundations from 40 tons to 21 tons would be transferred to the 8-foot wide footing, which puts the risk from defective foundations beyond all question.

(2.) That it will effect a saving of cost, though not a large amount.

(3.) That it will make a materially stronger pier.

(4.) That the piers themselves can be erected in half the time.

(5.) That it affords facilities in
"erecting the girders and superstructure, which I will explain at your meeting to-day by reference to the drawings. (6.) That it will facilitate the "doubling of the line, which I will also explain by "means of the drawings. There is, however, a dis- "advantage in the use of iron, which is important "to consider, namely, that it will require a cost of "paint every three years, costing 200l. Notwith- "standing this extra cost, I have not the slightest "doubt of the propriety of its adoption. These "suggested alterations in the design arise entirely "from the foundations turning out different from what was anticipated."

You, in the report to the directors, you had been led by the insufficient foundations to consider the advantages that would be offered under the circumstances by substituting a pier made of iron columns for the brickwork, and you had discussed the matter, and taken a good deal of trouble in discussing the matter with your assistants.—Yes.

16,547. And, I believe, with Mr. Grothe?—Yes, and Mr. Stewart, and all of them. We used to have weekly meetings at that time at the bridge, and I invited them to come and meet me, and everything was discussed; everything, of course, being decided by myself.

16,548. You had many alternative modes of arranging the columns suggested by yourself and by others under your consideration?—Yes.

16,549. Two plans had been suggested by Mr. Grothe?—Yes.

16,550. And Mr. Stewart had been in discussion with you?—Yes, they were all discussed. There was one plan which was signed which had "Eight columns," but I was induced to alter it for this considerations which I can explain.

(Mr. Bidder.) You asked for the correspondence relating to this alteration, or somebody on your behalf, and I think it will be convenient if I read him back what I understand from your last letter, as I have prepared fully complete plans of what I am going to say. I have telegraphed Paterson to come here to-morrow, and after seeing him will arrange a meeting. Then I see on the 6th of November 1874 Mr. Gilkes writes simply altering the date of the meeting; and then there is another letter of yours agreeing to the alteration, and then on the 17th you write to Mr. Grothe, "I will be ready with my plans of the pier by Friday morning. Can you come over to consider and discuss them with me? I have seen reason to considerably modify them since our meeting on Friday last. Arrange with Paterson to be here also." Then there is a letter from Mr. Grothe saying he will come, and there is a letter dated the 18th of November from you to Mr. Gilkes, saying, "I will be ready with my plans by Friday morning, and have asked Mr. Grothe and Mr. Paterson to come here on that day to discuss them with me. I have seen reason to considerably modify them since our meeting on Friday last.

Then there is a letter, "I should like to have him back again, as I want to be progressing with the plans of the Forth Bridge."

16,551. (Mr. Bidder.) I think there are all that are bearing upon that. (To the witness): On the 6th of October 1873 you wrote to Mr. Grothe, saying, "Will you kindly send me a tracing of the "drawing of the piers of the 200 feet spans which "you showed me on Sunday? I have an idea I can "improve upon it without increasing the weight." "If you think it not of much use to yourself, I shall "agree to this alteration, as I have prepared fully complete plans of the Forth Bridge during the period, in November 1874, there were further considerations of the subject, and discussions with Mr. Gilkes?—Yes. The final designs for the erection were settled in Middlelburgh. I was there, and I settled the thing with Mr. Gilkes. Mr. Grothe was not there then; he was in Holland.

16,560. I see on the 4th of November 1874 Mr. Gilkes says, "So far as we can see, the proposed new design for the large piers will be so far ready for inspection that Mr. Grothe and I could meet "you with it in Edinburgh on Friday. Will you "please let us know by wire whether this will suit "your other engagements, and where we can meet "you?" Then on the 5th you wrote to Mr. Gilkes to say that you had just received a telegram from Mr. Paterson stating that Mr. Gilkes was not coming through to-morrow, and you say, "I very much regret "this, as I have prepared very complete plans of the "pier which I wish to have described to you and "Grothe. I quite expect you will be pleased with "them. I have telegraphed Paterson to come here to-morrow, and after seeing him will arrange a "meeting. Then I see on the 6th of November 1874 Mr. Gilkes writes simply altering the date of the meeting; and then there is another letter of yours agreeing to the alteration, and then on the 17th you write to Mr. Grothe, "I will be ready with my plans of the pier by Friday morning. Can you come over to consider and discuss them with me? I have seen reason to considerably modify them since our meeting on Friday last. Arrange with Paterson to be here also."

Then there is a letter from Mr. Grothe saying he will come, and then there is a letter dated the 18th of November from you to Mr. Gilkes, saying, "I will be ready with my plans by Friday morning, and have asked Mr. Grothe and Mr. Paterson to come here on that day to discuss them with me. I have seen reason to considerably modify them since our meeting on Friday last."

Then there is a letter, "I should like to have him back again, as I want to be progressing with the plans of the Forth Bridge."

16,552. (Mr. Bidder.) I have verbally instructed Mr. Grothe to go on sinking the double cylinder from piers 26 to 26 inclusive—that is to say, working backwards. As to the depth they were not advise by Mr. Paterson in accordance as the material may turn out. From piers 16 to 22 inclusive I have instructed Mr. Grothe to sink the oval caissons, and these I do not intend to go beyond the bed of the river more than about 10 feet. Plans for the piers of the 200-feet spans I have discussed with Mr. Grothe this morning, and these are not to be altered in "my consideration." Then I see a letter which bears upon the subject indirectly, dated the 21st of November 1874. You wrote on that day to Mr. Grothe, ordering him, when Nos. 16 and 17 piers were completed up to the base of the columns, to load them with pig iron up to a load of 24 tons to the foot?—Yes, to test them.

16,561. So as to try the foundation?—Yes.

16,562. (Mr. Barlow.) On the top of the brickwork?—Yes.

(Mr. Bidder.) Then we have a letter of the 23rd November 1874, from Mr. Gilcke to you, noting the instructions and saying, "We shall be very glad to have the definite plans for the 200-feet spans as

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sou a possible, otherwise they will seriously retard
the work of the bridge."

(Mr. Traryer.) I do not know whether it will save
you any trouble, but all the correspondence I asked
for had wanted bore upon the reasons acting in the
minds of the different persons concerned for the
change after the original design was agreed. I do not
care for anything further.

(Mr. Bidder.) This is all while the change was
maturing.

(Mr. Traryer.) If you think it right to go on with
the correspondence, I do not wish to interpose. I
merely pointed that to save trouble.

(Mr. Bidder.) I do not find in any of the letters
that they state the reason for the change.

(The Commissioner.) A great portion of the reasons
were reasons communicated verbally.

15,553. (Mr. Bidder.) Mr. Grothe prepares a plan,
and Sir Thomas Bouch prepares a plan, and Sir
Thomas Bouch writes and says: "I see reason to
modify it. Come and have a talk with me." I had
better perhaps run through those letters. I have very
nearly got to the end. The next is a letter from Mr.
Grothe, dated November 25th, enclosing a letter from
Sir Thomas Bouch: "Dear Sir, I beg to acknow-
ledge receipt of that enclosures containing the longi-
tudinal sections of the pier. Both this and the former
drawings are, of course, not to be looked upon as attempts to produce
complete drawings, but only rough sketches, suffi-
ciently accurate to get out the weights. Under the
sections you will find an outline of the base in plan.

If you judge me by a telegram to-morrow saying
whether you will be at your office on Friday or
Saturday?" Then comes a letter from Mr. Gilkes, say-
ing, that he will be with you on Saturday. And then
follows a letter of the 22nd of January 1875, from
you to Mr. Gilkes, saying: "I send herewith
sections for the 200-feet span. It is designed
on the principle of the drawing submitted to you by
Mr. Stewart, but he told me you were inclined to
prefer making the joints of the metal columns the
same as the Bealhe and Deepdale. I have not the
slightest objection to this, and if you are still of this
opinion I will make out a new drawing accordingly,
so that I will send it to you; so that we may see
what our wishes are."

Then there is a letter from Mr. Grothe on the 9th of December 1875, saying, "Referring to the
long and careful consideration we had respecting
the enlargement of the spans and certain altera-
tions of the pier of the Tay Bridge, which you have
decided upon adopting, we have gone carefully into
the question of the increased cost caused by these
new arrangements, and find that the sum of £371,10s.
per pier for each large pier will barely represent
our increased expenditure. We will, however,
endeavour to carry out your instructions for that
amount per pier, in addition to the contract amount.
I am not reminded you that we have considered that the altered arrange-
ments, even with this increased cost, will be a most
important saving to the company. We hope this
proposal will meet your views, and shall be glad
to have your agreement thereto." That is from
Mr. Gilkes to Sir Thomas Bouch. With the excep-
tion of one letter, which I will bring in later, I think
these condense the correspondence, but I did not go back
now to when I commenced reading that correspondence.
On the 11th of December 1875 you reported to the Chairman of the Board, and I read
that report?—Yes.

16,554. In point of fact, as that correspondence shows, the ultimate form of the design of the iron
columns and pier was a matter that was under-con-
sideration for a very long time; many alternatives
were under discussion before you at last settled upon
that particular design which you determined finally to adopt?—That is so.

16,555. And it was not, I believe, adopted finally by
you until it had been thoroughly considered by your-
self and your assistants, both separately and together,
and looked at from every point of view?—It was
regularly discussed at these weekly meetings at the
bridge.

16,556. And at special meetings, as I gather from
the correspondence, when they were invited to come
to Edinburgh for the purpose?—Yes.

16,557. And, in your judgment, was the plan which
you adopted that which offered the greatest combina-
tion of advantages in the construction of the bridge?—
It was so. I formed that opinion, and I still hold it.

16,558. I will take you to one particular matter
that has been a good deal discussed. It has been
suggested that your bridge would have been better if
you had put two raking columns at the outside on
each side instead of one. That plan was presented to
you by Mr. Grothe. I think, at one time?—Yes, Mr.
Grothe, I may say, was in favour of eight columns;
at all events, he proposed a design of eight columns.

16,559. And I think of that design of eight columns
was under your consideration, and was carefully weighed,
as against the six?—It was.

16,570. Will you explain why you considered it
preferable to adopt a design with six columns instead
of that with eight?—It was almost entirely to get
less base that I did it.

16,571. In order to get a wider base?—I tried it in
every possible way—eight columns and six—and I
could not get a base with eight columns, pass it as
I would. You have 10 per cent. less base with eight
columns that you have with six. The drawings we
have of the eight columns show 10 per cent. less base.

16,572. The caisson, as we know, is 31 feet in
diameter?—It is.

16,573. But of that 31 feet there are 18 inches all
round which were not available for building the pier
upon?—No, inside the malleable-iron caisson there
is a rim of about 18 inches. I put that in for various
reasons.

16,574. (The Commissioner.) Inside the malleable-
iron caisson there is what?—A rim of brickwork. It
was partly to strengthen the caisson from the pressure
of the water, and partly to make a better connection
with the concrete inside.

16,575. (Mr. Bidder.) That is to say, in your
judgment, as an engineer, you did not consider it
as a dangerous or safe to put another pier or to
incumbent pier upon that external 18 inches?—I cer-
tainly did not. I wanted the material to be of a
uniform character; it must rest upon the concrete.
I would not have liked to have put the pier upon
that.

16,576. (Mr. Barlow.) You did not like to trust
to that rim of brickwork for pressure?—No.

16,577. (Mr. Bidder.) Whether you adopted six or
eight columns you did not feel yourself justified in
trusting to that?—No.

16,578. Of course, that limited you to a circle of
a diameter of about 28 feet?—Yes.

16,579. Then I think another matter which could
not be ignored was this: it was necessary that you
should have a sharp cutwater on each side for the tide
up and down the river?—A cutwater is a
desirable thing to have in such a current as that.

16,580. Without saying it was absolutely necessary,
it was highly desirable?—Yes, highly desirable.

16,581. You say you adopted the hexagonal form
because you found, after carefully trying it, that
by adopting that form you got a wider base than in any
other way what you could contrive?—Yes, I ought
to explain that there was a difficulty in pitching such
large cylinders in such a current with such a stream
of water as we had; in fact, I do not know that there
ever was a larger cylinder used in Great Britain, with
one exception, and that is the cylinder for the Saltash
Mr. Bidder. I think that was remitted to those gentlemen.
16,591. (Mr. Bidder.) That is so; there are 6 inches on each side, and that makes another foot, 6 inches on one side and 6 inches on the other.
16,590. (Mr. Bidder.) Just to correct your answer, you said that there were 2 feet outside the centre; I am coming to the 2 feet; I take first the 22.
16,592. (The Commissioner.) From centre to centre it is 22?—Yes; then the base is 4 feet square.
16,591. (Mr. Bidder.) Let me draw your attention to this; are you not making a mistake, you put your base pieces diagonally? It is more than 4 feet diagonally. I need not have done it, but we wanted a base of 4 feet square, and we just took in that way; then the 4 feet, 2 feet on each side makes 4 feet, and with the 22 it makes 26. Outside of the 4 feet base, I must have at least 6 inches within the line of the brickwork; that is 1 foot, that makes 27. Now come this question; how near to the outside we can plant this column, say instead of 2 feet we limited it to 1 foot, what would be 28, and then there are 18 inches of brickwork lining, and that brings it just up to 31 feet.
16,592. I see you did prepare a plan which was furnished to the contractors at one time for eight columns?—Yes.
16,593. (Mr. Bidder.) Have you the drawing? (It was handed to Mr. Bidder.)
16,594. (The Commissioner.) What is the width of the girder?—14 feet 10 inches. I was going to say 15 feet. It may be 14 feet 10 inches. I have tried it as far as I could, and I find whatever diameter to make the cylinder I can get with six columns 10 per cent. more base than I can possibly get with eight, and that weighed with me in resolving on the six columns.
16,595. (Mr. Bidder.) You have stated the principle on which you determined in adopting finally that particular form of arrangement of columns which had been carried out in the work as executed?—Yes. I had better explain what Mr. Grotch's objection was. He assumed that this column (pointing to the model) was to be perpendicular, these others being slightly sloping towards the top, and he assumed that these being perpendicular, and these sloping, the lugs would not be opposite that. But if you took them to have to be cast on in a different way; but I eventually convinced him that by making these of the same inclination as the others, these sloping in at the same rate that these two sloped in it would be a right angle in every place all the way down, and the lugs would be the same.
16,596. (The Commissioner.) It would be a slope in different planes?—Yes. The connection with them would always form a right angle.
16,597. (Mr. Bidder.) At the time when you settled this final design, had you in your mind the question of wind pressure as well as other things?—Yes.
16,598. About the same time, or rather before you came to consider and discuss these altered designs, you had been simultaneously preparing your plans for your bridge over the Firth?—Yes.
16,599. That plan, shortly I think, consisted of a compound structure?—Yes; partly suspension and partly girder.
16,600. Consisting of two main spans of 1,630 feet each?—1,630 feet.
16,601. At a greater height above the water than this?—Nearly double the height: that is 150 and this is 88.
16,602. I believe that that proposal was so unprecedented that the North British Company and the other companies who were asked to subscribe funds towards the construction of the bridge were not willing to embark in the undertaking until they had the assurance of other eminent independent engineers that it was a satisfactory scheme?—Yes, that was so.
16,603. I think that was in 1873?—Yes.
16,604. And I believe that four engineers, consulted by the companies?—Four of the most eminent engineers of the day.
16,605. Will you name them? Sir John Hawkshaw was one, I believe?—Yes; Sir John Hawkshaw, Mr. Harrison, Mr. Bidder, and Mr. Barlow.
16,606. I believe the detailed investigation of the work was principally carried out by Mr. Barlow and Dr. Pole?—I think it was remitted to those gentlemen to investigate the details.
16,607. Mr. Barlow and Dr. Pole were not satisfied with their own judgment upon the question of wind pressure, and it was they who consulted the Astronomer Royal?—Yes.
16,608. So that, the design being one of extraordinary magnitude, every possible precaution was taken to get the opinion of the best talent in the country as to its sufficiency in every respect?—That was so.
16,609. You had the report of those engineers before you, and you attached great weight to it when you were devising your alterations in the Tay Bridge?—Yes; it somewhat modified my ideas.
16,610. I find this passage at page 21 of the printed Report, "The effect of the wind on a structure of this magnitude" (reading from the Report to the word "available"). I will just pause there today, does that agree with your own knowledge at the time that there was great obscurity and very little definite knowledge in the profession upon the subject?—Very little, indeed.
16,611. "The ordinary source from which such estimates are taken" (reading from the Report to the word "meteorology").
16,612. (The Commissioner.) That is signed by whom?—By Mr. Barlow and Dr. Pole.
16,613. (The Commissioner.) After consultation with the Astronomer Royal?—Yes.
*16,614. (Mr. Bidder.) "And therefore" (reading the Report to the words "per square foot"). Then the Report proceeds, "We entirely concur in this opinion, which we consider highly" (reading to the

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* See extracts from this Report at the end of this day's evidence. 3 E 3
word "pressure"). Then follows matters which refer to that particular bridge which would not be in point here. Then I see it goes on, "The said surface of each span exposed to the winds" (reading to the word "tons"). That is the aggregate force. Then they say, "That produces a certain tension" (reading to the words "each side"). Then, I think the rest of the report; it is not important that I should read it. Upon this particular question of wind pressure naturally that Report carried considerable weight in your mind?—Yes; I thought if I made the bridge substantial enough to stand what is prescribed as the limit, there I was providing for it. As a matter of fact, in going to this pier, I put it strong enough to carry twenty times the greatest possible load that could go on it without taking the wind into consideration.

16,615. Twenty times the maximum load?—Yes.
16,616. (Mr. Barlow.) You mean downward load?
16,617. (Mr. Bidder.) You have said that the details of the calculations you employed Mr. Stewart to work out, to help you in carrying out the details; but did you satisfy yourself generally that the bridge was much more than strong enough to bear the 10 lbs. of wind that was mentioned in that Report?—Yes; to bear more than Professor Airy said it would be subject to.
16,618. And even taking either General Hutchinson's or Mr. Brunel's estimate, it was capable of standing 50 lbs. of wind to the foot?—You will get evidence upon that subject. It depends upon the tests that were being made.
16,619. I say, even taking their figures?—It brings it out to 40 lbs.
16,620. To go back to history. As we know, about the beginning of 1874, I think it was, Mr. De Bercogue became incapacitated from illness from standing to business?—Yes.
16,621. (The Commissioner.) What time in the beginning of 1874?
16,622. (Mr. Bidder.) March 1874 is the date I had given to me.
16,623. (The Witness.) He became insane.
16,624. And it became necessary to transfer the contract to other contractors?—Yes.
16,625. Messrs. Hopkins, Gilkes, and Company, of Middlesbrough, were originally, I think, the third lowest in the list of tenders?—Yes; in the original tender.
16,626. And when the contract was given up by Mr. De Bercogue they were invited to take to the work?
16,627. (Mr. Webster.) I am told that the death of Mr. De Bercogue took place on the 10th of April 1873.
16,628. (The Witness.) But he was insane before that.
16,629. (Mr. Webster.) That is the date given to me.
16,630. (Mr. Bidder.) But the contract was carried on by Mr. De Bercogue's widow some time after his death?—Yes; that was so.
16,631. It was not till 1874 that it was transferred to Messrs. Hopkins, Gilkes, and Company?—Yes; that is so.
16,632. The date of their contract is the 27th of June 1874?—Yes.
16,633. I believe you were well acquainted with Messrs. Hopkins, Gilkes, and Company before?—Yes, I was. They had built the Beelah and the Deepdale.
16,634. They were supplied with plans in some respects altered from the original plans?—Yes.
16,635. At that time, I think, no alteration had been made in the girders or the height or width of the spans?—No.
16,636. (Mr. Webster.) We are still dealing with the 216-feet spans?—Yes.
16,637. (Mr. Bidder.) I think you still had at that time oval caissons?—Yes.
16,638. Did the difficulty of the foundations, besides leading you to determine to adopt iron piers instead of brickwork lead you to reconsider the question of the spans of the central girders?—Yes; that was so. It was a very slow operation. By the original contract the work was to be completed in three years, and we took seven to do it. And one object in view was to push on the work, but another was to assimilate the cost of the piers to the superstructure. I mean to say that piers were more expensive than the superstructure, and by reducing the number of the piers I was able to put more into the girders.
16,639. The substitution of iron piers for brickwork made a more expensive pier than the old pier?—Yes; it turned out so.
16,640. It made it worth while, then, to increase the strength of the girder and the span of the girder so as to get fewer piers?—Yes; but the great expense was in the large caissons, which we were obliged to have below, and getting up the thing to the height where the columns commenced.
16,641. (The Commissioner.) That was the great expense?—That was the great expense.
16,642. (Mr. Barlow.) Do you know what was the cost of a pier as you constructed it all the way from the bottom?—I can give you that. I cannot give it you on hand.
16,643. (Mr. Bidder.) In point of fact, the great increase of cost in constructing the piers made it worth while to put more money into the girders, so as to reduce the number of piers.
16,644. In no way weakening the stability of the bridge?—Certainly not, because I strengthened the girders. Of course, I increased the cost of the girders as the squares of the spans.
16,645. The ultimate result of all these alterations was to put what weight upon the foundations per square foot?—I think about 3 tons per square foot.
16,646. 24 tons, was it not?—It may be.
16,647. Amongst other things which were under discussion were the details of the construction of the columns, their thickness, and so on. Mr. Grothe said that at that discussion at which he was present they were marked on the plan an inch and a quarter, and that you afterwards altered them to an inch, which I think also is correct; and then upon his own responsibility, and without any orders from you, subsequently he reverted to an inch and a quarter. Is that so?—No; that is certainly not true within my recollection. At one of our weekly meetings I decided to make these columns an inch and a quarter thick. When I gave the orders to do it, Mr. Grothe took his pen and wrote down on the plan, "An inch and a quarter." I never altered that after. I have asked all my assistants, Mr. Stewart and everybody, and they have no recollection of my having altered that. I well through it was really intended to be a half inch and a quarter. As a matter of fact, it averaged about an inch and three-sixteenths; it is very near it, but it was always intended to be an inch and a quarter.
16,648. Was that at a meeting at which Mr. Stewart was present?—Mr. Stewart was present, and he has a recollection that it was to be an inch and a quarter.
16,649. Mr. Stewart tells me that that was on the 6th of April?—Yes.
16,650. Mr. Stewart will be called hereafter. I will assume that the following is at present. I see there had been a letter written to Mr. Grothe previously to that from Mr. Wemyss, at your instance?—Yes; that was a few days before.
16,651. "April 1st. Sir Thomas Bouch desires me to inform you that the thickness of metal of the columns for piers of 200-feet spans, a tracing of which he handed you the other day, is to be one inch in place of an inch and a quarter, as shown off the tracing," I think that means the other columns. I do not think it meant those; but whatever it was it was decided at the meeting of the 6th of April. That letter was dated the 1st of April.
16,652. You do not recollect the date of the meeting?—No.
16,653. (The Commissioner.) It appears from that letter that they were to be altered from an inch and a quarter to one inch.
(Mr. Bidder.) Yes; that was on the 1st of April.  
(The Commissioner.) Let me see if I correctly follow you. Originally they were to be one inch; then there was an alteration to an inch and a quarter?  
(Mr. Bidder.) They began at an inch and a quarter.  
16,646. (The Witness.) These four columns were always to be an inch, the 18-inch columns.  
16,647. (The Commissioner.) They were continued an inch?—Yes; and made an inch.  
16,647. This only applies to the 18-inch columns?  
16,648. (The Commissioner.) They were an inch and a quarter.  
16,649. Before they were to be an inch, were they?  
16,650. (Mr. Bidder.) This letter does not draw any distinction between the 15-inch and 18-inch columns. On the 1st of April it says, "The thickness of the mistal of columns for piers 200-feet spans" (without specifying 15-inch or 18-inch columns), "a tracing of which he handed you the other day, is to be one inch in place of an inch and a quarter as shown on the tracing." Consequently, there had been before the 1st of April a tracing which showed generally the thickness of the columns to be 1½ inch. Then comes this letter of the 1st of April, saying that instead of 1½ inch it is to be one inch. (To the witness): Then, as I understand it, at the meeting, the date of which Mr. Stewart supplies me as being the 6th, it was decided that the 18-inch columns should be restored to 1½ inch; the 15-inch columns being left, as they were executed, at one inch.  
(The Commissioner.) That rests upon Mr. Stewart's evidence, and hardly upon Sir Thomas Bouch's.  
16,651. (Mr. Bidder.) That accounts for the mistake which Mr. Gröthe made. It is obvious how the mistake arose. (To the witness): There were increases of some of the lower spans, the smaller spans, were there not? For the same reason.  
16,652. Nothing turns upon them?—No.  
16,653. The 145-feet spans?—Yes.  
16,654. The object being the same?—Yes.  
16,655. Having regard to the altered foundations, it was considered that it was better to make larger spans?—Yes.  
16,656. All the plans, as finally altered, were prepared by your assistants under your supervision, and considered and decided upon by yourself before final adoption?—Yes.  
16,656. And, I believe it was your practice to go every week to the site of the bridge, and have weekly meetings of your subordinates and your resident engineers to discuss all questions that arose?—Yes.  
(The Commissioner.) Before you leave that I want to call your attention to the original drawings of the bridge. If you look at plan 31 you observe that the drawing in the lower right-hand corner is the drawing of an 18-inch column (1 foot 6 inches); then the dimensional at the extreme outer limit is 1 foot 6 inches, the internal diameter being 1 foot 4 inches, a difference of 2 inches. That would seem to imply that the columns were only to have 1-inch thickness. I am speaking of the plans sent to the Board of Trade.  
(Mr. Trayner.) I thought those plans were copies of those handed in at Dundee by the North British Company.  
(The Commissioner.) These plans are copies of the plans upon which General Hutchinson made his report, which were handed to the Board of Trade previous to the opening of the bridge.  
(Mr. Trayner.) I understood that they were copies of the plans that were handed in at Dundee by the North British Company.  
(Mr. Barlow.) I know that what Mr. Rotbery states is the fact.  
(Colonel Yolland.) These are not the plans handed in at Dundee.  
(The Commissioner.) That would almost imply that at the time the bridge was completed the impression they wished to convey to the Board of Trade was that the 18-inch columns were one inch thick.  
(Mr. Bidder.) That is clearly so. It is equally clear that a tracing had been prepared which showed that the whole of the columns were to be one inch and a quarter.  
(The Commissioner.) An inch and a quarter was written on the plan in the contractor's office, and they had, no doubt, tracings from that; but these plans were prepared in my office by my assistants from the old plans, and, no doubt, they copied the thing as one inch. They, no doubt, copied the original.  
(Mr. Bidder.) I can elucidate it one step further—that it was referred to by Mr. Gröthe himself. There were drawings prepared at the time the matter was under discussion by Sir Thomas Bouch. Here is one dated the 13th of March, and I think I am right in saying that, while, as in the Board of Trade drawing, the drawing would scale out an inch thick; there is written in the margin, "Inch and a quarter of metal." (The Commissioner.) What is the date of that?  
(Mr. Bidder.) March 13th.  
(The Commissioner.) Then Mr. Gröthe's evidence is consistent with that. Mr. Gröthe says that on March the 13th it was agreed that the thickness of the column should be increased to 1½ inch, and that he subsequently received a letter from Sir Thomas Bouch to say, "Do not make it 1½ inch, but make it an inch." (Mr. Bidder.) He is right, with this addition, that the letter would show it to be general and not confined to the 18-inch columns. Sir Thomas says nothing in contradiction of that. As I am going to call Mr. Stewart, I may as well clear it up and read this. I hold in my hand his diary, and under the date of April 6th I find this: "At the Tay Bridge "with Bouch, decided to raise pier 26 about 6 inches, "to increase level portion and steepen gradient 22 to 26; "decided to make outer columns 1½ inch thick, "and the inner columns 1 inch." No doubt, the way Mr. Gröthe was led into the mistake was that he remembered the fact of 1½ being written by himself on the tracing, and the fact of his afterwards having got a letter which said, "Make it an inch."  
(The Commissioner.) That may be satisfactory to a certain extent, but we must recollect that Mr. Gröthe was the agent for the contractors to cast the columns, and Fergus Ferguson was the man who cast the columns.  
(The Witness.) They were paid by weight.  
(The Commissioner.) We know what the thickness actually is, because we have got the columns themselves.  
16,656. (Mr. Bidder.) As to the concrete in the columns, what were your views in using it?—Simply to prevent rust. We could not get inside the columns to paint it. The sole object was to prevent rust.  
16,657. You did not calculate upon the concrete for stability?—Not in the slightest.  
16,658. As regards another matter that has been referred to—the ties, as we know, are connected with the columns by 1¾-inch bolts passing through the ties, or the plates in connection with the ties, and through a pair of lugs?—Yes.  
16,659. Had you adjusted those bolts and lugs so as to be considerably stronger than the ties?—Yes.  
16,660. According to the tensions which the cast iron would bear?—Yes.  
16,661. With regard to inspection, with the assistance which you bad, in your judgment, were the arrangements which you made such as secured a thoroughly adequate and efficient inspection of all the parts of the work as it proceeded?—I think so.  
16,662. You were engineer-in-chief, and generally responsible for the execution of the work?—Yes.  
16,663. Obviously it was impossible that you, or any other engineer, could with his own eyes see every rivet and every joint?—I could not. I appointed inspectors who, I thought, would see to that.  
16,664. You selected competent men, and you believe they did their duty?—Yes.
16,665. And you say that you weekly visited the bridge, and supervised the work also?—Yes.
16,666. You met them and checked their progress, and discussed difficulties with them?—Yes.
16,667. With regard to the cast iron, did any complaints come to your knowledge, or was there anything that gave you any reason to believe that either the quality of the iron or the workmanship in casting was inferior?—No, I never heard of anything at all about inferior quality.
16,668. Nor saw anything?—Nor saw anything. There is no doubt that the breaking down of the piers has disclosed some imperfections which, if I had known at the time, I would have had corrected; but I do not believe that the bridge fell from that.
16,669. Is it possible to execute a work of this magnitude without imperfections in some portions of it?—No, you must expect some.
16,670. It has been suggested in evidence that the malleable iron tie-bars were sent from Middlesbrough to Wormit, and before they were put upon the bridge there was no test applied to them to ascertain whether they were up to a proper test, and the specification has been referred to, from which it appears that the only test for malleable iron is under the head of "girders." In point of fact, did you take steps to have all the malleable iron that came from Middlesbrough properly tested, whether it was for girders or tie-rods?—Not all the malleable iron, but I sent specimens to Mr. Kirkaldy to be tested.
16,671. You selected pieces?—Yes.
16,672. That is the only way it could be done?—Yes.
16,673. You took pieces at random, and sent them to Mr. Kirkaldy to be tested?—Yes, but those were not specimens, of course, of all the iron. We made a selection of the iron that was upon the ground.
16,674. Have you the results of Mr. Kirkaldy's tests of the iron?—Yes (handing it to Mr. Bidder).
16,675. "Results of experiments to ascertain the tensile strength, etc., of fourteen pieces of iron received from De Rugghe and Co., from Wemyss" was a selection of the iron that was to be used.
16,676. That is preliminary, is it?—Yes.
16,677. I have one of 1877: "Result of experiments to ascertain the tensile strength of iron received from Thomas Booth, Esq.," and the extensions and the fracture are given according to Mr. Kirkaldy's usual practice, and the breaking strain, at per square inch, which I see are "22-7, 22-5, 22-1, 21-1," and in the last case, 14-1; and against that there is this note, "Flaw caused by straightening plate." With that exception, they appear to have been all 22 tons and over?—Yes.
16,678. And, therefore, they were up to the requirement of the specifications?—Yes, that is strong iron, 22 tons.
16,679. I need not follow that in detail, because it is admitted that the qualities of the wrought iron were good. Have you anything to say with regard to the cast iron?—The cast iron was tested with a transverse strain; that is always done in the foundry.
16,680. That was tested from time to time at the foundry, but the malleable iron was tested by Mr. Kirkaldy?—Yes.
16,681. (Mr. Bidder.) Do you know that it was tested at the foundry, or do you presume it?—16,682. (Mr. Bidder.) Do you know that it was tested at the foundry?—I was told so, and that it turned out favourably. I was told that.
16,683. By Mr. Paterson?—By my own people.
16,684. Mr. Paterson reported to you?—Mr. Paterson is my Inspector. I have only a general recollection that it was reported to be favourable.
16,685. Mr. Paterson was peculiarly qualified to be entrusted with the inspection of the cast-iron work; he had had a great deal of experience in cast iron?—He built that pretty large bridge at Stirling with cast-iron arches.
16,686. (The Commissioner.) The question asked you is: Are you aware that the cast iron was tested at all by anybody at Wormit?—No, not any special test.
16,687. (Mr. Bidder.) That is to say, of your own knowledge?—Not of my own knowledge; it was only the talk at the time at those meetings.
16,688. (The Commissioner.) Did any of your assistants say to you, "We have tested the cast iron"?—It is seven years ago, and I really cannot say; but I can say positively they told me that the iron was satisfactory.
16,689. (Mr. Bidder.) Who had the inspection of the iron that was made at Middlesbrough and Cardiff?—First, Mr. Wemyss had it, and then afterwards Mr. Macbeath.
16,690. (The Commissioner.) They had the inspection of it?—Yes.
16,691. (The Commissioner.) On your behalf?—On my behalf.
16,692. (Mr. Bidder.) I believe Mr. Macbeath came to you with a very high character as an inspector of ironwork?—Yes, and he was a good deal complained of for his strictness.
16,693. Did you find him a very careful and strict inspector?—I did. I am quite certain if he had discovered anything wrong he would have reported it, and have objected to it.
16,694. Mr. Macbeath, as we know, acted as inspector from the time of his appointment in June, 1877?—Yes.
16,695. Till some four months after the inspection by General Hutchinson?—Yes.
16,696. What were Mr. Macbeath's duties lately, after the bridge was finished?—Just to overlook the work, to go all up and down the piers and everything, and if he saw anything loose, nuts or anything, specially to caulk them.
16,697. Did you as the work progressed examine it carefully from time to time?—Yes, I often did.
16,698. Have you every reason to believe, from the most careful examination you could make, that the work was all as passed in perfectly good order?—It was; I was convinced myself that it was.
16,699. And that any inferior work had been rejected?—It would have been rejected if it had been inferior work.
16,700. It was rejected from time to time, as we have heard?—Yes, there were some things rejected for defects as the work proceeded.
16,701. We know, as a matter of fact, that there were certain cylinders in the columns that were of unequal thickness on the two sides?—Yes.
16,702. I suppose it was almost impossible in every case to detect any such inequality, as that?—It could only do it by boring holes through. I was not aware of the unequal thickness.
16,703. Had you been aware of the unequal thickness, you would not have passed it?—If any cylinder had been pointed out where there was a material difference in the thickness, I should have rejected it.
16,704. Did the unequal thickness in certain columns in any way, in your opinion, contribute to the accident?—Not the slightest; it does not materially weaken a column if the difference is only a matter of an eighth or a quarter of an inch, but when it gets more than that it becomes more serious.
16,705. (The Commissioner.) Would a difference of three-quarters of an inch materially affect the strength of the bridge?—I should have objected to that.
16,706. (Mr. Bidder.) You would not have accepted a column with that difference if you had known it?—No.
16,707. I believe, in point of fact, you never stinted your staff; wherever you thought it desirable you put on the best people to procure an efficient inspection of the bridge?—Yes. In my inspection actual outlay was far more than I had for the job as engineer altogether. I had about three per cent on the estimated cost for the engineering, that is about 10,000£, and I have vouchers for above 9,000£ paid to those inspectors. That does not include my own expenses.

16,709. You took every precaution you could to have ample and efficient inspection?—I did. I say best I did get a good job.

(Mr. Webster.) As to the testing at Wormit coming to his knowledge, you will find Mr. Beattie's evidence at page 257.

Mr. Bishop read it.

16,710. (Mr. Bidder, to the witness.) I do not know whether that recalls to your memory?—I have no doubt. Mr. Beattie told me all that at the time.

16,711. As regards one matter that has been referred to by Mr. Law, the suggestion that your looking at the bolts were drawn out of the stones, is there any foundation for your believing, as was suggested by Mr. Law, that that ever actually happened; that when the nuts were screwed up of the holding-down bolts, which were put into the holes to hold down the base-plates that were anchored by cement, the bolts were drawn out of the stone?—I do not believe that.

16,712. You have no ground for thinking that Mr. Law is right in that supposition?—No.

16,713. There is another matter I must ask you about, and that is as to the turning of the flanges; it has been suggested that it was a disadvantage to have a recess in the flange, and not to have a whole face right across?—I am not quite sure that I understand you.

16,714. It was said that your flanges had a recess. I think it is, where the bolt came through (like this drawing and diagram). Mr. Law took exception to that, because you had not a whole face right across. In your judgment, and according to your opinion, was there any disadvantage in that?—Not at all.

16,715. One other matter I must ask you about. It is also-pointed out that you had specified in the specification that the holes through the lugs were to be cylindrical and parallel, and that in point of fact they were cast somewhat conical, enlarging towards the point in some cases, and that in consequence of that the effect would be that the bolts, instead of bearing upon the whole width of the lug, would bear upon the outside edge, and when an excessive strain came upon it, it would bend, and so the structure would become inefficient. Were you aware that there were any conical holes?—I was not. If I had known I should certainly have had them drilled out square, though that would have somewhat reduced the quantity of metal in the lug, but I should have had that done certainly.

16,716. You will so far agree with what has been stated that that was a thing which you would not knowingly have passed, and in consequence of that you think it is an advantageous?—You could not see the thing by inspection; you could not see the conical shape of the hole.

16,717. It would be very difficult to see, even if you were looking at the lug itself before the bolt was in it?—Yes; my own theory is, that the ratcheting which Mr. Noble spoke of was due to the bolt bent in the conical hole. It would be drawn from the straight, and it would take its bearing on the cone.

16,718. That gave a certain distance?—Yes, and that would lessen the ties. I think I would occasion the ratcheting spoken of. I went up the columns with General Hutchinson, and when those big stones were running over at 40 ties an hour, we could find no tremor, and no shaking of the ties or anything; they were all braced up. I believe it was subsequent to that; it might have been with some of the great storms we had, but I believe subsequent to that the strain of the tie bent the bolt so that it took its bearing on the conical surface. When it was tightened it made it just as strong again. I would rather have had it square, but it tightened it up.

16,719. If I follow you, the fact of the bolt being conical made it possible when a severe strain came upon the tie for the bolt to be bent till it took its bearing upon the conical hole?—Yes.

16,720. That bearing of the bolt gave a certain extension to the tie, and of course of slenderness?—Yes.

16,721. Till that slenderness was taken up again, that tie would not be doing its duty?—No.

16,722. Though you said you would not have pressed them knowingly, in your judgment, assuming the slenderness of the ties was properly taken up when the bolts had bent, did the existence of those conical bolts materially weaken the structure?—No, they did not; not at all.

16,723. When the structure was completed, General Hutchinson inspected it on the part of the Board of Trade?—He did; he spent three days on it.

16,724. I believe you accompanied him on his inspection?—I did.

16,725. And that inspection, I believe, was of an unusually thorough and searching character?—It was the most strict inspection I ever experienced of the many I have had through the Board of Trade's hands. I never knew so much time and pains spent in a Board of Trade inspection as was spent by General Hutchinson at that time.

16,726. You were present at the time. So far as you could see, do you agree with General Hutchinson that the bridge was in every respect complete and efficient, and remarkably rigid?—I felt so. I thought so when I went through the inspection. I went along the piers with General Hutchinson, and I put my arms round the columns when those great cunei were going out at full speed, and there was no tremor at all; they were so rigid I was surprised at it.

An adjournment took place for the usual period.

16,726. (Mr. Bidder.) I think I have asked you enough as to the completion of the bridge. Shortly after the inspection by General Hutchinson, which was in February 1878, I think the bridge was open for traffic?—Yes.

16,727. But I think your connection with the bridge did not then cease?—No, it did not.

16,728. Was an arrangement entered into between you and the North British Railway Company whereby you were still to continue to supervise the bridge in its maintenance?—Yes, there was that arrangement, I took so much interest in it that before that arrangement with the company I really did continue to devote myself to it.

16,729. There were a good many letters upon this. Mr. Noble, as you know from his evidence, continued to be employed upon the bridge with a certain staff?—Yes.

16,730. And Mr. Noble stated that in regard to his examination of the piers of the bridge, he did not think that he did it simply of his own motion; is that correct?—That is not true. The staff was given him of two men, and when they were not sounding and finding out about the scour, which was the principal thing that I was afraid of, they were to be employed upon the piers seeing that the nuts were all right.

16,731. That which you were most anxious about, as I understand, and those were not engaged in taking soundings, their business was to examine the different parts of the structure?—Yes.

16,732. The duty of Mr. Noble and his assistants was to watch for that; and you say also, when they were not engaged in taking soundings, their business was to examine the different parts of the structure?—Yes.

16,733. (Mr. Balfour.) You say "Their duty was." How did the duty arise?—I shall have to prove it if you do not.
16,734. (Mr. Bidder.) I think, after the completion of the bridge, Mr. Noble was still going on with the railway upon the south side? Yes; the Newport Railway.

16,735. Had Mr. Noble any duties in connection with that?—He had the inspection of the masonry and things in connection with that; but that was a short line. He was not fully employed on that, and he still kept up his connection with the Tay Bridge.

16,736. Mr. Noble was partly paid by you, I think, and partly paid by the company?—Half the services were devoted to the Newport Railway, the company paying the other half for the inspection of the bridge.

16,737. (Mr. Barlow.) That was for a time only, I suppose?—Yes; that is when the Newport Railway was opened.

16,738. (The Commissioner.) You paid him for him for his services to the Newport line?—Yes.

16,739. And the company paid him for his work on the bridge?—Yes.

16,740. (Mr. Bidder.) There is a series of letters which will make the matter clearer, and show what Mr. Noble was doing. He reported, I believe, from time to time upon the bridge to you, did he not?—I do not.

16,741. On the 9th of May 1878 (that is before the opening of the bridge for traffic), Mr. Noble, I see, writes to Mr. Walker, who is the manager of the railway company, "I have the pleasure to inform you that the two ironworkers who have been engaged in the examination of the iron columns will have completed their work to-day. The bolts and bindings of the columns, also the rivets which required looking to, are now in a perfect state of security." It appears, therefore, that he had been making a further examination after General Hutchinson's inspection?—Yes; he was paid half his salary by the company for the purposes.

16,742. This relates, I suppose, to the examination which Mr. Macbeth took part in?—Yes.

16,743. These letters are all printed, and we propose to hand in the print of them.

(The Commissioner.) Could we have a copy of those letters now?

(Mr. Balfour.) Here they are; sir; there is one for each of the Court (handing them in).

16,744. (Mr. Bidder.) Mr. Walker, I see, encloses that letter to you the next day. On the 21st of June there is a letter from Mr. Walker, recommending that the woodwork of the Tay Bridge should be repainted simultaneously with the iron structure. It might have been well if the whole had been embraced in one contract; but as this has not been done, I see no objection to Inspector Noble's suggestion being adopted, viz., that he should carry out the work himself under your supervision.

16,745. Acting under your orders generally for the maintenance of the bridge?—Yes.

16,746. Not merely watching for oor, but generally for the maintenance of the bridge?—Of the whole of the bridge.

16,748. I see another letter of the same date from Mr. Walker to yourself, enclosing, for your information, a copy of the letter which I have just read?—Yes.

16,749. And there is a letter of the 5th of July from Mr. Walker again to you, saying, "I reported to the directors at their meeting yesterday, the arrangement embodied in my letter to Mr. Bell of the 22nd ult., a copy of which was transmitted to you, whereby you are to undertake the supervision of the piers and foundations of the Tay Bridge, and continue Inspector Noble's services for another year, and I have the pleasure to inform you that the directors approved of this." Then, on the 12th of December, I see you write to Mr. Walker, saying, "In answer to your letter, I have no written report this month from Noble, but I had him over here on other business, and learned from him that everything about the bridge continues satisfactory, and I authorised him to give you four of his men notice to leave, as he thinks he will not require them any more. He will, however, require one more carriage of stone, as there is a slight indication of company in one of the piers, but he thinks this will be the last. I am myself, however, of the opinion that both the iron columns will have completed their work to-day. The bolts and bindings of the columns, also the rivets which required looking to, are now in a perfect state of security." It appears, therefore, that he had been making a further examination after General Hutchinson's inspection?—Yes; he was paid half his salary by the company for the purposes.

16,747. There is a series of letters saying, which Mr. Noble, apparently, under cover, to Mr. Walker on the 24th. On the 26th Mr. Walker writes to you, saying, "I was duly favoured with your letter of the 24th instant, enclosing one from Inspector Noble, recommending that the woodwork of the Tay Bridge should be repainted simultaneously with the iron structure. It might have been well if the whole had been embraced in one contract; but as this has not been done, I see no objection to Inspector Noble's suggestion being adopted, viz., that he should carry out the work himself under your supervision." Then, on the 10th July, Mr. Walker writes to you again, saying, "I beg to enclose a list of Inspector Noble's staff, and the wages paid to each man. I presume the deposit of the rubble, at the piers is now nearly completed, and perhaps you will let me know whether the present staff is likely to be permanent, or if it can be reduced, a list of the staff being given. Then I see on the 18th of July you write in reply, explaining that Mr. Noble could not do with less staff. On the 19th Mr. Walker acknowledges your letter, and on the 20th you write to say, "I have had Noble the last two months three soundings around every
"pier, and find that of all those which were metallised".

"the result is very satisfactory. There is no change

"whatever excepting in two, where the sand is

"actually accumulating; but at some of the smaller

"spans at each end of the bridge, where no stone was

"deposited; there is indication of a slight swell, and

"Noble orders to stop it by depositing

"more stone. The cost of this will be about 2751."

In addition to that had you several reports yourself from Noble?—Yes.

16,750. I think they had better be put in too. The

first that I have is on the 31st of July 1878. This

would be exactly two months after the bridge was

opened, it is from Mr. Noble to me. "During the

present month I have placed rubble around most

of the piers you pointed out to me on the

drawing at the interview you granted me at

the Tay Bridge station on the 2nd of present

month. I have also made up with rubble to the

height of ordinary low-water mark all the

piers from No. 81 to No. 75 (north side of river).

I have entirely surrounded these piers with an

embankment of rubble that will defy the scour of

having any effect on the piers for years. My

reasons for so doing are twofold. In the first place,

the cylinders or bases of these piers are not sunk so

deep in the original bed of river as those further

from the bridge. Secondly, I find that the engine drivers

always pull up at this part of the curve, and the

brakes are applied to the carriages to enable the

man on the engine to snatch his orders from the

hand of the signalman before he can proceed

forward, thus causing a drop which was felt below."

The above passage makes me wonder what the effect of the traffic on the bridge?—Yes.

16,751. "This fine weather has enabled the steamer

which brings the rubble to deposit it at the exact

spot without fear of striking the columns, and can

only be done at high water. Since the rubble has

been banked up around these piers, the heaviest

waves make it perceptible. If you feel the noise you

would not believe a train had passed over. I should like to entirely surround

the other cylinders with stones from No. 73 to

No. 61 up to low-water mark; also, by so doing, it

would take in the whole of the curve, and as the

sandbanks from 61 to 57 are level, and in places a

foot or more below low water, there should have at least

water the whole of the north side of the bridge in

sight, so that if scour took place at this most

particular part of the structure it could be seen at

once and dealt with accordingly. Formerly, the

sandbanks were level with low-water mark; now

we have between 6 and 7 feet of water from low

water to high at these piers I have named, viz.,

from 73 to 61. From 61 to 53 the sandbanks are

generally in sight at low-water mark. If this was

done during the autumn it would be a capital job,

and a great saving to the North British Company in the future. It would take nearly 3,000 tons to carry out this suggestion, at a cost of 750. I

think you should call your attention to this, to a statement I

made in your presence at Edinburgh, in the month

of January of the present year. Mr. Stirling, the

chairman, asked how much stone it would take to secure the piers. I replied, about 5,000 tons, at a cost of 9s. per ton, including working expenses,

etc. Nearly that quantity was used and econo-

mically laid down at the time of seeing you at the

station on the 2nd. Since then I find that I have

exceeded the quantity by 670 tons. I merely

mention this to set myself right with you and the

gentlemen present at that meeting. I am happy to

say that the piers are not only secured at the price

stated, but upon a strict survey made every day

there is not the slightest sign of a settlement at any

of the piers. My staff of men who work the steam-

boats are always busy overlooking bearings, etc.,

while I am attending the Newport Branch. At

"high" and "low" water I never neglect to be

prevented to keep the sounding-tubes going in an

"the tides." Is it within your understanding that

his staff of men were continually engaged in overhauling the bracings and ties throughout the bridge?—Yes, that was the arrangement I made, that they should

devote their spare time to examining them.

16,752. When I say that you instructed Noble

that his men should employ themselves in going over

the ties?—I cannot name the time, but it has often

passed between us. There was no formal written order as to what Noble's duties were, but it was

perfectly understood.

16,753. I presume it was before this letter; because

he reports to you that they are doing it?—Yes.

16,754. Were those reports sent on to you by the

North British Company?—I think, as a rule, they were.

(Mr. Webster) This one of the 31st of July was

sent on the 16th of August.

(Mr. Bidder) I presume there is no doubt about it.

(Mr. Balfour) You may assume that they were forwarded.

(Mr. Webster) "I have yours of yesterday, and as

requested enclose you Mr. Noble's report upon the

"foundation of the piers."

(The Commissioner) That is so.

16,755. (Mr. Bidder.) Thus, I suppose, this is the

appendix to that letter. There is a list of the

apparently tons of stone on different dates, making

1,120 tons which he had deposited. I do not think

we want that. Now then I come to the next report,

which is one of the 31st of August 1878; sent on, as

Mr. Webster reminds me, on 3rd of September, under

cover to Mr. Walker: "I have received enclosed

"account from Mr. Speed, who supplies the rubble

stones, for the piers of the bridge, and find the

account correct. I have very little to say in regard

to the bridge, only to reiterate my former statement,

viz., that there is not the slightest appearance of

weakness at any of the piers. Every part of the

work from the foundations to the superstructure.

seems to be doing wonderfully well, and the least

doubt in my mind but will continue to do." Then I see

again you had a report from him on the 1st October, which is communicated on the 5th to Mr. Walker: "I have received enclosed account from Mr. Speed." Then he gives the account for the rubble: "You will perceive by the above that I have

used a very small quantity of rubble at any of the piers. I thought it advisable to wait till the Equinoxial

gales were over. We had a fair specimen of them

since the 13th of present month. On Sunday the

15th (that will be the 15th of September) it

blew a hurricane quite as severe as it did when the

girders fell. I am now going over all the piers

again to see if there is any difficulty, and I am not

the least doubt in my mind but will continue to do.

May I take it with reference to that statement of Mr. Noble's, that, assuming that there were any conical holes with bolts in them, which would be subject to a heavy strain and so cause slackness, such a hurricane as

described by Mr. Noble there would probably develop

such slackness?—It would strain the bolts and create a

certain clatter.

16,756. Especially if it had been subjected for some

months to the vibratory action of the trains?—I do

not think that the trains would do it.

16,757. Was that a very severe gale?—I was in

Italy when that took place. I went to the south of

France, and I believe you are at

16,758. On the 1st of November, I think, you had

another report, and that is sent on to Mr. Walker by

you the next day: "In my last letter to you, dated

9th September 30th, I enclosed Mr. Speed's account of

rubble stones brought to Tay Bridge by him and

deposited at the several places named by me during

September month, and I am happy to say that he

has not received the cash for the same. He has now sent

to me the enclosed account for the last month

and the month of October, and finding them correct I

have signed them as usual, previous to sending them

to you." In my last letter or report, dated Sep-

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16,763. (Mr. Bidder.) Did Mr. Noble ever report to you as to any of the tie-bars chattering?—No, never. I was very much surprised at it when I heard it.

16,764. Assuming that he found certain tie-bars chattering, and did as he describes in the report, that is to say, introduced packing pieces where necessary, and then hammered up the cotters until they were tight, would that, in your judgment, restore those tie-bars to their former efficiency?—I think it would.

16,765. You think the other way would make the tie effective again?—It would cost a little more money, and it would look more like engineering; that is all. I can say.

16,766. I think he did report to you that one or more columns were cracked, did he not?—He did.

(Mr. Webster.) The earlier ones seem to be entirely about the rubbling being put into the foundations; (The Commissioner.) I see there is no report for December, January, or February; (Mr. Webster.) Yes, we have the December one. (The Commissioner.) That was sent in December, but it was not written in December.

(Mr. Webster.) That report was up to the 18th of December.

(The Commissioner.) Then from that time until the 11th of April we have no report at all, and the one of the 11th of April refers simply to two particulars.

(Mr. Bidder.) Perhaps you will check the dates with those I have. I have one on the 12th of June 1876. (The Commissioner.) We have not got that.

(Mr. Bidder.) That I see is exclusively with reference to the rubble. There is something about the scour, and the rubble to be put under the different piers. I have another of the 18th of June 1878, but that seems to me more particularly to relate to the Newport line.

(The Commissioner.) That we have not got.

(Mr. Bidder.) And I do not think it necessary to trouble you with it. Mr. Balfour, or Mr. Traynor, if he likes, may see these reports.

(Mr. Balfour.) What we have lithographed are all that are in our custody.

(Mr. Bidder.) Except a slight grace or as to examinations of the foundations of the bridge.

(Mr. Balfour.) That was apparently not communicated to us at all, but to Sir Thomas direct; but perhaps you will kindly let us see it.

16,767. (Mr. Bidder.) Certainly you shall see them all. In the letter of the 18th June, Mr. Noble says:—If the weather is as favourable, I shall have completed my third series of soundings in about three weeks from present date. I will then send you a summary of the position of every pier in relation to the bed of river since September of last year, and February and June of present year; and there follows an account of the rubble. Then there is a letter on the 4th of July, which is not addressed to Sir Thomas Bouch, but to "G. Trimble," who is he?—My assistant.

16,768. (Mr. Bidder.) I beg leave to inform you that I have taken the expansion at the several piers, and then he gives the figures. Then there is one on the 31st of August, I do not think you have had that yet;—I would like to draw your attention to the fact that the repainting of the bridge is not being proceeded with; the reason why I cannot understand. It is time the work was commenced, or the season will be far too advanced to make a good job of it. It appears to be a complaint that they were losing a good time of the year for painting. Then there is a letter on March the 11th, 1879, which appears to relate principally to the lighting of the lamps. In regard
Mr. Thoms, the quantity of work done at the bridge since he got there, now lying in the right way between No. 12 and 13 piers, is cleared away." Then he asks to be allowed to engage a diver for that purpose. Then there is a portion of the letter upon the repainting of the bridge, and the amount of paint that it will take. Then there is a letter of the 4th of March, in which Mr. Noble says, "I saw Mr. Gilkes this morning at Dundee. He told me he was ready to commence the repainting of the bridge forthwith." He expressed a desire that it should accompany him across the bridge, and determine which of the girders, columns, &c., required scraping and repainting. I told him I could not determine anything till I received instructions from you, and should be ready at any time to carry out your orders in regard to the work being carried out in a workmanlike manner. I have made a start towards carrying out the blasting operation at the 'sunken girder.' (I am not reading it all. I am merely glanced over it.) Mr. Balfour shall see it is simply the question of the cost. "In going over the difference of cost upon one cubic yard of brickwork built one and two of sand and one of cement, I find that, taking the cement at 40. per ton as an average price, by having two of sand to one of cement, instead of the proportion of one to one, we have a saving of 1s. 6d. per cubic yard." That must relate to the Newport line, because you were doing no brickwork, and cementing to the bridge after it was finished?—No.

16,769. Then there is a letter of the 17th of April with regard to the lighting of the lamps on the bridge: "I have just had an interview with Mr. Thomas, engineer, and Captain Robertson being present. I informed them that the North British Railway Company wished to light up the lamps which are placed in position; that is entirely, I think, confined to the question of lighting. Then there is a letter of May the 15th, 1879, headed, "Repainting Tay Bridge," "I beg leave to call your attention to the fact that Messrs. Hopkins, Gilkes, and Company have not commenced to repaint the bridge, and seeing that it is near the middle of May and no sign of them starting the work, I thought it would only be consistent with my duty to remind you that your contract for painting the bridge in the month of April is due out, and it is necessary to have the work carried out in a workmanlike manner. I have made a start with the rubbels, &c., and I intend in the next month of September to commence the repainting of the bridge, and it is here that the lamp-lighter McKinnon assists all in his power: at the present time he has to rise at 3 a.m., and out at night at 9.30, keeps his twenty-eight lamps clean, sorts the burners, and records every night's burning from the meter. The quantity of gas burnt each week is then entered on a printed sheet, signed by me, and sent to Sir M. Magaret's, Edinburgh. I may mention that the lamp-lighter works every Sunday without extra pay. I hope the above is sufficient to show the necessity for keeping the men on under present circumstances." In reply to the question, 'Is the inspector's staff likely to be permanent?' I should like to be allowed to make a suggestion, one I think would not only secure confidence for the future, but be more economical. Of course, it is generally admitted that it will take two or three years before it can be ascertainment to a nicety the changes which we should all naturally expect would take place from the fact of so many piers being set down in the natural current of a tide. But the Tay, 'tapp'd as it is with so many shifting sand-banks, especially knowing the scour which actually took place from No. 22 to 27, from 46 to 48, and from No. 72 to Bow span, north side, all of which have been specially and successfully attended to, and the threatened danger averted. Now, I would suggest the following plan, after I have taken my next series of soundings in September, sent them to any place that may require it by depositing wagers among the good harbour due west of the Tay Bridge steamers in the dock and lock-up sounding apparatus, secure the small boat also in some place. The other could take the place of one of Mr. R. Bell's men, two of whom do nothing except the work is slowly but surely passing away." 16,770. (The Commissioner.) Were Messrs. Hopkins, Gilkes, and Company going to paint the bridge? It was part of the contract; they had not yet put the last coat on.

(Mr. Bidder.) Then he says: "The traffic on the Tay Bridge is commenced in earnest to-day," and "the bridge was lighted up for the first time on Saturday night." Then the next letter has nothing to do with it at all. Then there is a letter of July the 15th, and that is with reference to the painting of the bridge: "If the first instalment, amounting to 250l., is not paid, nor by Mr. Balfour, it is fair and reasonable for the quantity of work done at the bridge since he started!" That is the letter of the 16th of July, 1879; which I do not think you have got: "In answer to enclosed letter from Mr. John Walker, General Manager N.B.R., respecting 'rubbles at piers,' 'painter's staff,' possibility of reducing the same, on if intended to be permitted to use rubble stones at the piers, I intend in the forthcoming month of September to go through with the soundings at every pier, and compare the figures with those I have on my chart, which was taken in May; the result will determine whether any more reduction of the work is required. In answer to question as to reducing the staff, I beg leave to state that the services of the two men Neish and Bell cannot be dispensable with until the September soundings are accomplished. In the meantime they are busy every day fixing new points and washers, and each pass through the way-bams on which the permanent rails are fixed. The continual traffic on the bridge causes the nuts to get loose, and we have found a great many on the sand-banks. Now nuts are screwed on where required, and caulked to prevent their coming off again. This work necessitates the making of a scuffle, such as the one to be done on the bridge, and it is here that the lamp-lighter McKinnon assists all in his power: at the present time he has to rise at 3 a.m., and out at night at 9.30, keeps his twenty-eight lamps clean, sorts the burners, and records every night's burning from the meter. The quantity of gas burnt each week is then entered on a printed sheet, signed by me, and sent to Sir M. Magaret's, Edinburgh. I may mention that the lamp-lighter works every Sunday without extra pay. I hope the above is sufficient to show the necessity for keeping the men on under present circumstances. In reply to the question, 'Is the inspector's staff likely to be permanent?' I should like to be allowed to make a suggestion, one I think would not only secure confidence for the future, but be more economical. Of course, it is generally admitted that it will take two or three years before it can be ascertained to a nicety the changes which we should all naturally expect would take place from the fact of so many piers being set down in the natural current of a tide. But the Tay, 'tapp'd as it is with so many shifting sand-banks, especially knowing the scour which actually took place from No. 22 to 27, from 46 to 48, and from No. 72 to Bow span, north side, all of which have been specially and successfully attended to, and the threatened danger averted. Now, I would suggest the following plan, after I have taken my next series of soundings in September, sent them to any place that may require it by depositing wagers among the good harbour due west of the Tay Bridge steamers in the dock and lock-up sounding apparatus, secure the small boat also in some place. The other could take the place of one of Mr. R. Bell's men, two of whom do nothing except the work is slowly but surely passing away." 16,770. (The Commissioner.) Were Messrs. Hopkins, Gilkes, and Company going to paint the bridge? It was part of the contract; they had not yet put the last coat on.

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Sir T. Bouch.

20 April 1869.

that overtimes should be paid for, and no further
reduction proposed. On these conditions I could
not seek to treat Mr. Bourn, if I might be
considerable deal more wage. If the company
takes them over after next September they may be
induced to work for less than they now do get, to
ensure a permanency." Then there is a letter of the 13th of August, which simply says that the painting
is half finished, and then on the 6th of September
therein that Mr. Bannett wants
500L. on account of his contract. Then there is a
letter on the 8th of September, which is as follows:

"Will you please decide the colour you will have the
hand-rail painted? Mr. Bannett recommends blue,
and encloses card as a specimen colour. The bridge
is finished except the large girders. Should the
weather prove favourable during present month, the
job will be near completion." I think it is important
that you, sir, should know that Mr. Noble and
Sir Thomas Bouch were in constant communication
on the subject of the bridge generally.

(16773. (Mr. Bidd.) Did you see any other cracked columns except these two? I think there was one other?—Yes, there was one other.
16774. (Mr. Bidder.) Where was that?—Where the bridge fell.
16775. (Mr. Bidd.) One of the high girders?—Yes.
16776. (Mr. Bidd.) Were those the only columns that you saw
cracked?—Yes.
16777. (Mr. Bidder.) Did you adopt Mr. Noble's suggestion of letting the men go into the general service of the company?—No.
16778. (Mr. Bidder.) Did you go into the service of the company?—No.
16779. (Mr. Bidder.) That is bringing us very near to the disaster.
16780. (Mr. Bidd.) Yes, sir. This is from Mr. Noble to Sir Thomas Bouch, and I think it is important: "In consequence of the increasing heavy
traffic during the past three months, I felt it
unwise on my part to have a close scrutiny at those
columns, forming the ends of the bridge, and whilst examining was surprised to find that
since my last search, which was in October last, a
fracture had occurred in the outer columns Nos. 73 and
76. This circumstance induced me to try and
ascertain the cause, but previous to going I have fixed
eight strong iron bands around the defective columns,
thus making all secure. This part of the bridge
outside the curve, and the gradient is 1 in 78.
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ascertain the cause, but previous to going I have fixed
eight strong iron bands around the defective columns,
thus making all secure. This part of the bridge
outside the curve, and the gradient is 1 in 78.
16,790. With trains passing over you?—Yes; I thoroughly examined it.

16,791. Was there any looseness, or chattering, or perceptible slackness of any of the tie-bars?—Not the least.

16,792. With the exception of these particular cracked columns, did the bridge, to the best of your judgment, then appear to be in as good order as it was in originally?—You will recollect that this part where the columns on the north side were cracked is where the pier was composed of four columns, that is, where it is very low. There are three columns in one plane. There was no crack in any of the columns which were carrying double the load. (The witness declined the model to the Court.)

16,793. I think now I have brought the history of the bridge up to the date of the accident. I should like to ask you this one question: you have explained Mr. Noble's duties, and his reports have been put in; is there any ground whatever for suggesting that the maintenance and supervision of this bridge was neglected after it was opened for traffic?—I do not know what more I could do.

16,794. And do you believe that it was kept in good order after that date?—Thoroughly attended to.

16,795. Did you visit the site of the bridge very shortly after the happening of the accident?—Yes; I was called out of bed, and taken away by a special train.

16,796. You inspected the ruins, and you have seen the debriis that has been subsequently recovered?—Yes.

16,797. And, of course, you have heard the evidence of the divers and others who have deposited to what extent they have seen the bridge under water?—There is no doubt that in some of the debriis we see faults in the castings, which you would not see in the bridge itself. If I had had those pointed out to me I would have had them altered, no doubt; but I am perfectly certain that they were not the cause of the accident.

16,798. Will you give to the Court your opinion as to what did cause the accident that destroyed the Tay Bridge?—Well, I have thought a great deal about it, very anxiously, and my own opinion is fixed now; that it was caused by the capsizing of one of the last or the very last carriages—that is to say, the second-class carriage and the van; that they tumbled over against the girders.

16,799. In your judgment, the thing which caused the destruction of the bridge was the capsizing by the wind of the second-class carriage, and I suppose that would take with it the van?—Yes.

16,800. Against the lee girders?—Yes.

16,801. And so coming into collision with the girders?—I think so.

16,802. If such a thing happened, do you agree in the opinion of the gentlemen who have already given evidence, that it would be sufficient to destroy the bridge?

(Mr. Balfour.) I am not aware that there is any consensus of opinion as to that.

Mr. Commissioner. I think there is not a general agreement as to that.

16,803. (Mr. Bidder.) To meet my learned friend's view, I alter the question; at any rate, it is not worth arguing. If there is any doubt about it I will reform the question. (To the witness): As a matter of fact, in your judgment, would the collision of the second-class carriage and the van with the leeward girders, going at the speed at which the train was presumably going, be sufficient to destroy the bridge?—I have no doubt of it. Practically, the first blow would be the momentum of the whole train until the couplings broke. If you take the body of that train going at that rate if the van were broken, it would be the entire momentum of the last two carriages, plus whatever blow was given through the fracture of the couplings in the rest of the train?—Yes.

16,804. Of course, the total blow upon the girders, assuming the other carriages not to leave the line, would be the entire momentum of the last two carriages, plus whatever blow was given through the fracture of the couplings in the rest of the train?—Yes.

16,805. Would you explain the reasons why you have come to the conclusion that that is the real cause of what happened to the Tay Bridge?—In the first instance, take the position of the train as found. I believe that the plan in Court, which will be proved, does show it very accurately.

16,806. I think there are some things to correct in that plan, are there not?—There is nothing incorrect except the character of the carriage.

16,807. (The Commissioner.) There is the plan that you refer to (handing a plan to the witness)?—Yes.

16,808. (Mr. Bidder.) Will you go on explaining what you are going to explain?—First of all, we have the engine and tender lying on their sides. Next, we have all the carriages but the last two, namely, the second-class carriage and the van, standing on the wheels erect; then we have the second-class carriages and the van on their sides, the same as the engine. I think we can account for the four carriages being on their wheels by the fact that as they went into the water together, the principal weight being on the wheels and axles, the rotation would turn them up. The last two have not gone, and the question is, why? First of all the second-class carriage is completely destroyed; all the top of the carriage is gone; there is nothing to float, and it might be entangled with the girders; and in the case of the van there is the same thing, the east side next to the girder is entirely gone. In the case of these carriages as found they have all lost their tops, but they are not otherwise destroyed, though they have been destroyed since to a large extent. But the second-class carriage was entirely destroyed, and the framework of the carriage was smashed, and the van's side was entirely gone. The footboards on the east side of the second-class carriage are gone, as if they went against something, and the iron standards supporting the footboards are all bent as if they had gone against something.

16,809. Is there anything else?—There is nothing in the other carriages at all, although they got a broken good deal since, to indicate that they were smashed up then. Then in the case of most of the girders that are lifted the permanent way is visible, and they are not much damaged excepting here and there (pointing to the plan).

16,810. You mean between No. 3 and No. 4 piers?—Yes; where these two carriages are the wheels, the rails and the chairs are all smashed, and yet they are smashed in no other place, and that I think is an indication of the way in which the accident happened. Then there is another thing which to my mind is conclusive, and that is that the second-class carriage lost an axle-box by being forced against the side of the girder; the iron guide on which the axle-box vibrates is broken off on the east side. This axle-box and this horn were found in the trough of the girder. Now, it could not get into the trough of the girder unless the girder was standing; it must have gone into the trough before the girder fell.

16,811. You say that the axle-box and the horn of the second-class carriage were were broken, and were found when the girder was got up in the trough of that portion of the girder?—In the trough of the bottom boom of the east side girder.

16,812. That bottom boom, when the girder was in position, would be standing with its open mouth upwards?—Yes.

16,813. And when the girder fell over it would turn with its back, so to speak, to the carriage?—Yes.

16,814. The only time when that axle-box could have possibly got into that trough would have been when the girder was standing; that is to say, before the girder fell?—Yes; that is conclusive to my mind. Then there is this other fact, upon which you will probably get some more evidence hereafter, that the wind necessary to overturn this second-class carriage is a great deal less than would be necessary to blow down the bridge. If you get a 40-lb. wind to blow down the bridge that must have overturned the carriages long before.

...
16,815. I do not know whether there are other facts in connection with the debris; you mentioned the fact that in the girders between No. 3 and No. 4 the permanent way was "twisted" and the beams all broken—Yes.

16,816. Did you also find that at that part the girder itself is much more destroyed—Yes, the girders themselves are broken, and there are marks on them. We have photographs of the girders; but I have had a plan drawn, and this is brought up now to-day, and the plan which drew it will be here to prove it. The marks on the girder unmistakably show that the train was in contact with it.

16,817. You mean the scorings marked by the rubbing of the roof of the carriage along the lattice of the girder—Far more than that— the breaking of the bracing and the bending of some others.

16,818. The lattice bracing is broken and curved up—Yes; but you will have that put before you.

16,819. (Mr. Barlow.) Which of the girders upon the model is the carriage supposed to have struck—The van and the second-class carriage were on one side of the pier. It is along here where all the breaking is (pointing to the model); it is close to where they were found.

16,820. (Mr. Bidder.) It appears to me, as a matter of fact, that when the previous train passed over the bridge there was great friction between the carriage wheels and the guard rail, which caused the production of sparks—So I hear.

16,821. Would that, in your judgment, indicate that the wind was blowing symmetrically to the carriage at that time?—The direction of the wind was slightly behind the carriages as well as at the side; it was south-west-by-west, I should say.

16,822. I think the evidence varies upon that point; from that to west-south-west—Yes.

16,823. Again evidence has been given as regards a crenelling having been noticed in the carriage and guardrail of the previous train, at any rate as far as the spring would permit; would that indicate that the force of the wind was approaching the overturning point?—You may draw what inference you like from that; but, of course, it was not so strong then as afterwards. The force of the wind was affecting the train before, but not to the same extent.

16,824. There is no doubt that at the time when the train which met with the disaster passed on to the bridge the wind was very much greater than when the previous train went over?—Yes.

16,825. And, on the other hand, the second-class carriage was on an exceptionally light carriage?—It was. It was very much smashed; the body of the carriage is gone entirely, and the framework behind is so thoroughly broken that I think that would be broken when it was struck by the van coming behind it.

16,826. (The Commissioner.) You say it would be broken; what would be broken by the van coming into it behind; do you mean the body of the carriage?—Not the framework of the carriage, and the appearance of it would indicate that it was from a blow behind.

16,827. Is all this evidence that you have been giving to us from your own observation?—Yes, all but the very last. We got this girder flushed up, and I got an exact drawing made of it, which will be shown.

16,828. But, you have not seen anything of this axle-box?—No; I have not seen the last part of it, but I saw the second-class carriage.

16,829. (Mr. Bidder.) You do not speak of your own knowledge as to the axle being found in that position. You were not present, and you did not see it found yourself—No.

16,830. Evidence will be added to that effect; so also with regard to the marks upon the girders—Do you not speak there of your own knowledge—No.

16,831. (Mr. Bidder.) Those are all the questions, I think, that I have to put.

16,832. (Mr. Webster.) I have nothing to ask Sir Thomas Bouch.

16,833. (Mr. Balfour.) I have nothing to ask at present.

Examined by Mr. Treagor.

16,834. If you will attend to me, I will read to you: You said, "I have given this anxious consideration, and thoroughly satisfied myself that it is the best thing to do, and I confidently recommend its adoption for the following reasons: (1) That in the first place it reduces the pressure on the foundations from 44 tons to 23 tons per foot, which puts the risk from defective foundations beyond all question." Was the original pressure of the pier (I mean of the brick pier) to be 44 tons per foot according to your calculations?—It was; but I think that did not include the live load on it.

16,835. Simply the girders?—Simply the piers and the girders. I am not quite sure whether it did or did not include the live load; I cannot remember that, but I think not.

16,836. I am more particularly anxious to get your answer to this: did you in point of fact by erecting iron columns get down the vertical pressure to 23 tons?—Yes, by enlarging the area; certainly to 3 tons.

16,837. That, again, would be without the live load if you are right in your supposition that the 44 tons was not included in the live load?—I think it would be 6 tons reduced to 3 tons.

16,838. Then did the 3 tons include the live load in every case?—Yes.

16,839. Then your second reason was, that it would effect a saving of cost, though not a large amount; was that, as it turned out, correct in point of fact?—I did not meet with the anticipated saving—It did not cost more money than we expected.

16,840. It did not cost more money than the brick would have cost?—No; it had nothing to do with that.

16,841. But, in point of fact, did not the mode of erection that you ultimately adopted cost considerably more than the brick would have cost if you had gone on?—No doubt; but that is on the supposition that we had rock foundations.

16,842. Then you were wrong in the opinion that you formed that the adoption of iron columns would effect a saving of cost?—Yes; because I would have had a far greater cylinder, and I must have increased the base to carry the increased load.

16,843. No doubt, there may be many reasons for explaining the fact as it turned out; but the fact is that you did not effect a saving?—We only saved a great saving upon what it would have cost us if I had persevered with putting down—

16,844. Such foundations as would have carried the brick piers?—Yes.

16,845. But putting the cost of the actual erection against the cost of brick piers, estimated upon the bore's faulty description, you did not effect any saving?—No.

16,846. (Mr. Treagor.) It was a relative saving, relatively to what they would have had to do if they had gone on with brick.
foundation? — It was no saving at all. If we had had the rock we should have done it a great deal cheaper in brick than we were able to do it in iron. There would have been a great saving.

16,847. Then this second reason, as I understand you, is given in the view that the present columns would not only be a great saving of cost, looking to the cost that you would require to incur to carry out brick buildings, on the pier which you would necessarily require to find for them? — That is so.

16,848. Then the third reason is this: that it will make a materially stronger pier. Do you think that still well? It is stronger in this respect that it is a safe foundation. A brick pier would be very cokely.

16,849. Is a brick pier or a pier of iron columns the stronger? — It depends entirely upon the dimensions.

16,850. But would such a brick pier as you could get at was a foundation so stronger than the columns erected upon it? — You cannot get a brick pier upon that foundation; it would not stand.

16,851. Could you not have got a brick pier on that foundation? — No; I could not upon that foundation.

16,852. Upon that caisson? — No.

16,853. Do not let us misunderstand each other; is it not possible for an engineer to put up on that caisson a brick pier? — Not that will stand. You cannot build a brick pier on that foundation but what must have double the weight per foot on the foundation, and I dare not trust it at any rate on that.

16,854. You had a caisson of some 31 feet in diameter, if I recollect aright? — Yes.

16,855. With an edging of 18 inches of brickwork? — Yes.

16,856. And you filled that entirely with concrete? — Yes.

16,857. What is the depth of that caisson? — It varies with every pier.

16,858. Take any pier you like: what is the biggest of them? — I suppose from 15 to 20 feet.

16,859. Take it from you have a caisson of from 16 to 20 foot deep and 31 feet in diameter filled in the way that I have described; what is the difficulty of erecting a brick pier upon that? — You can erect it, but it presses the weight upon the foundation so that the foundation would yield; it would capsize and come down.

16,860. Of course I must take your view of it; whatever it may be, but I want you to see that there is no difference between us upon the conditions upon which I was putting the question and you were giving the answer. Given that caisson, a stone or brick pier upon it was not possible as a good piece of engineering? — No. I do not think it was. I did not hear the evidence of Mr. Law, but I have seen it reported that he put something like a chimney. Of course Mr. Law has his own views as to that, but I should not like to be responsible for that.

16,861. Mr. Law did put in a sketch. Have you taken any trouble to go over that sketch, and over Mr. Patten's figures, to see whether his scheme is practical or visionary? — I believe it is perfectly visionary; but I have not gone into it in detail. I think you will hear more about that from other witnesses.

16,862. Who is to give us evidence as to that? — I rather think you will hear that from Mr. Stewart and Mr. Barlow, but I cannot pledge them.

16,863. (Mr. Trayner.) Mr. Stewart seems to have assisted you in reference to your engineering works for a very long time? — A considerable time; this was the commencement of it.

16,864. But, in fact, before this, did he not, to some of your abortive schemes four or five years before? — I cannot recollect. He was not with me, nor did I know him when all these other big bridges, this one at Bosphorus and the Tee Bridge, and all those were being made.

16,865. Excuse me asking you this, but is Mr. Stewart in any way connected with you in business, or were those merely friendly assistances? — He was paid as an official; he was not a partner or anything of that sort.

16,866. You told us that there was a distinct relation between the depth of the girder and the breadth of the span. — The big span is one-ninth, I think, as a rule; I generally take one-eighth.

16,867. But your rule was that one-eighth of the span was equal to the depth of the girder, or, rather, that the depth of the girder was equal to one-eighth of the span? — Yes; but in this I did not carry it out quite.

16,868. These spans, originally under the approved of plans, were to be spans, if I recollect right, of 200 feet? — Yes.

16,869. And in your original design you had the girders for the 200-foot spans of the same depth at which they existed when they broke down? — Yes, they were one-eighth in that case, but I made them one-ninth here, and I kept the height very much the same.

16,870. In point of fact, when you changed the width of your span, did you or did you not alter the depth of the girders? — I kept the same, I think, as far as I recollect.

16,871. The girder as erected was according to the sketch and plan which you had adopted when you meant to have the spans only 200 feet long? — Yes.

16,872. (Mr. Webster.) I think your questions may lead to misapprehension. The scantlings were not the same, you know.

16,873. (Mr. Trayner.) Will you tell me if I am right in supposing that in the matter of safety it is essential to have a certain amount of height of girder in proportion to the length of span? — Yes.

16,874. Do you think in this case you should not have increased the height of your girder in proportion to the increase which certainly took place in the span, making it one-eighth? — No engineer makes it one-eighth but myself; they all make it one-twentieth or one-twelfth. The regular practice of the profession is to make the depth less than one-eighth.

16,875. (Mr. Barlow.) The Memai tubes are one-sixteenth, I think? — Yes; the Britannia tubes are one-sixteenth.

16,876. (Mr. Trayner.) The depth of this was 27 feet? — This is 27 feet, about one-ninth.

16,877. (Mr. Barlow.) There appears to have been one lazy edd? — Yes.

16,878. (Mr. Trayner.) Your resident assistant there was Mr. Paterson, you say? — Yes.

16,879. And you told us that one of his works had been the making of the Scotland Street Tunnel? — As resident engineer.

16,880. What age was Mr. Paterson when you employed him for the Tay Bridge? — He was very much my own age. I should think probably 57 or 58.

16,881. The Scotland Street Tunnel was made when? — I suppose you cannot tell me that? — That was before I came to Scotland.

16,882. Where did Mr. Paterson reside? — When? I do not know when he was not here, as your resident engineer? — For the greatest part of the time at the commencement he resided at Newport on the bridge, but afterwards he went to Perth.

16,883. Did he not reside at Perth during the greater part of the time occupied in the erection of this construction? — I cannot tell you how long, but he resided at Perth a good deal. He was at the bridge every day, I believe.

16,884. Were you there every day? — No.

16,885. Then you cannot say that Mr. Paterson was? — No, but I never went there without seeing him, when he did not know that I was going.

16,886. What else had he to do during the time that he was acting as your resident engineer on the

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"Tay Bridge disaster:"

16,887. Mr. Traylor. Then you include in the Tay Bridge not only the Tay Bridge itself, but the works at each end of it, north and south, including the tunnel on the north and the approaching railway on the south?—Yes.

16,890. The Commissioner. You include all that as the Tay Bridge?—Yes; that is the Tay Bridge undivided. Then he had for that two additional inspectors; he had one for the Leuchars side, that is the south side, and one for the north, in addition to the inspector of the bridge.

16,893. Mr. Traylor. Then you include in the Tay Bridge not only the Tay Bridge itself, but the works at each end of it, north and south, including the tunnel on the north and the approaching railway on the south?—Yes.

16,891. Had he the entire charge, not only of the permanent way as it was going up, but of the piers as they were being erected, and of the foundations as they were being laid?—He had the charge of everything.

16,892. Would you give me an idea of how often you went yourself?—When all these changes were going on I went there, say, on an average, nearly once a week, but afterwards, when it was all going on, I did not so often; and, indeed, I fell ill in one year afterwards, and spent three months on the Continent, in the south of France.

16,896. The Commissioner. Whilst it was building?—Yes; but it had then gone on so far that they could dispense with me.

16,894. You were three months on the Continent?—Yes, that was the outside.

16,895. Was it that in consequence of your health, or were you engaged in other work?—It was in consequence of my health, and on the advice of medical men: it was very much on account of anxiety in connection with this bridge.

16,890. Mr. Traylor. You had some meetings with Mr. Gröthe and others with reference to the proposed change from brick piers to iron columns; would you tell me if it was at any of these meetings when it was resolved not to put up two of the 18-inch columns, two raking columns?—No; Mr. Gröthe was not at that meeting. It was decided at Middlesbrough, at a meeting in Mr. Gilkes' office at the contractor's works.

16,897. The Commissioner. That is when it was decided to put up one raking column?—That is six columns, instead of eight.

16,898. Mr. Traylor. Can you give me an idea of the date when that alteration was finally resolved upon?—I cannot give you the date.

16,896. But Hopkins, Gilkes, and Company came into the contract in the month of June 1874?—Yes.

16,899. As I understand it within that year?—No, I do not think it was. They went on with the smaller spans; we had not got up to the large spans then.

16,901. I find in these letters which pass between you and Mr. Gilkes, frequent reference to plans as to the alteration of the 200-foot spans; did not those alterations include that alteration to which I have just alluded?—No; they were to leave out one of the raking columns?—I really cannot answer that question, for my memory does not serve me.

16,902. Perhaps this will help you. This is a letter from you to Hopkins, Gilkes, and Company on the 20th of November 1874: "My dear Sir,—I have instructed Mr. Gröthe that he is to go on sinking a double cylinder from pier 26 to 28 inclusive, working backwards. As to the depth that they are to be sunk, he will be guided by Mr. Paterson," and so on. Then you say this: "Plans for the pier of the 200-foot spans I have discussed with Mr. Gröthe this morning, and they are still under my consideration." Now, was one of the things that were under consideration the alteration of the previous plan of having one column of 18 inches instead of two?—No, I think that was referring to the caissons; it was two caissons.

16,903. That is quite true, but you had not two caissons for each of the 200-foot piers?—Yes, that was the first plan.

16,900. Was the object of the conversion of the piers from brick to cast iron a matter of frequent consultation between Mr. Gilkes and yourself?—It would be more between Mr. Gröthe and myself, but it no doubt was between Mr. Gilkes and myself as well.

16,907. I find in these letters that you corresponded with Mr. Gilkes to a large extent upon the subject?—Yes.

16,908. And not only did you write to him, but I suppose you went to him at his works at Middlesbrough?—Yes, I went to Middlesbrough sometimes and I saw him. He more often called upon me in Edinburgh.

16,909. I see that arrangements were made by you in correspondence where you should meet?—Yes.

16,910. Was there any reason given by Mr. Gilkes why iron should be used instead of brick?—No; I do not think so; it would emanate from my own desire. I think that the first time of discussing the question of iron versus brick was surely in De Bergue's time; it was before Mr. Gilkes had anything to do with it.

16,911. I believe you are right, it was spoken of before Mr. Gilkes' contract came into existence; but after Messrs. Hopkins, Gilkes, and Co. became the contractors had you not frequent consultations with them as to the proposed change?—Not as to the proposed change, but as to the arrangement of the columns.

16,912. Were your meetings with Messrs. Hopkins, Gilkes, and Co. rather with a view to see how they could carry out the change which you proposed: to make them consult them as to the desirability of the change itself?—They had nothing to do with the desirability; they would be consulted as to the best way of carrying it out.

16,913. According to the best of your recollection, there was nothing else that was the subject of consultation between you and Mr. Gilkes except the mode in which your plan should be carried out?—There was of course reference to the lifting of the girders and the floating out of the cylinders, and the whole construction of the bridge.

16,914. But there was nothing as to the propriety or desirability of changing brick for iron?—No, it was not discussed; it was decided before he had anything to do with it in De Bergue's time, and I do not think it was discussed.

16,915. The columns themselves as originally designed were to be of what thickness?—An inch, I think, as far as I recollect. I do not think that was so much discussed.

16,916. It was a matter of specification. Did you in the course of the progress of the work know whether or not the specification thickness was being followed?—It was, to the best of my belief. I was under that impression.

16,917. You were under the impression, of course, that they were being well done, and also done as specified?—It was dependent upon the inspector; I could not see it myself.

16,918. But you would not expect your inspectors to authorise a deviation from your specification without applying to you?—Certainly not.

16,919. And therefore, you were all along under the impression that the columns were being cast an
inches thick; I mean the 15-inch columns?—Yes, all
but the outside.
16,920. Did you ever hear in the course of the
operations at Wormit that they were being cast of an
extra thickness to that which was specified?—No, I
did not hear of it; but, of course, the pay-bill would
show that, if necessary, they were being cast so.
16,921. But you would examine the pay-bills, I
suppose?—No, they were all checked by the resident
engineer.
16,922. It comes back to this, that you did not know
at the time when the works were going on that the
pipes were being cast thicker than in the specification?
—No, I did not.
16,923. And you never authorised such a thing?—
I never authorised it.
(The Commissioner.) You are here speaking only
of the 15-inch columns.
16,924. (Mr. Trang.) The 18-inch columns are
specified to be what?—I think they are specified to be
an inch.
16,925. The 15-inch columns are not in the speci-
fication.
16,926. (The Commissioner.) The alteration was
made subsequently to the date of the specification?—
Yes, it was.
16,927. (Mr. Trang.) You have heard in the course
of this inquiry a good deal of evidence, have you not,
as to the way in which the founding and cast
g was carried on at Wormit and the results of it?
—No, I cannot hear, and I have never been in the
room; I did not hear the evidence.
16,928. Have you read it?—No, but I know the
fact that they were not cast vertically.
16,929. But they were something worse than hori-
zontally cast; for they were unequally cast in
thickness; do you think that is material?—No, I do
not; I would rather have them equal, but you will
ever rarely get it. Almost every column that is cast
thick in thickness, and it is to some extent the degree
that makes them dangerous or otherwise.
16,930. What is the degree?—I think you should
not go more than a quarter of an inch on one side;
you might go three-quarters without weakening it. I
never tried any experiments, but there have been
experiments tried of unequal columns, and the results
have been published, and they show very little
difference in the strength of the columns.
16,931. Do you think that it is a safe thing in a
structure of this kind to have your columns with a
variation of a quarter of an inch between the thickness
of the metal of the two sides?—I think it is perfectly
safe. The columns are designed to be 20 times the
greatest load that could be put upon them.
16,932. I have no doubt you thought the margin
quite ample, but is it not a serious question in esti-
matine the resiling power of these columns if they by
any chance got off the perpendicular, that one side is
a quarter of an inch thinner than the other?—No, I
do not think it is. I do not know whether it is
something in the cooling of it or not, but we have had
the columns tried, and we have had the results of
that testing published, and they are very nearly the
same. When they vary in thickness the difference is
not great; but it is quite right that if I had known
much, that I should have taken the benefit of them
cast vertically, and getting them all of a thickness.
16,933. If it had made no difference in the strength
of the structure, what objection would you have to
it?—It is not a workmanlike job.
16,934. But it is not seen outside?—No, but that
does not matter.
16,935. I do not follow your reason. Is not the
object of having a thing workmanlike to have it serve
the purpose for which it was intended without fear of
risk or failure?—I should like to have it so.
16,936. Of course you can have it to look better
outside by more careful workmanship than it would
look if the workmanship were slovenly; but apart
from their appearance, do I correctly understand you
to say that there was no defect in these columns as
regards the work which they had to do, although they
were a quarter of an inch different in thickness the
one side from the other?—I do not mean to say that
where there is a quarter of an inch difference in
thickness, it is not to some extent an objection; but
it is a trifling one. I would prefer it all of equal thick-
ness if I could get it.
16,937. If a quarter of an inch difference in
thickness does not affect the safety, will you tell me
what inequality would be unsafe?—I cannot tell; it
would require experiment.

The witness withdrew.

Adjourned till Monday next at 11 o'clock.

Extracts from Report of Engineers on Forth
Bridge.

(See Evidence, Question 16,614.)

"Effect of wind." In a structure of this magnitude,
and placed in such an exposed situation, the probable
effect of wind may form an important subject of con-
sideiration. It is known that suspension bridges of
large span have hereafter suffered considerably from
this cause; and it is necessary, therefore, to examine
carefully what kind and amount of strain the wind is
likely to cause on such a structure, and what means
Mr. Bouch has provided for resisting it. The first
question, of course, is wind. What is the pressure per
square foot, which may be expected to act on the
bridge? On inquiring into this, we found much
obscurity in the data available. "The ordinary
sources from which such estimates are taken is
the well-known table presented by Smeean to the
Royal Society in 1789. This table gives 6 lbs. per
square foot for the "high winds," 8 lbs. or 9 lbs.
for "very high," and 13 lbs. for a "storm or tempest.
There are still higher figures for "great storms or
hurricanes," but these are of doubtful authority, and
only apply to tropical meteorology." In this un-
certainty it was suggested that we should make an
application to the Astronomer Royal, in order to
ascertain what information he could afford us on the
point, with the aid of the valuable meteorological
records kept by him at Greenwich Observatory. We
accordingly had an interview with Sir George Airy,
on the 28th March last. He courteously placed at
our disposal his official registers of the wind, and
pointed out and explained to us the diagrams of the
heaviest storms that had occurred for many years;
and he afterwards put in writing his opinion on the
point in question. The Astronomer Royal says,—
"We know that upon very limited surface, and for
very limited times, the pressure of the wind does
amount sometimes to 40 lbs. per square foot, or in
Scotland probably to more. So far as I am aware,
our positive knowledge, as derived from instrument-
al observation, goes no further. But in studying the
registers, it is impossible not to see that these high
pressures are momentary, and it seems most probable
that they arise from some irregular whirlings of the
air which extend to no great distance. I should say
certainly to no distance comparable with the dimen-
sions of the proposed bridge; and I think the
highest estimate of the pressure on the entire bridge
would be formed by taking the mean of the recorded
pressures at one point of space for a moderate extent
of time, as representing the mean pressure on a
moderate extent of space at one instant of time.
Adopting this consideration, I think we may say
that the greatest wind in our possession to which a pile
such as that of the bridge will be subjected in its whole
extent is 10 lbs. per square foot." Then the report

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proceeds—"We entirely concur in this opinion, which we consider highly authoritative and valuable; and we may therefore safely adopt 10 lbs. per square foot, as the side pressure due to the wind, for which Mr. Bouch has to provide. We may now describe the means which Mr. Bouch has adopted in order to provide against this side pressure." "The side surface of each span exposed to the wind (but making an allowance for some parts which may be assumed to bear directly on the piers) is given by Mr. Stewart at about 34,000 superficial feet. This is for one surface only, i.e., the one first exposed to the wind. But behind there are three other similar surfaces, one about 15 feet away, the second about 120 feet away, and the third 185 feet away. The wind must rush past these after passing the first one, and although each will be, no doubt, to a certain extent, sheltered from those in front of it, we cannot suppose that they will be free from the wind's action. Possibly it would be a fair estimate to double the surface of the front face, but as an outside estimate we have taken three times, or 42,000 feet. To this has to be added 8,000 feet for two trains which may be on the bridge, giving 50,000 square feet of surface exposed to the horizontal action of the wind. Allowing, therefore, 10 lbs. per square foot, we get a force of about 225 tons." "This will produce, we find, a certain effect of tension and compression on the stiffening girders, which must be included in the general strains. Some large suspension bridges originally built without stiffening have suffered materially in gales from a disturbance of the platform, which has been thrown into waves of oscillation as if acted on by forces from above or below, instead of horizontally, as the wind is usually assumed to act. It is difficult to account for this kind of action, except by supposing the existence of irregular eddies acting partially in oblique and unexpected directions. It is obvious that with the strong stiffening arrangements adopted by Mr. Bouch no such effect need be apprehended in the Forth Bridge." "The effect of the wind on the towers has also to be considered. It will consist partly of the direct pressure of the wind on the surfaces of the towers, and partly of the action of the suspended span, the lateral pressure of which must be borne by the towers at its two ends.—Making an ample allowance for these, we find that their combined effect will be to add a strain of only a small fraction of a ton (from 3/4 to 1) per square inch to the compression of the cast-iron pillars on the lee side.”

**TWENTIETH DAY.**

Monday, 3rd May 1860.

Sir Thomas Bouch called again.

Further cross-examined by Mr. Trayner.

16,938. I asked you for a date on Friday, can you give it me now, or can you give me any approximation to the date when you altered your plan from two outside columns to merely one?—I have been trying to get it; the alteration took place at Middlesbrough; I cannot give you the date.

(The Commissioner.) I should like before you go any further just to see your original plan (the witness handed it to the Court).

16,939. (Mr. Trayner.) Did you in designing this bridge make any allowance at all for wind pressure?—Not specially.

16,940. (The Commissioner.) You made no allowance.—Not specially.

16,941. (Mr. Trayner.) Was not there a particular pressure had in view by you at the time you made the designs?—I had the report of the Forth Bridge.

16,942. What makes me ask you that question is this: I will refer you to a report or a letter by Dr. Pole and Mr. Stewart in reference to the bridge and the pressure on it.

(Mr. Budd.) Is that the report which is referred to in the Minutes of Evidence?

Mr. Trayner. It is the report which we have been speaking of once or twice already as Dr. Pole’s and Mr. Stewart’s report.

(Mr. Budd.) You mean the report on the cause of the accident.

16,943. (Mr. Trayner.) Yes. (To the witness): This is a letter written to you by Dr. Pole and Mr. Stewart bearing upon a letter which had been addressed by the Company to the railway company?—It is very odd that I have never seen it.

16,944. It is a letter bearing upon a letter which had been addressed to the railway company by the Court in reference to the causes of the accident; and it contains this passage on page 22, in the last paragraph of heading 14:

(Mr. Macrory.) It is page 13 in our copy.

16,945. (Mr. Trayner.) It is the last paragraph under heading 14: “It has, however, been explained in the answer to the last question that up to a wind pressure of 20 lbs. per square foot, for which the bridge was designed, there could be no tension upon the bolting,” &c. Did you tell Dr. Pole and Mr. Stewart that the bridge had been designed to resist a lateral pressure of 20 lbs.?—No, I did not. Mr. Stewart was present at those meetings, when the thing was done, and he may have had the idea of 20 lbs., but I had not. I was more guided by the report on the Forth Bridge.

16,946. You think that that statement has arisen because Mr. Stewart, one of the gentlemen who signed it, was present at the time that the thing was discussed?—He was present at a great number of meetings.

16,947. Meetings when the design was discussed?—Yes.

16,948. Your idea was that the greatest lateral wind pressure would be 10 lbs. to the square foot?—There or thereabouts. I was getting such an excessive strain apart from the question of the wind (I called it 20 times, but I have gone through the calculation since and I find that it is 25 times) that I thought it was providing for all wind that could arise after I had got that report.

16,949. Taking the bridge as you built it, did you anticipate that the vibration of passing trains as well as the wind pressure on both sides of it at different times would have a tendency to loosen the bracings?—No; that loosening of the bracings took place because of the conical holes. I had no knowledge of them—none of us had.

16,950. You had no knowledge of the conical holes, and therefore you were not anticipating the loosening of those nuts from any cause whatever?—No.

16,951. Therefore you made no provision whatever against such an event?—I can only answer that question by saying that I designed the holes to be square holes.

16,952. Not anticipating such a result, you, of course, made no provision against this happening?—No; but I explained, I think, on the last day, that after the bars got shaken with the pressure of the wind the bolt would take the bearing of the conical hole, and when they were tightened again the thing was quite as strong—practically as strong.

16,953. But before they were tightened up the
loosening of the braces would enable the column to give a little; is not that so?—During the pressure of a high wind it would not yield to the extent of going off its shape or form; it would come back again.

16,954. If the ties got loosened from any cause whatever to the extent to which we know they did get loosened, permitting a packing piece to be put in, would not that allow the column to some extent to give out of its strictly perpendicular line?—Only for that.

16,955. You think that the putting in of the packing pieces would restore the column to its place?—I do, but it is rethraing it.

16,956. By putting in the packing pieces you are not bringing back the tie to its original place, are you?—No, but putting in the packing pieces and driving up the threads would do it. Besides, the wind blows from various quarters, it would blow from the west, and then it would be corrected by a wind from the east.

16,957. But you do not suppose that the wind would blow it back into its place, do you?—No, I do not think it would; but the bracing it up again would bring it back into its place.

16,958. You think so?—Yes, I do.

16,959. If these ties had given to the extent of a quarter of an inch, so as to permit the column to go out of its place to the same extent, do you think that the bracing of it up, and the tightening of it up again, would bring the column back again all that length?—I do.

16,960. Is there any limit to the distance out of the vertical to which a column might go by the loosening of the braces which would not be brought back by the rethraing it?—That would be beyond the limits of the elasticity of the iron. I cannot answer that definitely, but of course if it lengthened the bars and the bracing and all that beyond the limits of elasticity, it would not come back.

16,961. What is the limit of elasticity?—It varies with the quantity of iron—generally half, I think.

16,962. Half what?—Half the ultimate strain. What I mean is this, that when you are testing either iron or steel by tensile strain it reaches a point a long way below the breaking point where it does not come back—at least it will not come back wholly, but that is a long way below the breaking point.

16,963. (The Commissioner.) Do you say it is a long way below the breaking point?—Generally, about half.

16,964. (Mr. Trueman.) We have opinions against opinions, and I do not want to go over your whole examination. I would like you to attend to me now a little upon the question of your opinion as to what caused the accident. Your opinion, I believe, is this: that the second-class carriage and the guard's van went off the line and struck the girders, and so brought it over?—I should almost think that they just cantled a bit; there is, no doubt, I think, that the carriage ran bodily off the line; they first cantled and then struck the girders.

16,965. If they had been thrown off the line entirely, that is to say, if they had first cantled and had been then thrown off the line, would you have expected to see marks of that on the rail of the permanent way?—I hardly think, when they had cantled, over, that you would.

16,966. You say the second-class carriage first cantled over to the east, and then went bodily off?—I think afterwards, with the wind blowing on the bottom of the carriages, everything would go bodily off.

16,967. Do you think in the canting the wheels of the carriages would not have made some marks which would have been visible on the rail on which they had been running or on the guard rail?—No, I do not think I have been trying to find out the condition of the rails there, and I find the rails are all gone at that particular place.

16,968. What would have happened to the flange of the tire if such a thing occurred as you suppose to have happened?—If it was as I have described it (and it is merely hypothetical), with such a wind as that, the carriage presenting part of its bottom to it would be lifted up; I do not think that that would affect the tire at all.

16,969. The guard rail was there for the purpose of keeping the wheel from leaving the line?—Yes.

16,970. When the train, if your theory is right, canted over, what would have been the effect of the rail on the guard rail on that?—It was suggested to me that the flange of the east-side rail would get under the guard rail, and, of course, would press it up, and break the chairs; the chairs are broken altogether, but on looking at it I was not sure that that was the cause of the breaking of the chairs.

16,971. You have told us the effect of it upon the rail and the guard rail; would you kindly now revert to my question: what would the effect of that be upon the flange of the tire?—I do not think it would have any effect.

(Mr. Budder.) Do you mean the windward one or the leeward one. (Mr. Trueman.) The leeward one—the one on the east side.

16,972. (The Commissioner.) What effect would it have upon the flange?—There might be some grinding, but I do not think it would have any effect.

16,973. (Mr. Trueman.) When the carriage canted over towards the east, would it not be the flange of the wheel be nipped between the rail and the guard rail?—No, most certainly not; it would press against the guard rail, but it was not nipped between the two.

16,974. If it was entirely thrown over in that way, so that the roof of the second-class carriage reached the girders, would there have been no mark at all on the effect produced on the flange of the tire, in your opinion?—If, as you assume, it was pressing against it in running there would be a mark; but I do not think it was pressing against it, the wind was blowing the other way.

16,975. I think you are mistaken; I am taking the easternmost,—And I am taking the easternmost, too; the wind is coming from the west; it is only the back of the flange that could touch the guard rail; it is not the flange that is running on it, it is the wheel.

16,976. You think that in that event there would be no mark produced upon the flange of the tire at all?—There would be a mark, it turns out that the wheels and the axle went altogether, the axle and the wheel bodily.

16,977. One of your chief grounds for the opinion you expressed on Friday was this, "The second-class carriage was entirely destroyed and the framework of the carriage was all smashed." Are you aware that the framework of the second-class carriage was not all smashed?—I saw it, and I judged from what I saw it was smashed in the hinder part, where I think the van ran into it.

16,978. Here is a photograph of the second-class carriage; do you see that on the east side of the second-class carriage the sole plate is entire?—Yes, it is less smashed than the other, I think.

16,979. Is it smashed at all on the east side?—The sides of the carriage and all that are gone, but the framework is not smashed.

16,980. I am talking of the framework—I rather think, speaking from recollection, that the axle-boxes and guides, and things, are smashed.

16,981. Will you keep to one thing, if you please?—I am explaining. The footboards on the sides with the attachment are all gone and bent.

16,982. Kindly, if you please, adhere to the particular thing I am drawing your attention to? (Mr. Budder.) Sir Thomas Bouch, when he is answering a question, is entitled to explain it at the time.

16,983. (The Commissioner.) But Sir Thomas Bouch is asked now, as far as I understand it, simply a question relating to the framework of the carriage,

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Mr. Trayner. You have mentioned several times this morning that the footboards were gone; I want to know that there was no footboard, and this, of course, would set the framework of the carriage on the contrary that there were iron steps, and that one of them is entire on the right-hand side—the east side?—At all events, I say that the thing that supported those steps is all bent.

You and the footboards are all gone, was there a footboard on that carriage or not?—I cannot answer that question.

Mr. Trayner. If the carriage was canted over with the force of the wind.

The Commission. I do not think Sir Thomas answered your other question about the iron steps.

Mr. Trayner. Do you observe on the photograph, that one of the iron footsteps near the centre of the framework is still on the framework; look at the picture on the top of the sheet?—Will you point it out to me.

Mr. Biddulph. I think when you put to Sir Thomas Bough whether there was a footboard or not, you meant a continuous footboard, did you not?

Mr. Trayner. Yes.

Mr. Biddulph. It must not go upon the note, that we did not know anything about it.

The Witness. I saw the standards bent.

Mr. Biddulph. It must not go upon the note, that he did not know anything about it; his answer did not assume that it was a continuous footboard.

Mr. Trayner. We will argue what his answer meant when we come to speak about it. (To the witness): If the carriage had canted over in the way you suggest, what part of it would first have struck the girder?—I think the roof.

The front corner of the roof?—Yes, but I believe it almost simultaneously went off together.

The Witness. I saw the standards bent.

Mr. Biddulph. It must not go upon the note, that he did not know anything about it; his answer did not assume that it was a continuous footboard.

Mr. Trayner. The frame in that condition.

The Commission. I do not think you quite follow you there.

Mr. Trayner. Is this your view, that when the front of the second-class carriage struck the girder coming on in this way (describing), it was canted over, and presented its west side to the advancing van?—Yes, that is to say, it would throw it further east than the advancing van. I think the second-class carriage would go off the rails when it struck the girder, and go that way (describing, the direction in which it would go.

Mr. Biddulph. You mean that it would go across?—Yes, it would go off the rails: that is my idea; especially if the wind caught the under side of it, it would blow it that way.

Mr. Trayner. Upon your theory, it being thrown off the rails, it would present almost its western side at right angles to the advancing van; is it not so?

The Commission. How do you mean, that it just explained?—It could not do it; the carriage is so much longer than the bridge is broad.

Mr. Trayner. It would throw it over the rail transversely across the line to some extent?—Yes.

The Commission. Another point that you adverted to as a reason for your theory was that there was another thing which to my mind is conclusive, and that is, that the second-class carriage has lost an axle-box by the side girder being forced against it. The iron guide on which the axle-box vibrates is broken off on the east side. This axle-box and these horns were found in the trough of the girder. Now, it could not get off the carriage unless the girder was standing; it must have gone into the trough before the girder fell. Are you aware that the screw coupling of the tender was found in the trough?—I understand it was.

The Commission. How did that get into the trough?—It is hard to call upon me to explain this; but my idea is, that the coupling was broken from the tender, and that it was naturally broken by the carriages pulling it to one side, and I think it would swing.

The Commission. Would not that account also for what you
found in the trough of the girders belonging to the second-class carriage?—I do not believe that that screw coupling went into the trough of the girders after the girders fell.

17,018. Your opinion is that the screw coupling from the tender fell into the trough of the girders just as the horn did from the second-class carriage before the girders went?—Or while they were going.

17,014. About the same time?—At the same time.

17,016. Will you look at the picture at the left-hand side of the photograph and at the bottom; do you think the axle of that second-class carriage?—Yes.

17,016. The axle is bent, is it not?—The axle is gone.

(Mr. Bulder.) You mean the hind axle is gone.

17,017. (Mr. Troman.) I mean at the north end.

How do you account for that axle being bent in that way?—That bending in the axle is not in the middle of the axle; it is rather that axle (pointing it out in the photograph).

17,018. How do you account for that bending?—It is puzzling to account for that and the other bending of the axles, but my idea is that it arose in this way. General Hutchinson, when he examined the bridge, ordered me to put across from the way beams there two malleable-iron plates to keep the way-beams in gauge. These plates were put on the top of the way-beams, and so, if the train goes off the line, it has thus to mount about 8 inches. It would strike it with its full force of running, and it is only one wheel that has to do that. If it gets off the line the other isouden, and my idea is that the bending of the axle was due to that. I brought up one of these things, which I have outside the room, and I can show it.

17,019. Are you aware that all the axles are bent more or less?—Every one of them, but they are not all bent in the centre, and that would almost show that the carriages were off the line all the way; the carriages were off the line at all, they would vary in position between the two rails, and the axle would bend differently; and that is just as we find it.

17,020. If the carriage was on the line, not that be more likely to create a bending of the axle than if the wheels had left the line?—What would it be if the train kept the line, getting a shock, than—if it had gone off the line?—No, I think it would be when it struck the bar.

17,022. Are you aware that, except the bending, there is no mark on the axles at all, from call to end of the train?—No, I do not think there would be a mark on the axles; there is none, I see. I would not expect it, because it touched nothing.

17,028. So far as you know, is there any one of the wheels marked on the flange of the trestle?—No, I do not know that there is; but you will have the witnesses who have examined it, the divers and so on, before you, who have examined that more minutely than I have.

17,024. I do not know whether you know this, that, when a train goes off the line, you invariably find marks on the flanges?—Yes, invariably; and the sort of marks—we have found are these: there was a plump cast up at Newport, and it was spoken to by the Newport Station agent, and he brought him here to speak to you if you like. It was unfortunately washed away the next morning, but there were distinct marks of wheels running over it.

17,025. But that is not a mark on the flange; it was a mark upon something else?—Yes.

17,026. So far as you know, none of the flanges are marked at all?—Not from my own knowledge. I did not examine them so minutely as that; I would hardly expect it.

17,027. (Mr. Bulder.) When you say you always find marks on the flanges when a train goes off the line, do you mean the flanges or the way-beams?—I have not examined the flanges to see.

17,028. (Mr. Troman.) As a matter of experience, when a train goes off a line are you aware that there are marks on the flanges produced by the train going off?—I do not know that there is any general rule upon the subject at all. I have seen wagons and things run off the line, and I never saw any marks on the trestle of the wheels.

17,029. You cannot tell me from observation what the general rule is, if there is any rule upon that subject?—My general experience is the contrary of what you have said; I never saw marks on a flange.

17,030. (The Commissioner.) When the train has gone off the line?—Not on the wheels, except they come in contact with some special object: going on the ballast and on the sleepers there is never any mark.

Re-examined by Mr. Bidder.

17,031. So far as you know, is that which my friend in his questions assumed to be a fact, as to which he only asked you as to your knowledge or ignorance, a fact at all, namely, that when a train leaves the rail there is necessarily a mark upon the flange?—I was trying to think of my experience. I have seen many a train run off the line, and I have no recollection that in the case of an ordinary train running over the ballast and the sleepers there is any mark.

17,032. I do not see how it necessarily arises that there should be a mark upon the flange?—No.

17,033. As regards the coupling of the tender, my friend asked you whether you are aware that the coupling of the tender was found in the boom. I do not know whether you are aware of it?—No, not from my own observation.

17,034. I do not think we have had any evidence of the fact, perhaps we may hear more of it hereafter; but if it was so I understand you to say that you hold, as in the case of the axle-box, it must have been deposited there before the girders were turned over. —Yes.

17,035. That is to say, it must have got there whilst the trough of the girder was in its vertical position?—I think so. I do not know how it got there, but it could not have got there after the girder had fallen over.

17,036. The breaking of the coupling of the tender would necessarily occur, would it not, before the girders fell in that part where the tender was?—I think so.

17,037. It would depend on how the broken portion swung when it was broken where it would alight?—Of course it would. It evidently broke at two places; it broke at the tender, and it broke at the carriage.

17,038. I want to make this perfectly clear: whether it be a coupling of the tender, or an axle of a carriage, or anything else that is found in the trough of the girder, your judgment is that something must have been deposited there before the girder turned over?—That is my theory.

17,039. Do you see how it is possible that it could have been deposited in the girder after it had turned over, so that the open part was facing eastward?—No, nor anywhere facing the eastward.

17,040. Consequently it follows that the axle-box of the carriage must have been smashed before the girder turned over?—Yes; and there was a lot of the glass of the windows of the carriage found in the trough.

17,041. In the boom?—Yes.

17,042. You say that the glass of the windows of the carriage was found in the boom?—Yes.

(The Commissioner.) We only know this from hearsay: it is going to be proved, of course.

(Mr. Bidder.) Yes.

(The Commissioner.) Nor do we know anything about the axle-box except from hearsay.

(Mr. Bidder.) I thought I stated on Friday that you would have proof of that hereafter.

(The Commissioner.) Just so; in the meantime we are going upon assumption.

17,043. (Mr. Bidder.) Just so. (Mr. witness):
The place of the carriages, you say, was found in the trough?—Yes; as far as I can reason the thing, the carriage must have struck the girder when it was vertical. If it struck when it was falling the glass would not fall into the trough; it would fall down into the water, of course.

17.048. My friend asked you some questions with reference to the effect of the slackening of the ties, as to which, I think, he hardly apprehended your view of the manner in which the columns would necessarily behave. If the ties were capable of slackening through conical holes or any other cause, the effect would be, when a heavy horizontal strain was put upon the pier by the wind, to bend the column over to some extent?—Yes, to the extent allowed by the conical holes.

17.047. That fixture of the column, of course, would be resisted by the column so far as its strength would resist it?—Yes.

17.046. The column being bent over to a certain extent, owing to the tie being slack, and not holding it vertically, with a strong lateral pressure, when that strong lateral pressure is removed, does not the column necessarily return to its original position, unless you pass the limits of elasticity?—Yes, that is my view of it.

17.045. I mean, unless you have passed the limits of elasticity, which nobody has suggested had occurred, it is an absurdity to suggest that a cast-iron column, that is only bent by a strong pressure, will remain in that bent position of its own accord?—Yes, for this reason: whatever may be said of the strength of the ties and the lugs, the strength of the columns themselves was so far in excess of any vertical weight that might come upon them that they would necessarily return; it could not approach anything like the limits of elasticity.

17.044. And the fact that a tie-bar was slack afterwards, and could be tightened up, showed that the column had returned?—Yes; they could not have tightened up these with thirty ships of iron if the columns were permanently bent.

17.043. If there had been a permanent set of the column there would have been no slackness of the tie?—No.

17.042. It is only because the column has returned to its normal position that the slackness of the tie can develop?—That created the matter; the columns coming back to their place simply loosened the ties; that was the whole cause of the looseness.

17.051. The column having been bent over that way returned by its own resilience, and so slackened the tie; so that when the packing pieces were put in and the cotsers were driven home that slackness was taken up?—So it was; it was not quite so scientifically taken up as I should probably have had done, but it was taken up.

17.052. My friend put it to you that, not anticipating the loosening of the ties, you made no provision for such a case; were the cotsers themselves a provision for tightening up any slackness that might occur?—Certainly.

17.053. You told us the duties of Mr. Noble with reference to inspecting the bridge in case there was any slackness?—Yes.

(The Commissioner, to Mr. Rider.) I think from the correspondence, unless there is any further evidence to contradict it, it is perfectly clear that Mr. Noble's duties were to look after the branches and ties.

(Mr. Rider.) I think so.

(The Commissioner.) But he threw some doubt upon it himself, and said it was a voluntary act upon his part.

(Mr. Halford.) I may say that if there is any doubt upon that point, Mr. Noble would be brought here, and we shall clear it up; but I think it really is as you say, Sir.

17.054. (Mr. Rider.) My friend asked you another question upon the paragraph in Mr. Stewart's and Dr. Pole's Report in which it is stated that the bridge was designed for a wind pressure of 20 lbs. to the square foot; you said you had not designed it for any special pressure, but that Mr. Stewart was the gentleman who had worked out the details of the strain for you when the design was under consideration?—Those things were all discussed at these weekly meetings, and his opinion was taken.

17.055. And he had worked out the details of the strain on the bridge?—He had on the girder specially; I do not know whether he had on the piers in the same elaborate manner—it was a general consultation, and I cannot carry my memory so far back as to give you the details.

17.056. He was perfectly conversant with all that was done and all that was provided at the time of the design of the bridge?—Thoroughly. I took him into my confidence, and all these things were discussed at these weekly meetings.

Examined by the Commissioner.

17.057. I must ask you some questions, and I will endeavour to put them in such a way that they shall not in any way distress you, for we all have a feeling for you under the circumstances; but you can quite understand that it is our duty to ascertain the cause of this casualty, and nobody, perhaps, has a greater interest in that cause being ascertained than you yourself. These plans which I have before me are the designs for the piers of the high girders, are they not?—Yes.

17.058. There were two piers, were there not?—Two cylinders.

17.059. Wrought-iron cylinders?—Yes.

17.060. Similar to those which you afterwards used?—Yes, for the smaller spans.

17.061. They were 15 feet in diameter externally, were they not?—Yes.

17.062. Did you intend to fill these cavities or wrought-iron cylinders with brickwork or with concrete?—Concrete so far (pointing to the plans).

17.063. How far up would that be?—I lined them with brickwork.

17.064. You intended to line them with brickwork?—Yes.

17.065. And to put concrete in the centre?—Yes.

17.066. That was quite down to the bottom, was it not?—Yes; I have not a note of it, but I think at the bottom it was entirely concrete.

17.067. Then did you intend to float out these cavities without internal brickwork?—Yes, I think so, as far as my recollection goes; but we have more details of this somewhere.

17.068. You told me that the pressure that you computed for the columns and the superstructure upon three piers would be about six tons to the square foot?—I did.

17.069. Did you compute the pressure over the whole surface of the base of the pier?—On the supposition that it was in rock, I did.

17.070. And on the supposition also that it was a casing first of iron, then of brickwork, and then of concrete?—Yes.

17.071. What weight did you suppose the brick piers and the superstructure altogether would amount to on the foundations?—The brickwork and everything to five feet above high water would be 275 tons, or 1,900 square feet.

17.072. That is as originally drawn, is it? We are speaking of the design which was not carried out?—This is the bridge as constructed.

17.073. I want to know what was the computed weight of the brickwork as not carried out, and the superstructure too?—Up to five feet above high water it was 749 tons or 210 per square foot.

17.074. I am asking you for the total weight?—I am going to give it you. To five feet above high water 749 tons or 210 per square foot.

17.075. You are not omitting the present one now?—No, these are the original designs.

17.076. What is above the 749 tons?—About high water to the girders 783 tons.
17,077. And then the girder?—The girders and live load 460 tons.

17,078. That is 1,962 tons?—Yes, and per square foot it is 590.

17,079. Upon an area of what?—360 superficial feet.

17,080. That would include, would it not, the whole area of the brickwork and the concrete?—Yes, it would, but it would be on the foundation.

17,081. Do you know what the superficial area of the caisson which you afterwards sunk is?—I will give you it. It is as nearly as possible 760 square feet.—Page 362.

17,082. What would that give you, taking the piers as originally built with the live load and everything; it will give you between 2 and 3, will it not?

(Mr. Bidder.) The weight of the caisson has to be added; you cannot arrive at it so off-hand as that. You have put a different sub-structure.

(The Commissioner.) Yes, I will take that.

(The Witness.) I cannot give it off-hand, but it can be worked out.

17,083. You have told us that in your original design you intended to line the inside of these caissons with brickwork, and to fill them up with concrete;—I would like to be more sure of that; at this moment I can hardly speak to that.

17,084. Your own designs show it, do not they—does not this show it to you?—No; it is seven years ago or more since those designs were made, and I can hardly bear them in my recollection.

17,085. At any rate, whether you did or not intend to have the inside of these caissons with brickwork, and to fill them up with concrete;—I would like to be more sure of that; at this moment I can hardly speak to that.

17,086. Your own designs show it, do not they—does not this show it to you?—No; it is seven years ago or more since those designs were made, and I can hardly bear them in my recollection.

17,087. I do not think that is quite an answer to say—Your own designs show it, do not they?

(Mr. Bidder.) That is not quite the way in which he put it.

(The Commissioner.) That is what he said.

(The Witness.) No.

(The Commissioner.) Will you read what he did say?

(Mr. Bidder.) This is what he said at page 708, Question 15,591: "Outside of the 4 feet base I must have at least 6 inches within the line of the brickwork; that is 1 foot, that makes 27. Now come this question, how near to the outside we can plant the column; say instead of 2 feet we limited it to 1 foot, that would be 28; and then there are 18 inches of brickwork lining, and that brings it just up to 31 feet."

17,102. (The Commissioner.) Then why is it that the 18 inches of brickwork lining would not be as good a bearing, having two courses of stone above it, as the concrete was?—I did not think it was homogeneous, the concrete and the brickwork. I did not think it would be so.

17,103. But in your other piers very near that you have carried your raking column upon the brickwork, and close over the edge, a portion of the column resting, so far as I understand, over the base of the pier?—This is the base of the pier here (pointing to it).

17,104. Do you recollect the pier in which the top of the outer column takes in?—No.

17,105. Perhaps Mr. Law knows what number it is? (Mr. Law.) That is one of the piers still standing.

17,106. What is the number of it? (Mr. Law.) No. 27.

(Mr. Bidder.) That is so; but you will find that those columns are all upon brickwork, and are not partly on brickwork and partly on concrete.

17,107. (The Commissioner.) That I did not know; that is what I wanted to ask Sir Thomas Bouch. (To Sir 3 H.)
Sir T. Bouch.

3 May 1840.

The Witness: Do you recollect at all those columns?

—No, I do not.

17,108. You do not recollect them at all? —Not those that you are referring to.

17,109. Not where the top part takes in? —No.

17,110. The bottom of the outer column of No. 27 pier overhangs the base, does it not? —Yes; we could not plant some of them. In several cases in floating them in we were obliged to shave off a bit to bring them within the cylinder.

17,111. But it bore over the base of the pier in that case, did it not? —Yes, it did.

17,112. It overhung? —I do not know that it went beyond the cylinder; it would go beyond the brick-work on each side.

17,113. You had no difficulty about it in that case?

—No.

(Mr. Bidder.) That is an entirely different structure altogether.

(The Commissioner.) That may be so; but I want Sir Thomas Bouch to explain it.

(Mr. Bidder.) There was no concrete in that case.

(The Witness.) I should like to look at the thing again; it is seven years ago, and I do not remember it.

(The Commissioner.) I did not quite understand about the thickness of the columns.

(Mr. Webster.) Before you leave that point with reference to the question of the weight, you put to Sir Thomas Bouch that by simply comparing the 350 tons with the 750 tons you got the figures reduced from 530 tons to about two; if you look at his report at page 708, you will see that he makes an exact statement there which gives the difference of weight of brickwork in the enlarged caisson, which would increase the weight in the base enormously: "On the foundations, as originally designed, the weight per square foot would have been 64 tons, of which 64 tons was due to the weight of the brickwork. On the foundations, as proposed to be enlarged, the weight per square foot would be 44 tons, of which 8 tons is due to the weight of the brickwork in the pier alone." It was considered not safe to put three tons per square foot on the large caisson.

17,114. (The Commissioner.) Quite so. (To the witness): With respect to that, do you consider that the superstructure and the live load were equal to about 2½ of a ton per square foot? —That would be so.

17,115. You took it at that? —I had to go into the calculation, and that was the result.

17,116. With respect to the thickness of these columns of the high girders, they were all designed originally to be one inch thick; were they not? —They were eight of them, and then eight of them.

17,117. When they were originally designed, there were eight? —Yes.

17,118. And then they were all one inch thick?

—They were all one inch thick.

17,119. When the first alteration was made, you still intended to have eight columns, did not you? —I think so.

17,120. Why did you make the change from having two small caissons to having one large caisson? —The larger caisson, of course, contains nearly double the area; therefore I was reducing the weight per square foot by doing that.

17,121. With respect to the thickness, I think originally, almost up to the 30th March at any rate, you had intended to have them all one inch, had you not? —You had an interview with Mr. Grothe, and you marked upon the plan that the 18-inch columns should be ¾ inch, that plan being dated the 30th of March.

17,122. (Mr. Bidder.) No, I do not think you are correct in the date; the alteration was not made then? —I did it at one of the meetings; on the 6th of April, I think it was.

17,123. (The Commissioner.) There is a meeting before that, because there is a letter of the 1st of April, when you wrote to say that the columns were not to be ¾ inch, but that they were to be one inch?

—My assistant, Mr. Wemyss, wrote that at my suggestion.

17,124. Therefore, clearly before that 1st of April there had been some instructions from you that some of the columns should be ¾ inch? —Only at that meeting on the 6th.

17,125. How could it be only at the meeting of the 6th, if you wrote a letter on the 1st of April, stating that the columns were to be one inch instead of ¾ inch. I will read you the letter—

(Mr. Bidder.) It is at page 12 of the minutes.

17,126. (The Commissioner.) On the 1st of April Mr. Wemyss writes to Mr. Grothe in these words: "The thickness of the metal of columns for pairs of 300-foot spans, a tracing of which I handed you the other day, is to be 1 inch in place of ¾ inch, as shown on the tracing"? —I had mentioned ¾ inch before that.

17,127. But you had originally one inch? —It says make it one inch in lieu of ¾ inch, as shown on the tracing which I had given before.

17,128. The tracing showed one inch, and then it was altered at the interview with Mr. Grothe, so Mr. Grothe tells us, to ¾ inch.

(Mr. Webster.) The tracings showed nothing, but ¾ inch was written on it.

(The Commissioner.) But the thickness was shown in the tracing, was not it?

(Mr. Bidder.) No, it was marked "1 inch" upon it.

(The Commissioner.) Have you the tracing with you? (The drawing was produced and handed to the Court.)

(The Witness.) The letter of Mr. Wemyss referred to all the columns.

17,129. Here is the note to which Mr. Grothe referred about the 1½ inch metal, is that not so?

—Yes.

17,130. A note made by him at his meeting with you? —Yes.

17,131. Then before that it had been one inch?

—Yes.

17,132. Then he agreed with you that it should be 1½ inch? —Yes, at that meeting.

17,133. Then you wrote to him a letter on the 1st of April, did not you? —Yes; Mr. Wemyss did on your instructions, telling him that the metal of 1½ inch should be 1 inch? —He wrote the letter.

(Mr. Bidder.) The meeting was not before the 1st of April, but on the 6th of April.

(The Witness.) Mr. Stewart took a note of it at the meeting, in his own diary; he will explain that.

17,134. (The Commissioner.) That is the 6th of April. Then you say, on the 6th of April it was altered back again to ¾ inch? —Yes, that was the last alteration, and that alteration only referred to the two outside columns.

(Mr. Webster.) May I remind you that I do not think Mr. Grothe said that the 1½ inch was put on the 30th of March. He only identifies the plan as of the 30th of March: "I have here a drawing marked dated the 30th of March, on which there was a 1½ inch put." I do not remember any statement of Mr. Grothe that the actual time of writing the 1½ inch was the 30th of March.

(The Commissioner.) But Mr. Grothe says that he received a letter subsequently after he had marked it 1½ inch.

(Mr. Webster.) He did not say that he received a letter subsequently; he said it was verbally.

What he said was this: "This was a drawing which at that time we were to act on; but in consequence of further conversations some time afterwards, of which I do not remember the date, a counter order was given, and the 1½ inch was made ¾ inch." I take it that Mr. Grothe's evidence was this: A plan comes to him dated the 30th of March; there is some discussion as to whether it should be 1½ inch, but as a subsequent conversation the ¾ inch is determined on. I do not understand that the date was fixed when the 1½ inch was written on the plan.
17,135. (The Commissioner, to the witness.) Did you tell us that you had adjusted the bolts and lugs so that they should be considerably stronger than the ties?—I was under that impression.

17,136. And it was your impression that the bolts and the lugs would be stronger than the ties?—I think so. It is a very long time ago, and I cannot recollect very distinctly.

17,137. You told us also that the bolt holes ought to have had the sides, as you say, perfectly square or parallel?—They ought to have been.

17,138. And if you had known they were not, you would have had them rimmed or drilled?—I certainly would. Probably if I had known it earlier, before more of the bridge was built, I should have had them squared; I might have had them rimmed out, but I would have calculated the strength of the lag before I began to take the metal out.

17,139. When you had them cast, you could have had the holes cast rather smaller, and you could have had them rimmed out?—Yes.

17,140. That would have been better?—That would have been better. It is not in the specification. The specification says that the holes in the flanges are to be drilled, and it certainly is an omission in the specification so far as the holes in the lugs are concerned. I think it was a fair inference that the holes should have been drilled.

17,141. Surely it was intended that the holes to contain the bolts should not be conical?—Yes.

17,142. It says: "All bolts to be made of Low "Moore iron, or other such make as shall be specially "sanctioned by the engineer, and to be nearly finished, "head and nut, and not projecting more than 1/4 "inch through the cut, to be carefully forged and "screwed, and made to fill the bolt holes"?—Yes.

17,143. So I suppose there is no doubt whatever, if that had been carried out, you would have had these bolt holes with the sides perfectly level and perfectly parallel?—Most decidedly.

17,144. It was a defect not to have them so?—It was.

17,145. The defect I understood you to thus: that the bolts would give till they got a fair bearing upon the sides of the holes?—Yes.

17,146. Let us begin with this outer column—column No. 1. Suppose, for instance, that the bolts at the bottom got bent, that tie would go loose, would not it?—Yes, both bolts would be bent.

17,147. That tie I suppose holds the head of the other column up, does not it?—Yes, it holds the head of the column up to there (pointing to the model).

17,148. Take one a little higher up; that tie holds the head of the column, does it not?—Yes.

17,149. Suppose, for instance, that the bolts at the bottom got bent, that tie would go loose, would not it?—Yes, both bolts would be bent.

17,150. And you would get a double bending, therefore?—Yes.

17,151. The top of that column would be likely to fall in that direction?—In this direction (pointing to the rails) it would have no tendency to do anything unless the wind was blowing, because there is no side pressure.

17,152. Are these bracings entirely for side pressure?—Entirely for the wind; at least not for wind, but there is very little strain on it unless in wind.

17,153. Do you mean that there is no tension upon these bracings?—I do not mean that there is no tension upon these bracings, but that there is not a very severe tension, but there is a certain strain upon the ties which is very slight in excess in wind.

17,154. Even when a train is going over it?—Even when a train is going over it.

17,155. Would not there be a strain on the ties?—It would be very slight.

17,156. You mean that the whole of the strain was upon the columns—the crushing strain would be upon the columns?—Yes; this keeps the column, no doubt, from bending out one way: that is the stress it is subject to; but that is very slight compared with the pressure of the wind on this.

17,157. You mean that the ties themselves are chiefly, in fact, to resist the pressure of the wind?

17,158. And not to keep the columns in their position?—It does that; but there is very little tendency to go out of position.

17,159. Suppose there was no wind, do you mean that without the ties the structure would remain standing?—No: without the ties, but very slight tie would do.

17,160. You said that your attention was called by Mr. Noble to these two cracked columns?—Yes.

17,161. Did you go to the bridge at once as soon as you heard of them?—Yes, at once, but he got the bolts round before I got there.

17,162. Did you suggest some plan better than that which he had adopted for the purpose of preventing any further cracking? I think they were done when I went, and I think they answered the purpose.

17,163. Did you not suggest some other plan?—No.

17,164. Was there not before the bridge came down some bracing suggested, so as to connect the outer column with the inner columns?—No.

(Mr. Webster.) Not under the high girders.

17,165. (The Commissioner.) I am not talking of under the high girders; I am talking of columns 73 and 76. Was there not some plan of bracing suggested so as to connect the outer column with the inner columns?—I really do not recollect anything of that.

17,166. Do not you recollect that there was some suggestion made as to how those pillars could be better protected?—I have no recollection. I have thought of a plan for strengthening all that part of the bridge.

17,167. Why?—On account of the public feeling since the fall of the bridge.

17,168. What do you mean when you say to you whether you had thought of that before?—No.

17,169. Do you recollect Mr. Noble writing to you, "The friction at this part of the bridge must have been very severe, and there can be no doubt but that the columns were daily receiving a great strain upon them"?—I know that has been said to be the case when you are going down say, and especially since the Westinghouse breaks have been introduced.

(Mr. Bidder.) I think Mr. Noble's letter is directed to the point of what should be done with a view of preventing strain to cause the cracks, and not a remedy for the cracks.

(The Commissioner.) That is how I am putting it. (The Witness.) When you get to where the bridge is low, I braced the columns to resist that. As a matter of fact, I have asked the permanent-way men if they had found anything of the sort, and they have always told me they had not.

17,170. I want to know what, in your opinion, was the cause of this crack; whether it was, as Mr. Noble seems to think, from the trains running over that particular part putting on the break there, or whether it was from the contraction of the iron upon the cement?—I do not know Mr. Noble's idea of it, but it could not have been the action of the trains on it, because it only occurred where there were four pillars instead of three; that is to say, it was where there was a group of columns.

17,171. It was a place where there would be a great strain brought upon it; it was at the part where it was curved?—At all events, it occurred on a pier where there was a group of columns; it did not occur on any of the other piers.

17,172. What would that show?—I do not think it arose from the cause he suggested.

17,173. (Mr. Barlow.) What you mean is this: there was less real stress upon these columns because there were four of them?—A much less stress.

17,174. Therefore it was not the stress that caused the crack?—No.

17,175. (The Commissioner.) Then you do not agree with Mr. Noble in this statement of his?—No.

17,176. With respect to the crack having been produced by the contraction of the iron upon the cement, what do you say to that suggestion?—It a little alarmed me at first, and I made inquiries of other
engineers who had had cracks in their columns; for instance, Mr. Brunless, who had cracks in his bridge on the Solway, and there are all kinds of

17,177. The cement is put in wet?—Yes.

(T. Webster.) I do not think water goes off.

17,178. Where there any means adopted by you to allow the moisture to escape by holes at the bottom?—No, there were no means of that sort.

(T. Webster.) I do not think water goes off.

17,180. You mean that it would expand at once?—Certainly not.

17,181. That would bring a strain upon the iron?—Yes, but I do not attach much importance to that.

17,182. You do not think that would be a sufficient strain to break the iron?—Certainly not.

17,183. You have been asked by Mr. Traynor whether or not a difference of a quarter of an inch in thickness between the two sides of a column would be an important thing; and you say you do not think it was important?—No, but it is a thing which I would rather be without.

17,184. Suppose, for instance, one side of a column was about half-an-inch thick and the other side was nearly 14 inch thick, would that be a matter of importance?—I should object to that.

17,185. Would you think that a serious defect, and one which was likely to injure the structure?—If the column was proportioned to anything close approaching the duty it had to do, it would be serious; but with the enormous excess which we had here, where it would take 20 times the greatest weight that could come upon it to break it, I think it of very little importance.

17,186. You have told us that you think the cause of the accident was the train coming into collision with the girder—with these ties, I suppose?—Yes, I think it was caused by those two things—coming into collision with the ties and being capsized by the wind.

17,187. You do not mean that it came into collision with the boom? you mean that it came into collision with one of these ties?—Yes, I think so; with one of the girder ties.

17,188. You think that it came into collision with one of these and broke it?—Yes, I think that would be the way.

17,189. Do you think that the mere breaking of any one of these ties of the girder would be sufficient to break it down?—I do not know that the mere breaking of one of them would be sufficient, but there are several struts and ties where this second-class carriage and the van were found, and I have had the thing surveyed and made into a plan.

17,190. What is the distance of these ties?—They are about 27 feet apart.

17,191. Twenty-seven feet at the base?—Yes.

17,192. Do you think that taking away two of these and the strut there would be sufficient to bring the bridge down?—Most undoubtedly, with that wind.

17,193. Put the wind aside. Do you think that the breaking away of two of those ties and the strut would be sufficient to bring the bridge down?—Yes. (Mr. Webster.) Do you mean by a blow, or by cutting them through?

17,194. (The Commissioner.) By cutting them through. (To the witness): Do you think that would be sufficient to bring the bridge down?—Yes. As a matter of fact, however, there are more than two or three that are gone—both struts and ties; I could show you that on the plan.

(The Commissioner.) Let us see the plan. (Mr. Bidder.) It is rather anticipating.

(The Commissioner.) He wishes to explain what he says by the plan. (The plan was produced and shown to the Court.)

17,195. (The Commissioner.) You think, therefore, that this bridge was so constructed that if one or two of these three gave way the whole bridge between the high girders would come down?—I think so; that is to say, if you cut them.

17,196. So constructed that if the one or the other of these ties gave way?—I do not know as to one, but certainly two.

17,197. If two of them came down, the whole length of the bridge between the high girders would come down?—Of course the girder coming down sends the pier down, and they all go one after the other like.

It is a curious thing that in the first plan (showing the carriages) at every joint where an expansion takes place the ends of the girder are smashed.

17,198. (Mr. Barlow.) In every case at the expansion joints the ends of the girders are gone?—Yes.

17,199. (The Commissioner.) Can you tell us when it was you were abroad from illness?—I do not know; but it was when that accident happened.

17,200. In 1877?—I think it would be in 1877.

17,203. When they were raising the high girders; when the two girders fell down?—Yes.

(The Webster.) That was December 1877?

(T. Witness.) I understand that Mr. Gilkes telegraphed to me, but I never got his telegram; I was unaware of it.

17,202. (Mr. Barlow.) In the Report of Dr. Pole and Mr. Stewart it is calculated that a wind pressure of 20 lbs. per square foot would cause a strain on the tie-bars of 679 tens per inch upon the minimum section of the tie-bar?—I have not read the Report, but I heard that stated.

17,203. I will put a question upon that to Mr. Stewart or Dr. Pole. I may ask you this: in designing ironwork it is customary, is not it, to arrange the ironwork in such a manner that the greatest stress on any part of it should not exceed five tons to the inch?—That is the Board of Trade rule.

17,204. In practice it is applied not only to the minimum section of the principal member under stress, but also to the shearing rivets or other fastenings?—Yes.

17,205. And to the bearing surfaces of the rivets or other fastenings?—Yes.

17,206. In wrought iron a stress exceeding 10 or 12 tons to the inch would create a permanent extension if applied in tension, or deformation if applied in compression?—Yes; this girder, applying that principle, has no tensile strain exceeding 6 tons, and the compression of the iron, I think, is about 4 tons or 4 tons 10 cwt.

17,207. That is with regard to the girders themselves?—Yes.

17,208. I am rather speaking of wind-ties?—I did not take the wind on the piers at 20 lbs. after that report on the Forth Bridge.

17,209. The wind-ties, as they are put in your original specification, are 3½ inch by 3½ inch angle iron?—I suppose they are.

17,210. And they seem to have been executed 4½-inch by 4-inch flat bar. Do you remember for what reason you made that change in the structure?—I do not remember.

17,211. What pressure of wind do you consider would be necessary to upset the carriage that you suggest as having been upset—that is, the second-class carriage?

(Mr. Bidder.) I shall have to call Dr. Pole and Mr. Stewart upon that point.

(The Witness.) I had rather leave that to Dr. Pole and Mr. Stewart.

17,212. (Mr. Barlow.) You do not remember for what reason the change was made from angle iron to flat bar?—I do not.
17,213. It seems to me an important change, because of its effect in reducing the strength of the cross-bracing; very materially; in one case it would act as struts and ties, and in the other as ties only; if you could recollect anything about the reason for that change it would be of use. I cannot remember it.

17,214. Do you remember what description of horizontal ties were used in your Bealach Vadamit?—Yes.

17,215. What did the horizontal ties consist of; from the drawing I have seen they appear to consist of girders placed quite across between the columns?—That is from column to column—yes, and the ties go into them.

17,216. In this structure you departed from that construction?—Yes.

17,217. Why did you depart from that construction?—I can only tell you this, that I had a different idea of the force of the wind at that time before I got the Report on the Forth Bridge.

17,218. (The Commissioner.) Is that the only reason why you did away with those ties?—They were so much more expensive; this was a saving of money.

17,218a. (Mr. Barlow.) There was more fixing connected with the other form of construction?—Yes; it required the columns to be turned.

17,219. The size of the bolts for the columns as specified was 1½ inch, which was altered to 1 inch; was there any special reason for that alteration?—It is not within my recollection.

(Mr. Webster.) Was there any alteration in number corresponding, because the two things go together?

(Mr. Barlow.) Do you remember whether at the time that the dimensions of the bolt was altered the number was altered so as to make the total sectional area the same?

(Mr. Webster.) Coordinately more.

(Mr. Bidder.) The 1½ inch in the specification refers to the holding-down bolts.

(The Commissioner.) No; the 9800 were not holding-down bolts.

(Mr. Webster.) Mr. Barlow is alluding to page 4.

(Mr. Barlow.) It is the bolt holes that are put at 1½ inch. The part of the specification that I am reading from is headed “pier for 66-feet spans.”

(Mr. Bidder.) They are the bolt holes in the fanger of the pier.

17,220. (Mr. Barlow.) There was no alteration in the number; there has been for some reason a reduction in the size of the bolts, and I wanted to know if Sir Thomas recollected why that was. (To the witness.) The top member of the pier is made in two divisions, the bolts being quite separate from the other, except that there is a wrought-iron horizontal member beneath them; what was the reason for making those separate; why were they made in separate pieces instead of our continuous piece across the top of the column?—This (pointing to the model) had a special duty to perform, to carry the weight; it was not a part of the bracing.

17,221. Why was the one distinct from the other?—Because this has nothing to carry (pointing to the model). The dimensions of this are in reference to the weight to come upon it actually as a girder.

17,222. Had it anything to do with the convenience of towing the girders in the process of erection?—Yes, it had; the girders were made so as to clear these two columns; the girder came up inside this, and as it came up these outer columns were built up after it, that is entirely the reason why it is put in this shape, to allow those two girders to come up from the bottom right away up both sides. It gives great facility for erecting the structure in that way.

17,223. If that had been connected quite through to the top, would not it have given great extra stiffness to that part of the work?—Yes, but I do not think it was altered for that.

17,224. Whose duty was it to inspect the iron work?—It was Mr. Wemyss in the first instance, and Mr. Macbeth’s afterwards, and Mr. Paterson’s.

17,225. It was the business of those persons, then, to see that the holes were properly formed, and that the columns were of a proper thickness?—Yes, it was their duty to see to everything.

17,226. And to report to you if anything was wrong?—Yes; first of all Mr. Paterson was the resident engineer, and Mr. Paterson was always in the foundry, and they would report to him or to me, but generally they would make a report to Mr. Paterson, and he would report to me if there was any occasion.

17,227. Was Mr. Noble instructed to report to you anything he found wrong?—Yes, he always used to do so.

17,228. He did not have any decided written instructions to do so?—No, I do not think he had; but from the south end of the bridge to the Leuchars Junction, and also from the north end of the bridge through the tunnel through Dundee, I had two additional inspectors, both able men, and, though officially they were not inspectors of the bridge, they lived one at one end of the bridge at Newport and the other in Dundee, and they really were perpetually on the bridge, and anything they saw wrong they would report.

17,229. Mr. Noble stated that he found these ties loose, and provided the iron to pack them with, and that he never reported the thing to you.—No, he did not, and I was very much surprised when I heard it.

17,230. When did you first hear of it?—Not till the bridge fell.

17,231. (The Commissioner.) With respect to those bolts, I find that on the 12th of August 1874 the Cleveland Nut and Bolt Company write to Messrs. Hopkins, Gilkes, and Company: “We have to thank you for your esteemed inquiry of the 11th instant, and in reply beg to say that the above quotation, in supplying 9,800 1½-inch bolts to your tracing, at 21½ 6d per cwt.” Then that order was cancelled, and on the 15th of September Mr. Gilkes writes thus: “With this we beg to enclose you order for 9,800 1½-inch bolts to our tracing, at 21½ per cwt.” Therefore it appears that Mr. Noble instructed to report to you any circumstance why it is put in this way. (Mr. Webster.) Would you ask him whether those were holding-down bolts or lag bolts?

(The Commissioner.) They could not be holding-down bolts.

(Mr. Webster.) I mean flange bolts. Mr. Grotie said that the 1½-inch bolts were ordered for a different work altogether, and then they were substituted for 1¾-inch. Those were not column to column bolts.

(The Commissioner.) Have you do not remember anything about the alteration?

(The Witness.) I do not recollect anything about the alteration.

Mr. Charles McLay called again.

Examined by Mr. Biddick.

17,232. Did you proceed to Dundee on the 24th of last month?—Yes, I did.

17,233. And did you take a survey and take the dimensions, with the view of plotting it, of a portion of the eastern girder, No. 4 span, which had been recently raised?—Yes.

17,234. And does that plan which you hold in your hand correctly represent the girder as now to be seen at Broughty?—The portions of the girder that I saw.

17,235. I believe that that shows that several of the struts and ties of that girder have been bent and broken?—Yes.

17,236. Is it the eastern girder, is it not?—It is the eastern girder.

17,236a. (The Commissioner.) The under girder?—The under girder. I saw it after it was up.

17,237. (Mr. Biddick.) The side nearest you is
the lower member of the girder?—This is the lower member of the girder.

17,238. The left hand of the plan is the eastern end?—The northern end of the girder.

17,239. That shows several ties and struts to have been broken; does it not been broken?

17,240. And broken by something that impinged upon them, the blows coming towards the north?—Yes.

17,241. A blow from the south?—Yes, apparently from the south.

17,242. The plan is a correct survey of what you actually saw yourself?—Yes.

17,243. Did you also find upon those portions of the girder any peculiar marks or scorings?—Yes, I found scorches in several places.

17,244. Are those horizontal lines marks of something abetting the girder in a horizontal direction?—There appears to have been some body scraping over the plates and ties.

17,245. Those you also show upon the plan with red lines?—I have shown them with red marks.

17,246. They are horizontal, that is to say, lines in a horizontal direction, and I believe their height upon the girder corresponds with the height of the roof of the carriage?—Some of them, and some of them are low even.

17,247. Further on towards the north they get lower, but at the first they correspond accurately with the height of the roof of the carriage?—Yes.

(The Commissioner.) Do you mean the height of one of the carriages in an upright position?

(Mr. Biddler.) As they canted over, one mark corresponds with the roof of the second-class carriage, and one mark with the roof of the guard's van.

(Mr. Traynor.) All that Mr. Biddler is entitled to get from the witness is that he has given me exactly what he saw, and that the measurements are correct; but to say that those marks correspond with the roofs of the carriages is assuming heights which he has not before him.

17,248. (Mr. Biddler.) You do not know of your own knowledge what the height of the carriages was?

—I have some idea of it.

17,249. At the first place at which those abrasions occurred, the southernmost of those abrasions, do you find that a rivet has been struck out?—Yes, in this corner (pointing to the plan)

(Mr. Traynor.) You mean that the rivet is not there.

17,250. (Mr. Biddler.) Is it that the rivet has never been put in?—The rivet has been struck out; the cover has been lifted up.

17,251. The cover has been lifted up by something forcibly parting it?—By something forcibly parting it.

17,252. Did you find anything between the cover and the lattice?—I found splinters of wood.

17,253. (The Commissioner.) Where did you find those splinters of wood?—Between the cover and the tie. This is the cover on the tie (pointing to the plan). There are two covers, and between this inner cover and the tie there were splinters of wood.

17,254. (Mr. Biddler.) This is the southernmost place where the abrasions occur?—Yes.

17,255. That cover and tie would be riveted up close together in the ordinary state of things?—The cover would be close on the tie.

17,256. With regard to those splinters, do they appear to have been driven in with considerable force?—Very considerable force indeed.

17,257. They had lifted or widened the opening between the cover and the tie?—I cannot say that the splinters opened the cover plate from the tie, but the cover had been lifted up from the tie, and the splinters were between the cover and the tie.

17,258. You found the cover open?—Yes; lifted up from the tie, and the splinters in between.

17,259. And the rivet struck off?—Yes.

17,260. To what extent had the tie been open?—From the tie it had been lifted 1/4 inch, and it gradually died away.

17,261. The tie plate was cracked from the edge to the rivet hole?—The tie plate was cracked from the rivet hole to the edge of the tie.

17,262. (Colonel Yolland.) Which lattice bar was that with reference to the third pier? Whenceabouts did it begin?—This is the fourth pier (pointing to the plan); this is the south end, that is No. 3 pier (pointing to the plan); that is No. 4, and this is the eastern girder.

17,263. That is the third tie from the north.

(Mr. Biddler.) Where will that be upon the plan?

(The witness pointed it out.)

17,264. (Mr. Biddler.) It would be 70 feet 6 inches from the end of the girder?—Yes.

17,265. All the parts which are not coloured in your plan are gone?—Yes.

17,266. (Mr. Biddler.) Do you know the dimensions of this piece of iron (pointing to it)?—Sixteen inches by nine sixteenths.

17,267. What is the total sectional area?

(Mr. Biddler.) Nine inches.

(Mr. Biddler.) That would be a tension bar.

(The Commissioner.) Will you put your finger on the model at the place where those first scorings are?

(The witness did so.)

17,268. (Colonel Yolland.) Then the lattice-bar appears to be inside the cover-plate, is that so?—There are two covers, double covers, on each tie; it is not shown here.

17,269. There is a cover inside as well as outside?—There is a cover inside as well as outside.

17,270. (Mr. Biddler.) It is between the inner cover and the lattice-bar?—Yes.

(Mr. Webster.) There is a section which will show it.

(Colonel Yolland.) Is the site of the second-class carriage shown on that plan?

17,271. (Mr. Biddler.) It is not shown. If you like I can tell you where it was. The second-class carriage was there (pointing to the situation), just at that post. The wheel of the second-class carriage was just south of that post; we shall call a witness to prove that.

(The witness.) The next suspension-rod was bent, being bent towards the north?—Yes, the inner one of the two; there are two suspension-bars.

17,272. The next tie we come to, that would be the tie of compression, had marks upon it?—That had scores on it.

17,273. At a lower level?—Yes, at about the same level at which the suspension-bar was bent.

(Colonel Yolland.) Will you ascertain whether the top boom had been removed by dynamite or not?

17,274. (Mr. Biddler.) Are you able to answer that question?—I am not able to answer that question.

17,275. (Mr. Traynor.) You found that it was gone when you came to make the drawing?—I found it was gone when I came to make the drawing. I put down on this paper all I saw.

(The Commissioner.) Was the top boom gone at that part?

(Mr. Webster.) From the last two bays, the last two rectangles, the top boom was gone. The dotted line is what ought to have been there; the blue line is what is there.

17,276. (Mr. Balfour.) It looks as if there was a separation; did you find it all in one piece?—No, it is in two pieces.

17,277. It is placed and pictured together?—Yes.

17,278. Apparently there are two fragments, and you have put the two fragments in juxtaposition and drawn it?—Yes.

17,279. (Mr. Biddler.) Now, then, if we go on northwards when we come to the tie-bar nearest to the end of the girder, that had been broken, I see, and bent, and the suspension-bar has been bent also towards the northward, and broken away from the tie-bars, as shown in the drawing?—Yes.

17,280. Was there anything more to note in this
suspension bar?—At one point there was a jagged piece of iron, and two splinters of wood in the last suspension bar.

17,277. The bottom boom was also partially fractured, was it not?—Yes, at this end (pointing to the drawing).

After a short adjournment—

Examined by Mr. Trayner.

17,289. You pointed out the positions; that there may be no mistake about it, that is the south end of the drawing, is it not?—Yes.

17,288. Of how many pieces of girder was the erection, so to speak, composed of which you have given us a sketch here?—Of the separate pieces.

[The Commissioner.] All apparently in connection.

17,284. [Mr. Trayner.] They were put together in order that you might sketch them?—I put them together in pieces.

17,286. Were they standing together in juxtaposition on the beach as you have put them on the paper?—No, they were lying separate.

17,287. Then it is two separate pieces of girder that were lying on the beach that you have put together to make a complete drawing?—Yes.

17,287. Whether these were originally connections you have no means of knowing?—I have; I am certain they were continuous.

17,285. What led you to that certainty?—The size of the tie.

[Mr. Webster.] They vary according to the strain.

17,288. [Mr. Trayner.] The tie in the girders vary, do they, for different places, so that, from your drawings, and from your knowledge of the construction of the bridge, you thought that these were continuous pieces?—Exactly.

17,290. I find in your sketch (I have no doubt perfectly accurately) that the southernmost portion of the plan is all doubled up on the beach, and has been drawn as it was originally in the girder?—In laying it on the beach they have got this tie bent, and this line over the top (describing the drawing).

17,291. But this is not a representation of what you saw on the beach?—It is not a representation of the girder as it lies.

17,292. You have fastened it out, and put it in position?—Yes.

17,293. Is this tie No. 3 connected with the top boom as you have shown it on the sketch?—It is.

17,294. [The Commissioner.] It is now connected?—Yes.

17,295. [Mr. Trayner.] What part of it is doubled up?—It is doubled up from here (pointing to the drawing).

17,296. It is doubled up about two-thirds of the way between the top boom and strut No. 3.—Yes.

17,297. Above the junction of the strut and the tie there is a cover-plate?—Yes.

17,298. And it is riveted by a number of rivets. Are they correctly shown on the sketch as far as number is concerned?—The number is correctly shown.

17,299. And the one that is darkened is the one that you say is wanting?—Yes.

17,300. So that originally there had been in that cover-plate twenty rivets?—Yes.

17,301. Are these rivets, apart from the one that is away, started at all?—They do not appear to be.

17,302. Do I rightly understand that it is between the place of the tie on which the plate is placed that the splinters of wood are so to be found?—Between the inside of the cover and the tie-plate.

17,303. That is between two pieces of metal which are connected by the rivets shown?—That is so.

17,304. Can you suggest how the splinters of wood got between those pieces of metal?—They must have got between the cover-plate and the tie by some wooden body coming violently against the edge.

17,305. The cover-plate and the tie are both iron?—They arc.

17,306. And the rivets are holding, without, as far as I can see, any giving at all?—Those that are in.

17,307. There is one of them away altogether, but those that are there are just as tight as rivets can be?—I did not test them with a hammer; they may be slack.

17,308. Did you look at it?—I looked at it, but I did not test them with a hammer.

17,309. Do you think that a piece of wood driven with any force you like against the edge of these plates would have forced its way in between the two plates that are rivetted together?—The wood is there.

17,310. But can you form any opinion as to how it came there?—I have just said that it must have come there by some wooden body coming violently against the ends of the plate.

17,311. It must have separated the rivetted plates sufficiently to admit of its getting in?—The plate is started. The tie-bars round it have been started away from the tie. The corner of this cover-plate is forced away from the tie.

17,312. But the splinters of wood according to your sketch do not enter there (pointing to the drawing)?—There is a slight opening all the way up there, but I could not see it.

17,316. What is the extent of the opening between the plates in which you found the wood splinters?—I should say about the thirty-second part of an inch; I did not measure it accurately.

17,314. What is the size of the splinters that you found in there?—They are short.

17,315. Did you remove any of them?—Yes, I have brought some of them (producing them). I brought up a portion, about a quarter I should think, of what was there.

17,316. Is that about a quarter of the whole thing that was there when you saw it?—I think less than a quarter.

17,317. You cannot tell of course whether that wood which was between the plates was from a carriage, or from one of the beams, or from the flooring?

[Mr. Bidder.] The way-beams, you mean?

[The Witness.] It appears to be hard wood. Of course I cannot say.

[The Commissioner.] What do you mean by "hard wood"?

[Mr. Bidder.] Hard wood as distinguished from fir.

[The Witness.] I cannot say definitely whether it is hard or soft.

17,318. [Mr. Bidder.] I understand that all you can say is that it appears to you to be hard wood?—Yes.

17,319. The way-beams, I suppose, are of fir?—Yes.

17,320. [Mr. Trayner.] Do you remember what is the distance between the easternmost rail and the girder?—I cannot say exactly.

17,321. It is about three feet, I think?—It is shown on the drawings.

17,322. How high above the line of the rail is the nearest point at which you find splinters of wood?—You will be able to take that with a scale.

17,323. Will you be so good as to do it with your own scale?—After measuring it. It seems to be about 11 feet 2 inches.

[The Commissioner.] From where? [Mr. Trayner.] From the level of the rail. [The Witness.] I had no plan of these girders from which I could draw that.

17,324. [Mr. Trayner.] Does that correctly represent or not the relative positions between the rail on which the carriages ran and the point in the tie at which you found the wood?—As far as I could draw it, it does.

17,325. And therefore, to the best of your capacity, this drawing shows that the lowest point at which you found these particles of splinters was 11 feet 2 inches above the level of the rail?—That appears so on the plan.

17,325. You have marked on the No. 3 places in red
which indicate, according to your note, that there are scores or scratches across the cover-plate?—Yes.

17,327. I understand, from the fact of there being no representation of such thing on strut No. 3, that there was no such thing observable on that strut?—I did not observe it.

17,328. I suppose your examination of strut No. 3 would be as careful as your examination of tie No. 3, and would have enabled you to see these scarring if they had existed?—I would have seen them, if they had been there.

17,329. So I may take it that they are not there?—So far as I can say, they are not there.

17,330. Have you considered this question? At what angle or in what position the railway carriage (for that is the assumption) was coming from the south towards the north, which was so sent against tie No. 3 as to leave parts of the wood in the cover-plate, and at the same time entirely to pass strut No. 3 without any mark?—I have not considered what angle it was coming at; but this strut being further back than the tie, it would naturally catch the tie before it caught the strut.

17,331. How much is the strut behind the tie in point of width; what is the thickness of the tie?—The tie is 4½ths of an inch, and there is this plate in between the tie and the strut, so that it brings this tie farther out than that (pointing to the drawing). I think that is 7 inches wide, but I cannot be certain.

17,332. At most you have ½ths and ½ths?—Yes, and then of course the ½ths of an inch cover is outside that again.

17,333. But the splinters were made of the cover, you know?—Exactly.

17,334. Are these suspension bars hugging in pairs?—They are in pairs.

17,335. And one of them, you said, was pushed northward?—The inner one.

17,336. Has anything at all happened to the outer one, or is it intact?—It appears to be intact.

17,337. Have you any scale which enables you to judge whether the breaches in the booms or any of the contortions in the ironwork had been produced by dynamite-blasting?—I have formed no opinion upon the effect of that.

(Mr. Balfour.) I have no question to put to this witness.

Re-examined by Mr. Biddulph.

17,338. You are perfectly certain that these two fragments are contiguous portions of the same girder?—I am certain of the fact that the tie correspond and come in sequence.

17,339. You say that you have put the rail level here to the best of your ability?—From memory I do.

17,340. The position of the scoring upon the tie is put from measurement?—Yes. (The drawing was laid before the Court.)

17,341. (Colonel Yolland.) Are these scorings that you speak of indent of the iron?—Not exactly indent; the paint is all scratched off. There are some scratches in the iron too, but they are not deep.

17,342. A thirty-second part of an inch, or a sixty-fourth part of an inch?—I did not measure them, but they are very slight.

17,343. You have got a crack in the tie-plate here; where is that?—It extends from the edge of the tie-plate to the rivet hole.

17,344. No farther?—That is as far as I can see, because the cover-plate covers it.

17,345. It does not go through?—It does not go through the cover-plate.

17,346. We understand you to say that you are not prepared to say how any of these fractures were made, whether by blasting or by other means?—I say I have no experience of blasting, and I do not express an opinion.

17,347. There was nothing farther south than those which showed any damage?—Not that I saw.

17,348. On the easternmost girder?—I did not see any more than that on the easternmost girder.

There was no more above water when I was there.

17,349. (The Commissioner.) Therefore you do not know whether that farther portion was injured or not; is that so?—Exactly.

17,350. The only thing that you saw was this piece, and that perfectly separate?—Perfectly separate.

17,351. And you do not know whether or not that rupture was made by dynamite, and whether this corresponding one below was made by dynamite or not?—I do not.

17,352. And you do not know what has become of that top boom?—I did not see that top boom.

17,353. Only those two pieces were given you for you to make a drawing from?—They were the only pieces that were above water at the time I made the sketch. I believe there are some more above water since.

17,354. (Colonel Yolland.) This was bent (pointing to the drawing)?—Yes.

17,355. Both pieces, or only one?—The inner bar.

17,356. (Mr. Barlow.) Which is the tie, and which is the strut?—This is the strut (pointing to it).

17,357. Can you see the fracture of the strut?—Yes; it is close up to this plate.

17,358. You do not know what has become of the strut?—I have not seen the bottom part.

17,359. (The Commissioner.) You have never seen the bottom boom at all?—No, I have not (describing the drawing).

17,360. The bottom boom is under water, you suppose?—Yes.

17,361. It has been taken up in small pieces?—It has been taken up in small pieces as compared with the whole girder.

17,362. (Colonel Yolland.) Do you know where the axle-box was found?—No, only from what I have heard.

17,363. (The Commissioner.) Do you know what the roof of the second-class carriage is made of; is it made of hard wood?—I could not be certain.

17,364. (Colonel Yolland.) Do you know its height above the rails?—No, I cannot speak as to that.

(The Commissioner.) Is there anybody besides Mr. Meik who has seen these?

(Mr. Biddulph.) I shall call other witnesses, Sir, who have seen them.

17,365. (Mr. Trunem, through the Court.) Can you identify on any of the photographs the bits that you have sketched?—Yes, I can; that is one piece (pointing to the photograph).

17,366. Which piece is that?—That is south of my sketch, and this is the same, at the south end, but a different view of it.

17,367. Do these represent the whole?—No; that is one piece, and this is the other piece.

17,368. This is the north end (handing another photograph to the witness)?—Yes. (The witness laid the photographs before the Court, and described them.)

17,369. (Mr. Biddulph.) These are photographs of the same pieces, see they?—Two of these are photographs of one piece, and the others are photographs of another piece.

The witness withdrew.
Examine by Mr. Biddell.

17,370. You were examined at Dundee as a witness, I think?—Yes.
17,371. You were sworn then?—Yes.
17,372. That is effacious still. Since you were examined in Dundee, have you been several times under the pier on the site of the bridge?—I have been down once since I was examined, with the harbour people.
17,373. I think that, at the time you were examined, you had not been down where the second-class carriage was found, had you?—No.
17,374. Since then have you been down at that part of the pier?—I went down to the second-class carriage.
17,375. And, I think you were the first to find the second-class carriage, were you not?—No; Fox was there before me; but I went down to see it, too, after him.
17,376. Where did you go down when you came upon the second-class carriage?—About 30 feet to the southward of No. 4 pier.
17,377. Do you recollect which of the diamond-shaped spaces it was?—It was this one here (pointing to the model).
17,378. The first one?—Yes.
17,379. Did you there find the second-class carriage?—Yes.
17,380. How was that end of the second-class carriage situated as regards the girders?—She was lying on her side.
17,381. But was it up against the pier?—No.
17,382. Was it near it?—She was lying about half-way between them, I took it to be, as near as I could judge.
17,383. (The Commissioner.) Between what?—Between the two booms.
17,384. (Mr. Biddell.) You mean as they lay upon the ground?—Yes.
17,385. Against which of the two was the wheel of the carriage?—It was not against any tie that I saw; it was the upper wheel that I saw. I could not see the lower wheel.
17,386. She was lying on her side?—She was lying on her side.
17,387. Whereabouts was the wheel?—Just about the top boom (pointing to the model).
17,387a. Of course this was lying with its side down?—With its head to the east.
17,388. Supposing that you are at the Dundee end of the bridge, is that about where the wheel was (pointing to the model), in that first diamond-shaped space?—Yes.
17,389. And near the north end of it?—Near the north end of it.
17,390. Did you pass southward along the buffer beam of the carriage?—Yes.
17,391. And was any part of the sides or roof of the carriage there then?—No, none.
17,392. Had there been any dynamite explosions at that time?—No, not then.
17,393. You got to the other end of the carriage, the south end, did you not?—I went about the distance of the wheel. I was looking for the other wheel, and I could not find it. I went about that distance, and I returned back north again.
17,394. Were the other wheels gone?—I could not find them; they were not there at all.
17,395. The southern pair of wheels were not in their place?—They were not; they were gone.
17,396. Did you find anything else at the south end of the carriage?—I found a beam on the top overlapping, as I was going along with my hands, and I took it to be a part of the other one, but it turned out to be a part of the van overlapping.
17,397. Was it resting on the top of the frame of the second-class carriage?—It was resting on the top of the frame of the second-class carriage.

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17,398. How many feet did it overlap?—Between 4 and 5 feet.
17,399. Was there much left of the van?—I did not examine the van. I did not see it. There was another diver to the northward of me, and he examined the van. He took it for the van, and he passed the remark that it was painted white.
17,400. (The Commissioner.) That was to the northward of the one you were examining?—To the southward of me. I made a mistake.
17,401. (Mr. Biddell.) Just look at this photograph of the second-class carriage (handing it to the witness)?—She was just the same when she came up.
17,402. It was very much in that condition before there had been any dynamite explosions?—It was.
17,403. And at that time there had been no dynamite used there?—No.
17,404. Was the water clear on the day you went down?—Very clear.
17,405. How did the carriage lie in the bridge; was it straightslashed, or was it slanting?—It was as a bit of an angle. The north end was canted a little east.
17,406. And the south end to the west?—And the south end to the west.
17,407. Was there a carriage in contact with it at the north end?—No.
17,408. There was a space?—There was a space.
17,409. Were you afterwards employed in the lifting of the girders?—I went into Mr. Waddell's employ on the 9th of March.
17,410. Do you recollect the portion of the girder being lifted where those carriages were?—Yes.
17,411. Did you see it before it was lifted?—Yes, I saw the carriages before it was lifted.
17,412. But I mean the portion of the girder?—Yes.
17,413. Did you see it while it was under water?—Yes, I saw the girder. I was present at the binding of it together, and putting chains under it from one boom to the other.
17,414. I do not know whether you have seen this plan: this is intended to represent the part that lay on the ground, what had been the eastern girder, and it shows the top boom gone. Do you recollect that piece coming up (handing a photograph to the witness)? Had you anything to do with binding that piece?—No, I had nothing to do with that piece.
17,415. You were not there when the girders were lifted?—Yes, I was there when we lifted the piece with the carriages, when the accident happened to the pontoon and took away this side of the carriages, and that left this part on the ground remaining, and slewed the other part to the eastward.
17,416. That is to say, you removed the portion of the girder that was above the carriages?—Yes.
17,417. That would, I believe, have been the western girder?—Yes, as the bridge stood. The lower part was left lying on the bottom, and that left the carriages clear for lifting.
17,418. (The Commissioner.) And then you lifted the carriages, did you?—We lifted the carriages singly.
17,419. (Mr. Biddell.) And then you lifted the girder after the carriages were gone?—I was not there then. I only set up the carriages, and then I went away.
17,420. Afterwards did you go down to help to attach a chain to the third-class carriage, which was the one next to the north, on the other side of the north pier?—Yes.
17,421. Did you notice the condition of that carriage when you went down?—No, I did not notice.
17,422. I mean whether it had its sides?—No, I had never seen it before.
17,423. When you did see it, did you notice whether it had sides?—No, I did not; it was on the south-west end of the railway.
17,424. Are you able to form a judgment as to how far the end of that carriage was from the second

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class carriage?—I suppose it would be about 10 or 12 feet.

17,425. Did you see that carriage lifted?—Yes.

17,426. Was there not an unsuccessful lift on the first occasion; did not that carriage, or some part of it, come to pieces as it came up?—I saw the upper end of it come to the surface, and then I went away to get myself shifted, and they told me when they put on extra.

17,427. Never mind if you did not see it yourself. You were present in the body, or rather in the 'dlying dress, but not in such a condition as to be able to observe all that was going on. You had your helmet on; I suppose?—Yes.

Examined by Mr. TRAYNER.

17,428. I suppose you made no measurement, so as to be at all accurate in your idea about the third-class carriage being 12 feet to the northward of the second-class carriage?—No; it was so near as I could guess.

17,429. You were just down once, I think, after you were examined last at Dundee?—Yes.

17,430. When you went down on that occasion, who was it that asked you to go up?—It was Mr. Lumadren and the Harbour Trustees people. I went into their employ at that time, and we went in search of bodies that day, and, owing to the water being so clear, we thought we would look at the remainder of the train.

17,431. When you found this part of the second-class carriage, you say there was some part of the third-class carriage overlapping it?—Some part of the guard's van. It turned out to be that, but I did not examine it that day to see what it was.

17,432. You were only down once, were you?—Just the once.

17,433. Did you satisfy yourself upon that occasion by your own inspection that it was the guard's van that was over the second-class carriage?—No, I did not.

17,434. Then was it what somebody else told you afterwards?—Mr. Lumadren asked me if she had spaeked wheels, and I told him she had; and that was the way they found that it was the second-class carriage.

17,435. But by your own inspection are you able to say that the guard's van was over the second-class carriage, or do you only say that from what somebody has told you since?—It was over it.

17,436. Did you see it?—I felt it. I felt the beam overlapping it.

17,437. Did you not see it?—No; the water was too muddy.

17,438. The water was clear that day?—Yes, but I only felt it with my hand, and then I turned back. I went about the distance of the wheel that day.

17,439. Having found the foremost wheel of the second-class carriage, you went back to see if you could find the after-wheels?—Yes.

17,440. You did not find them?—No.

17,441. What did you find at the south end of the second-class carriage?—Just the beam overlapping the other one.

17,442. What beam?—The buffer beam. I took it to be the end of the second-class carriage doubled up. I said, when I came up, that I thought it was a piece of herself coming up.

17,443. That would be the west side of the second-class carriage?—Yes.

17,444. Which was very much smashed?—Yes.

17,445. You thought, when you came up, that it was a part of the west side of the carriage doubled on itself. What led you to change your mind, and to think afterwards that that was a piece of the van?—When we went to lift them, me and my neighbour went down, and he had been forward to the southward of me, and during the time that I was listening a line on to the second-class carriage's after-wheel, he went on to the southward, and he went to the floor of the van, and he discovered the coupling hanging there. I came up, and I told the foreman there that we would put a chain on this one, and draw it up; and he went to take the upper one; so I put the chain on round the side of the wheel of the second-class carriage, and the buffer beam by the side of the wheel, and we hove her up, and went back at low water at night, and got the van. We hove her up then.

17,446. At the time that you went down to fix on the chain to bring up the second-class carriage, near the wheel of the second-class carriage, did you yourself go southward to see whether there was anything overlapping the second-class carriage or not?—No.

17,447. Were you down again after that, so as to be able to tell whether anything was overlapping it, or whether the carriage and the van could be lifted without your going down again?—I went down and slung the van in the evening.

17,448. That was after you had got the second-class carriage up?—Yes.

17,449. Between the time of the fastening of the chain on the second-class carriage, and the time that you went down to sling the van with another chain, you had not gone southwards to see these two carriages were lying against each other?—No.

17,450. We do not expect you to be very accurate about this groping down below; but give me, if you can, an idea whereabouts the wheel that you found was. Mr. Bidder pointed to this, and said that it was somewhere in the centre?—It would be close to here (pointing to the model). The ladder just went down beside the wheel.

17,451. Was it lying close to the side of the easternmost girder, or was it in the middle between the two girders?—It was in the middle between the two girders.

17,452. Between the east lower boom and the top?—Yes.

17,453. (Mr. TRAYNER.) It was, as near as possible, in the centre between the top and the bottom booms?—Yes.

17,454. (The Commissioner.) And lying on its side?—Yes.

17,455. (Mr. TRAYNER.) You said it was lying slanting; can you give me any idea of how near the front of the carriage was to the side of the girder?—No, I could not say.

17,456. This east girder was lying on its side?—Yes.

17,457. Was the front of the beam, the sole-plate of the carriage, lying across the girder?—Not much; it had a little cant.

17,458. A little turn to the east?—A little turn to the east.

17,459. Was it very little?—Very little. I found that the centre coupling was gone, and I turned back against the buffer again.

17,460. But the cant was very little?—Very little.

17,461. (The Commissioner.) Did you tell us that the north end of the second-class carriage was canted a little to the east?—A little to the eastward.

17,462. And the south end a little to the west?—It may have been a little, but not much.

17,463. But how did you see it; if the van was over it? I thought you said you had not gone to the van?—I never observed the van.

17,464. But you were able to observe the south end without observing the van?—When I came to this piece of wood on the top of it, I thought it was rather a log or piece of herself overlapped. I did not observe the van.

17,465. And you do not know that it is the van?—No, except that my partner and me went down in the evening, and we got her to the southward of where we got her up.

17,466. But you told us that the south end of the second-class carriage was turned a little to the west; and I want to know how it was, if the van was
lapped the second-class carriage, and you never saw the van except this piece, that you knew it was casted towards the west?  

(Mr. Bidder.) That was my statement, Sir, I think, with the witness's.  

17,467. (The Commissioner.) Were the coupling chains attached between the van and the second-class carriage?—I did not see it.  

17,468. (Colonel Yorkland.) Can you say whether the wheels that you found there were a pair of wheels or a simple single wheel?—I did not find any wheels. The two wheels were on the second-class carriage that came up, and those were all the wheels that came up.  

17,469. Do you know whether that pair of wheels was at the front of the carriage, or at the rear part?—It was at the front part.  

17,470. The leading wheels?—The leading wheels; the north-end of the carriage.  

17,471. Was the axle bent?—I did not notice.  

17,472. (Mr. Trayner.) Did you try to lift the girder in which the second-class carriage and the van were lying before you separated it?—Yes.  

17,473. You tried to lift the girder and the carriages inside?—Yes.  

17,474. When was that?—I do not remember the day.  

17,475. How long was it before the 6th of April when you got up the second-class carriage?—I think it was on the Wednesday.  

17,476. I am told it was about the 24th of March; that would be nearly a fortnight before you got up the second-class carriage; would that be near about it?—It would not be so late as that.  

17,477. You did try to get up the girder with the carriages inside some days before you got up the second-class carriage?—Yes.  

17,478. And I believe you found that you could not get it up?—We could not get it up.  

17,479. It would not come?—It would not come.  

17,480. Was dynamite then applied?—It would have come, but one of the divers cut the west boom, and that prevented it coming off the ground, as it was lying on its side.  

17,481. You mean that it was cut by dynamite?—Yes.  

17,482. And that had not been done then?—No.  

17,483. And you could not lift the girder?—We could not lift the girder.  

17,484. And some one went down again to apply a further charge of dynamite?—No.  

17,485. Was not the girder that the second-class carriage and the guard's van were in cut in with dynamite before you raised the second-class carriage?—It was cut away to the southward of the carriages.  

17,486. Perhaps this will recall it to your recollection: do you remember using a charge of dynamite on that girder, the result of which was that you blew up your own pontoon?—Yes, that was the same day that we were trying to lift the girder with the carriages in.  

17,487. That day you applied dynamite with the result that you sank the pontoon?—Yes, but that was on one of those top brackets. It never disturbed the girder with the carriages from the ground.  

17,488. Was it the top boom which was cut that day by the dynamite?—It was one of these diagonals across.  

17,489. Near what pier was the diagonal cut on the day you sank the pontoon?—Near No. 4.  

17,490. In how many diamonds, if any, from pier No. 4 was the dynamite charged?—I could not say.  

17,491. Was it near the place where the second-class carriage was lying?—I could not say.  

17,492. But you know where the second-class carriage was lying?—The pontoons had this single part away off the top of the carriages, and when they were cutting one of these struts I did not exactly see the distance between.  

17,493. You had got your separation at No. 4 pier?—The binding chains on the two booms here all broke, and this boom was not cut with dynamite before, and this part away, and left the other part all lying upon the ground.  

17,494. When your pontoon blew up it sank with its machinery, did it not?—Yes.  

17,495. Was that to the south of No. 4 pier?—Yes, but she lowered round to the eastward a little.  

17,496. Did it sink with its machinery over that girder?—No.  

17,497. How far to the east or west of the girder?—I could not say.  

17,498. Do you know whether it sank on the top of the girder or not; it would sink necessarily upon what was the uppermost part of the girder?—The pontoon went down with a part, but did not injure the carriage; it was too far east.  

17,499. I am not talking about the carriage; did the pontoon with all its machinery, having failed to lift the girder, go down upon the top of the girder?—The pontoon did not go down there.  

17,500. Where did the pontoon go down?—To the eastward of the carriages.  

17,501. Did you go down to see that yourself?—I was down at the raising of the pontoon, but not disconnecting the broken girder.  

17,502. How far to the eastward of the girder was the pontoon lying?—The girder was in between the pontoons.  

17,503. Then the pontoon was on the top of the girder, was it not?—The pontoon was resting down on the sand.  

17,504. There were two pontoons, were there?—Yes.  

17,505. And they went down, one on each side of the girder?—One remained up and one went down.  

17,506. Did it go down on the side of the girder?—To the side of the girder.  

17,507. (Mr. Bidder.) The two pontoons, as I understand, were connected by an iron girder?—Yes.  

17,508. And they were placed so that the girder to be lifted should be between them, so that they would be like two pantours on a donkey's back?—Yes.  

17,509. One of them went down?—Yes.  

17,510. It did not fall on the girder, but it fell upon the said?—Yes.  

17,511. Were you there when this portion of the strut was cut by dynamite?—I was on the pontoon deck when the thing happened.  

17,512. Do you know where it was, to be able to say whether it was within reach of the carriage?—No, I could not say that.  

17,513. Was it near the surface?—Yes, I believe it was about the surface, but I do not recollect.  

The witness withdrew.

HENRY DOWY sworn.

Examined by Mr. Bidder.  

17,514. You are a diver, I believe?—Yes.  

17,515. Were you engaged by Mr. Waddell to assist in raising the wrecked girders of the Tay Bridge?—Yes.  

17,516. I believe the first day you went down was the 6th of April?—That was the first day.

17,517. Were you working at the same time as the last witness, Thomas?—Yes, I was his mate along with him.  

17,518. Did you go down near the second-class carriage was?—Yes.  

17,519. On the same day?—On the same day; it was my first day's work.  

17,520. What was the first thing that you came to?
when you got down?—We went down about on the middle of her.

17,521. On the middle of the second-class carriage?—On the middle of the second-class carriage.

17,522. Did you go down at the same place where others went?—Near about the same, but he took the right, and I took the left, and that would give it to us.

17,523. Right and left of the boat?—Yes.

17,524. Did he rightly describe the place in his evidence?—Yes.

17,525. You came down, you say, near about the middle of the second-class carriage?—Yes.

17,526. What did you and when you got down there?—I worked myself the other way to the southward till I came to the buffers of the other carriage.

17,527. How were they situated with regard to the second-class carriage?—On the top of the others.

17,528. Are you quite sure that they were parts of another carriage?—Most decidedly. I was looking for the end of the one I was on, but when I came to get the buffer over my head I knew I had got to another one.

17,529. Did you try to ascertain whether they were attached or not?—Yes, that was my first object, to see if they were clear.

17,530. What was the result of your search?—They were disconnected.

17,531. The couplings were broken, were they?—Yes.

17,532. Did you after that go and assist Thomas in sling the chains?—Yes, I came up to report to Mr. Armit that I had just left the carriage down there.

17,533. Did you report that the one carriage was on the top of the other?—Yes.

17,534. Did you then proceed to make the slings fast to the second-class carriage?—Yes.

17,535. For that purpose did you go to the north end of the second-class carriage?—I left my line fast again; I got one out to take the other away. I proposed to take the south first. Thomas had got his line ready to take that end; he proposed to take that first, so I said: "We will leave the one that is on the top till the last." So we had the second-class carriage up first.

17,536. For that purpose did you go to the north end of the second-class carriage?—After I came up we both went down together, and slung the second-class carriage.

17,537. You put the chain on?—Yes.

17,538. Did you notice whether at the north end of the second-class carriage there was another carriage or not?—No, there was nothing round about there when I was there.

17,539. No other carriage in contact with it?—Not so close as where I was.

17,540. Afterwards, I believe, you went down again with the line that you had fastened, and lifted the van?—Yes.

17,541. Did you make fast to the thing which you had found riding on the second-class carriage?—That is it.

17,542. All that you got to the surface?—Yes, before we made fast.

17,543. Was it long afterwards?—Yes, certainly; it was then got to the surface.

17,544. When it was lifted up did you see that it was the van?—Yes.

17,545. There was no doubt about it?—No doubt it was the van.

17,546. What then? (hanging a photograph to the witness) the condition in which it was?—Yes.

17,547. That was the thing that was lifted?—Yes, that was the thing that was lifted—that was the thing that was lying on the top.

17,548. You are perfectly certain that that is the same thing that you found riding on the top of the second-class carriage?—That is the same thing.

17,549. Are you able to speak as to what the state of the girders was underneath those carriages?—No, I never touched the girders.

Examined by Mr. Trayner.

17,550. Before you took the second-class carriage and the van out of the girders, did you not and your fellow workman to try to raise the girders with the carriages inside?—I was not there at the time. This was my first day's work, the day the carriages were raised.

17,551. Did you say that when you got to the south end of the second-class carriage, or the sole-plate of the second-class carriage, you found the buffers of another carriage above your head?—Yes; when I say above my head, it was because I was crawling along on the beams.

17,552. On the girders?—No, not the girders, on the second-class carriage.

17,553. Was the water clear—could you see well?—No, it was dark.

17,554. Was that the same day that Thomas went down?—The 6th of April was my first day; the water was quite dark.

17,555. But you felt the buffer?—Yes, I felt the buffer; you could see nothing; you could only feel.

17,556. Have you any opinion as to how far the buffer of the van had overlapped the second-class carriage sole-plate?—I reckoned about four feet or as near as I could judge, for I did not stop any great time there. As soon as I came to the buffer my first object was to put my hand across to see that the couplings were clear.

17,557. Did you find any difficulty in raising the second-class carriage from under this?—None at all.

17,558. It came up quite easily?—Quite easily. I suppose it hardly shook the other one as it came out.

17,559. Then the other one was resting upon something else, I suppose?—She was resting on her end, because when we went to sling her on she was not enough to raise the buffers, and because the girders were so far away that we could not reach to move the chain round.

17,560. Have you any opinion as to how far the under side of the buffer would be above the sole-plate of the second-class carriage that you were crawling along?—I should say about two and a half feet—that is a rough guess.

17,561. You could get well in under it?—I could put my hand under it, but I did not want to get under it because I had the coupling of the carriage on the top.

17,562. And you had your pipes attached to your helmet?—Yes.

17,563. I suppose you did not want to get under anything that you could avoid?—No.

17,564. (The Commissioner.) Supposing that these two books that I have in my hand are the platform of the second-class carriage and the platform of the van, they were both on their sides, were they not?—Yes (the witness described the position of the carriages). I came along the beams until I found the buffer. I found the couplings were clear, and that was all I required.

17,565. (Colonel Yolland.) Were they coupled together?—No, they were clear.

17,566. (The Commissioner.) But how did you take up one with the other over it?—With the drift, and that did not disturb it. She was not bearing her whole weight on that, because it struck perhaps on the girders in the ground. But when I came along I found the buffer just over my head; that told me there was another carriage on the top of that, and I came up and told Mr. Armit that there was another carriage on the top of that, so we took that first.

17,567. (Colonel Yolland.) Were there any side chains coupled together?—All clear.

17,568. (Mr. Barron.) What was the guard's brake reeling upon to prevent its going down to the ground?—Part of it was reeling upon the ground.

17,569. You say the after part was reeling on the
Examine by Mr. Bidder.

17,573. Are you a diver?--Yes.
17,574. Were you engaged by Mr. Waddell on the west bank of the Tay Bridge?--Yes.
17,575. I believe you have had a great deal of experience at shipwrecks?--Yes, about 16 years.
17,576. You were employed on the "Eurydice," were you not, and the "Grosser Kurfurt"?--Yes.
17,577. Were you in charge of the dynamite that was used?--I was superintending it when Mr. Turner was not there.
17,578. Had you any instructions as to the way in which you were to use dynamite?--Not to use any more than was really necessary for the cutting of the boom, and so forth.
17,579. Small charges?--Small charges that would do the required execution.
17,580. Did you yourself examine any of the carriages before they were lifted?--Not officially.
17,581. Never mind whether you did it semi-officially or unofficially--did you do it?--I went over them several times, but the observations I made were only for my own use.
17,582. Did you see the second-class carriage and the van before they were lifted?--Yes.
17,583. Did you see whether the second-class carriage was on the top of the van or not?--I could not say. I was running over them to go to some other work at the time, looking for booms.
17,584. Did you notice whether the second-class carriage and the third-class carriage in front of it were together, or whether there was a space between them?--There was a space of about 10 feet between them, about the width of the pier I should think.
17,585. Before the third-class carriage was lifted, did you notice whether it had got its eastern side or not?--Yes, it had its eastern side when I saw it.
17,586. As represented in the photographs, after lifting it has not got the eastern side?--No, I am aware of that.
17,587. Can you tell us how that is?--Its own weight would not carry it up; it broke in the lifting. The action of the water in raising it would have made more effect upon it than any dynamite would have upon it. The action of the water would take it off as it was lifted. It was like a wing. There is a great leverage coming through the water as you have it up.
17,588. Did you notice the position of the rear end of that third-class carriage as regards No. 4 or No. 5 girder?--The northermmost end of the carriage was lying on what was then the east side.
17,589. I am speaking now of the third-class carriage in front of the second-class carriage--So am I. The wheels of the northermmost end of the carriage was lying in an angle to the east side as it that lay, and the rear end of the same carriage had an inclination towards the pier.
17,590. Which girder was it in?--Between No. 4 and No. 5, the first part of No. 5.
17,591. Were the rear wheels of it in No. 4 or in No. 5?--The northermmost wheel would be just touching abreast of where she stood over the pier. That would have been the right-hand wheel of the after-wheels.
17,592. Do you recollect the attempt being made to lift the portion of No. 4 girder with the second-class carriage and the van in it?--Yes.
17,593. That was a failure, as we have heard, owing to its not having been properly separated from another part of the wreck?--Yes, it was.
17,594. And I think you used a charge of dynamite in cutting some strut or tie that required to be severed, did you not?--I was not there. I went aboard the tug during that time.
17,595. Were you there when the hole was broken in one of the pontoons?--I was not on the pontoon.
17,596. You saw the thing happen. How did it occur?--Through a piece of iron striking the bottom of the pontoon, I should imagine.
17,597. The pontoon sank, as the last witness told us?--Yes.
17,598. Did it sink on the girder or on the sand?--It sank on the sand. I know, by the pieces I lifted afterwards, where the pontoon sank, because she had the pieces attached to her where she dropped them.
17,599. I believe you went down the next day, did you not, to see what prevented the girder coming up?--Yes.
17,600. What did you find?--I found that a pair of rails had not been cut, part of the east boom when it was upright.
17,601. It ought to have been severed?--It ought to have been severed.
17,602. Can you tell me which of those separations had been done with dynamite, for the purpose of raising the boom? This is the west part of the girder as it lay (pointing to the plan), and that is the east part; and this is where the second-class carriage was, and the van here (pointing to the plan). Can you tell me which had been separated by dynamite, if any?--The west boom was not severed, not to the north end. There was a fracture in it, but it was not severed anything like it ought to have been for coming away. The fracture was not in the place where the dynamite should have been put according to rule.
17,603. Are you speaking of the end of it where it joined on to the next girder?--I was speaking of close up to the pier.
17,604. I am talking of No. 4?--Yes, I am speaking of No. 4.
17,605. Underneath the second-class carriages and the van?--Yes.
17,606. Were any parts of the west or east booms that were underneath the girder cut by dynamite before you got them up?--I could not say; there was a fracture, but I could not say whether it was done by dynamite; it did not look like it. It may have been struck by a column or something of that sort.
17,607. Was that near the end?--Yes.
17,608. Whereabouts on the model?--About here (pointing to the model).
17,609. Was this cut into pieces to lift?--It was cut into sections from one pier to the other, in the first place, from No. 3 to No. 4.
17,610. You tried to lift them as a whole?--Yes.
17,611. (The Commissioner.) But you found that you could not do it?--No, we could not. The pontoons pulled the top part into pieces.
17,612. (Mr. Bidder.) You mean the top girder?--Yes, the top part was pulled over to the eastward, so that she rested as it were on the pier and eventually trying to clear it with another small shot, it made a hole in her and she lay away more to the eastward.
17,618. Was she fast on the eastern part of the girder? — Yes.

17,619. Whereabouts was she fast? — There were eight chains altogether right along, and the distance would be about eight feet, and then it goes again perhaps for 24 feet before you come to another chain. Then there are two again.

17,620. Were they all fast to the eastern boom of the lower girder? — They were all fast, but we had chains from the boom to the pontoons, what we call binder chains. Previously to our lifting we put a binding chain from the boom to the next one, to bring the lower boom up with this (pointing to the model).

17,621. You are pointing to a place where there is no boom (the model was turned sideways). If you imagine the structure lying on the bed of the river, instead of standing on the column, how was the pontoon fastened, by chains? — To the upper girder.

17,622. Did the pontoon ever tear away the lower girder? — No. Previously to lifting we put chains from this part to that part to strengthen it. This side did not require it, because they are all strong sleepers. This side required chains from there to there as a binder (pointing to the model).

17,623. And you put chains so that the lower girder should follow it? — Yes.

17,624. But you were unable to do that? — Yes.

17,625. And the pontoons were fast to that upper girder, and broke away portions of it? — Yes.

17,626. Did you go down when you were trying to lift the lower part with the carriages on it to see what had prevented the girders coming away? — Yes. 17,627. And what did you find? — This boom had not been cut through (pointing to the model).

17,628. How did that prevent its coming up? — Because there was a continuation on to No. 5.

17,629. It had not been severed from No. 6? — No.

17,630. Were there any signs of any shots of dynamite having been fired near the boom? — Yes, there was a fracture.

17,631. Whereabouts? — A little farther to the southward than the proper place where it should have been.

17,632. You mean the proper place for dividing the two booms? — Yes.

17,633. How far from the end? — It would be about this position, I should think (describing the same).

17,634. You were not engaged in lifting the second-class carriage, I think? — No.

17,635. Did you afterwards go down to look for the missing wheels? — Yes.

17,636. Did you find them? — Yes.

17,637. Where did you find them? — About 40 or 45 feet, I suppose, south of No. 4 pier.

17,638. (Mr. Biddre.) Those are the wheels of the second-class carriage? — Yes.

17,639. (Mr. Biddre.) Was there anything remarkable about the position of them? — They were standing on their ends vertically, that is to say, one wheel was on the ground, and the other wheel was up.

17,640. (Colonel Y. C.) They were standing on the end of the axle? — Yes.

17,641. (The Commissioner.) On the side of the wheel? — Yes.

17,642. (Mr. Biddre.) Did you also lift portions of No. 4 girder afterwards, after the carriages had gone? — Yes, I lifted the different fragments of No. 4 girder.

17,643. Did you notice anything with regard to the position of the rails and the permanent way; were the rails there on the way-beams? — Yes.

17,644. How about the planking? — The planking was all gone. I never saw a piece of planking in the vicinity of No. 4 pier.

17,645. As regards the condition of the rails, were they still straight? — There was one pair of rails I noticed bent, near No. 4 pier.

17,646. And I think some of the chairs were broken? — Some of the chairs were broken; just the bolts were left, where they fasten the chairs.

17,647. Did you look at any of the photographs which have been shown in the photographs, and in this drawing? — Yes, I slung that by myself.

17,648. You went down and slung it? — Yes.

17,649. You see that it is broken in various parts? — Yes.

17,650. Was that done by dynamite? — No, I should say not; dynamite was fired near on this end.

17,651. Will you explain why you say that these fractures were not done by dynamite? — Because this part they have up free from this end of the strut. This is a strong strut, nearly as strong as the boom. This was detached and I could not have hoist it up very well without noticing it; it would have come a good strain.

17,652. You superintended the firing of the dynamite that was used, as I understand? — Not on this particular girder. I was putting on chains that day.

17,653. Do you recollect that portion being got up (handing another photograph to the witness)? — Yes.

17,654. were those fractures, in your judgment and according to your knowledge, made by dynamite or not? — They could not have been made by dynamite, because there are shorter lengths than what we cut with dynamite. It is impossible for it to have been all dynamite. Our dynamite cuts would have been nearly the length of a span from each other.

17,655. Which way was the uppermost did you lift that portion which is the bottom boom; did it come up as it is in the photographs? — No, it was lying on its side; it was half buried in the sand. I couldn't get the chaim round the boom itself, so I put it round this ring strut, and that brought it up and everything that was in it. If I had had my own way I should have put it into the boom, if I could have got round it, but I could not get round there.

Examined by Mr. Travers.

17,656. You were trying, with other workmen, to raise the girder between No. 5 and No. 4 pier? — Yes.

17,657. And you had two pontoons floating near the site of it, with, I suppose, very powerful machinery? — Yes.

17,658. Your purpose was to lift the girder from pier to pier, and all that was in it, without breaking it at all? — Yes, without breaking it.

17,659. How long did you strive with such machinery as you had to raise the girder before you found that you must use dynamite? — We were all night. We finished attaching the chains at about true o'clock on the first evening, that was on a rising tide, and it was the next afternoon before the pontoon sank.

17,660. Then you were pulling at it for something like 24 hours before you found that you must go down and cut it with dynamite? — Yes, pretty nearly.

17,661. Suppose that in 24 hours you gave it a good deal of straining? — Yes.

17,662. No doubt as much as you could? — Yes; we were trying to raise it, and we gave it all the power we could.

17,663. You had steamers towing at it? — Yes.

17,664. And you had anchors attached to it? — Yes; we had anchors attached to all the pontoons in position.

17,665. But all the power that you could bring to bear upon that girder was brought to bear upon it, with a view of raising and shifting it? — Yes, with a view to towing it away.

17,666. Having tried so long ineffectually, I understand that you went down to the north of No. 4 pier to cut away something which you found was still connected? — We did not know what was the cause of her holding. The little dynamite that was fired was got with a view to cut it away and take this top part over.

17,667. Did you want to separate the two sides of the girder? — We wanted to have the lower beams
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17,653. Did you then put in the dynamite in such a position as to effect that purpose, namely, to separate the one side of the girder from the other?—We did not separate them, but that was the purpose.

17,654. If you had done that, and had hauled up the girder that was the uppermost of the two, would you not have had to pull away sleepers and railway and permanent way, and everything else?—We should have got away with all we could have held on to, there is no doubt.

17,655. And even before you put in the dynamite I understand that you had chains so fastened to the lower boom on the west side that you were really 'raking' at the permanent way?—We pulled so much that we broke almost all the chains that had been put on to assist the lower part.

17,656. Did any of your chains which were attached to the other side give way?—We had no chains. As I explained just now, these are very strong iron sleepers, and no chains were required.

17,657. You were trusting to the strength of the permanent way?—Yes.

17,658. The two booms that were westward in the fallen position?—Yes.

17,659. When you were straining at this for 24 hours, were you pulling the upper girders in such a position as to have any effect upon what had been the permanent way in distorting it?—Very little. This permanent way by this boom had come into so many pieces that we could not tell which was which.

17,660. That had broken away in the course of your straining?—Yes, that was the result of these pieces which you see.

17,661. Had these ties between the booms, what had been the roof of the way, given way too, or many of them?—They were nearly all gone. I could not swear that they were all gone, but I know that the majority of them had gone; I heard them break one after another.

17,662. (The Commissioner.) Whist you were pulling at them?—Yes; that was on account of this part not coming away.

17,663. (Mr. Trager.) When you found that there was something keeping it from rising, where was it that you applied the dynamite; was it to the south or to the north of No. 4 pier?—To the south.

17,664. How far to the south of No. 4 pier?—I could not tell you.

17,665. Had you been down before that and seen the position of the second-class carriage?—Only just from a slight observation, not to make examinations.

17,666. You do not know how far to the south it was lying?—No; of course I was over all the carriages when I was putting on the chains, kicking them with my legs, and so on.

17,667. A good deal of the third-class carriage is left, I believe?—Yes.

17,668. You may the east side of it came away as you were raising it?—Yes.

17,669. Had it been very much shattered?—No, I see the portion of this carriage up intact afterwards, the east side of it.

17,670. The east side broke away in a piece?—Yes, as it was being lifted.

17,671. Was it in very much the same condition as this side?—It was more whole. That was after we had fired the dynamite all around it. The dynamite made no material difference to that carriage.

17,672. How do you know?—Because I was there at the last, after we fired the shots, and the carriage was in the same condition as it was when I first saw it before the dynamite was fired, and I saw the whole of the east part of it afterwards, and it was intact.

Re-examined by Mr. Bidder.

17,673. When you were pulling and trying to lift, and certain things gave way, as I understand, you were fast to the upper girder?—Yes.

17,674. You never succeeded in moving the lower girder?—No, we never altered its position at all; it was lying when I went to examine it again in its original line.

17,675. And, in your judgment, had these pullings at the upper girder, as the wreck lay, altered at all the position of the lower girder that was under the carriages?—It may have lifted up a little way, but it went down again in the same line when the pontoons had done pulling of it.

17,676. Do you believe that your pullings of the upper girder caused the fracture of the lower one underneath the carriages?—It is just possible that it may have done.

17,677. Do you think it is likely?—It must have had some effect upon it, I think.

17,678. That upper girder was afterwards lifted and carried away separately, was it not?—It was all lifted in pieces, as you see some of them.

17,679. These are the pieces of the other one?—These are some of the portions that I lifted with the upper part. There are many other pieces besides these that you have had photographed that were landed at Tarport and other places.

(The Commissioner.) Your impression is that these pieces were pieces of the upper girder?

(Mr. Bidder.) I think you are mistaken about that.

(The Witness.) The other piece that you see is a part of the west boom as she lay along the bottom.

17,690. (Mr. Bidder.) The boom that was under-neath, as she lay along this bottom, had been cut off?—Yes.

17,691. (The Commissioner.) That would be the east one?—It would be the east when she was upright. What was the east boom when she was upright, would become this boom when she fell down.

17,692. The eastern girder lay down at the bottom of the river; you know that?—Yes, of course.

17,693. And is that the one that you have been saying was buried in the sand?—Yes.

17,694. And the other boom at the other end, how was that?—That had buried also?—No, that was lying more clear, because you were able to discover it quickly and put your chains round it without going under the boom.

17,695. But these were the pieces that you raised, were they?—That was the girder that you raised in pieces?—Yes; I recognise that piece there, as this piece on the east, the east boom.

17,696. In your opinion the strain that you brought to bear must have destroyed that lower girder?—Yes, it must have come away altogether if this part had been cut.

17,697. (Colonel Yolland.) Did you break that lower boom of the undermost one in lifting it?—We broke it in lifting it up.

17,698. Had it been broken at all either over the pier or farther south by dynamite when you attempted to lift it?—As I have already said, there was a slight fracture. I did not observe whether it broke in that fracture or not. I broke one on Friday in the same way.

17,699. Did you lift the top girder before you attempted to raise the lower one?—Yes.

17,700. Did you attempt to raise the carriages before you lifted the top girders?—No, the object was to raise the carriages in the girders intact.

17,701. You first lifted the top girder?—Yes, the left one or the westemmost one.

17,702. Then the carriages, and then the girders that were undermost, was that the order?—Yes.

17,703. In pieces?—Yes.

17,704. And you did not know whether the pieces that you hauled up had been broken by dynamite or had been broken originally?—I am sure they were not broken by dynamite, because they were too short a length.

17,705. (The Commissioner.) But you do not know whether that had been broken by your straining at it with the pontoons?—That is the most suggestive.

17,706. (Mr. Bartlow.) Was the girder as it lay at
TWENTY-FIRST DAY.

Tuesday, May 4th, 1880.

Further examined by Mr. Bidder.

17,709. Have you heard the statement which I have just made to the Court?—Yes, I quite confirm it.

17,710. Is it a fact that at the time of the contract being made with Messrs. Hopkins, Gilkes, and Company, you had no interest whatever in that firm?—None whatever, and never had; I knew nothing about my brother's interest in it; I knew he had an interest, but I knew nothing of the extent of it.

17,711. Am I right in stating that the only interest you ever acquired in the firm was that which came to you under the will of your brother, who died in the year 1876?—That was all.

(The Commissioner, to Mr. Webster.) Have you any questions to put to Sir Thomas Bouch?

(Mr. Webster.) No, Sir.

(Mr. Bidder.) Nor have I.

17,712. (The Commissioner.) I understood Mr. Bidder to say that you knew nothing of Messrs. Hopkins, Gilkes, and Company until you entered into this contract. I do not know whether I understood him rightly?—No, they had done work for me before; they did the Beoch and the Despide.

Sir Thomas Bouch called again.

(Mr. Bidder.) What I said was that Sir Thomas Bouch had only been inside their works.

17,713. (The Commissioner.) But you knew Messrs. Hopkins, Gilkes, and Company, perfectly well?—Yes.

17,714. Was your brother an engineer?—Yes.

17,715. Was he in partnership with you?—No, he was a mechanical engineer.

17,716. Since that, I think, the company have failed, have not they?—They have failed, and there has been an attempt at reconstruction.

17,717. And in that way you have lost a considerable sum of money?—A very large sum of money.

17,718. That is, I suppose, the property of the trustees; you were not universal legatees?—No; I was not universal legatee, but that, I think, was in my legacy, the shares in Messrs. Hopkins, Gilkes, and Company.

17,719. That was in your legacy?—Yes, that was done so, because there was so much liability about it.

17,720. Can you tell me what the interest of your brother was in the firm of Messrs. Hopkins, Gilkes, and Company?—I think he would have something about 35,000l. in it, with a liability for calls for some 13,000l. more.
17,721. And of that you have lost something like 18,000?—Yes, but that was not the alarming thing to me, it was the obligation to the bank jointly with four other gentlemen for 100,000, and three of those other gentlemen, I think, went into liquidation, or at all events, were unable to meet their obligation when the works failed, and I personally, along with another gentleman, became liable to the bank, and, of course, they would not let me out.

The witness withdrew.

Mr. JAMES WADDELL sworn.

Examined by Mr. Biddis.

17,722. Are you in the employment of Messrs. John Waddell?—Yes.

17,723. I believe you have been engaged for some years in works of railway construction?—Yes, I was on the Tay Bridge for a few years while it was under construction.

17,724. Have you assisted in the work of recovering portions of the wreck of the Tay Bridge?—I have acted as assistant to Mr. Armit.

17,725. Were you on board the vessel called the “Henry” which was employed in lifting portions of No. 4 girder?—I have been on board the “Henry” once while employed in lifting No. 4 girder.

17,726. Were you there when the portions which had been photographed were lifted?—One of the portions.

17,727. The portion containing a piece of the bottom trough of the girder?—Yes, containing a piece of the bottom boom.

17,728. And you saw it lifted and conveyed to the tidal basin where it was photographed?—Yes, to the tidal harbour in Dundee.

17,729. When it got there did you go in a small boat and examine it?—I did.

17,730. And amongst other things in the course of your examination did you examine the inside of the trough of the boom?—I did.

17,731. Did you find anything there?—I found a part of the guard plate of a carriage.

17,732. Have you got that?—It is in Court somewhere. (The Commissioner.) What does this mean by a guard-plate?

(The Witness.) The guard plate is what the axle-box is set into.

17,733. (Mr. Biddis.) Is it the front plate in front of the axle-box?—Yes, the horn plate.

17,734. Will you just point out on one of those photographs?—This is the part of the guard plate or the horn of the guard plate.

17,735. Is it that the thing you found in the trough of the boom?—That is what I found in the trough of the boom.

17,736. I do not quite understand where that goes in the carriage. (The witness pointed it out on the photograph.)

17,737. It goes down each side of the axle-box?—Yes.

(The Commissioner.) Mr. Barlow calls them horn plates.

(The Witness.) That is so.

17,738. (Mr. Biddis.) I do not know whether you are able to tell us which of the carriages it belonged to?—The second-class carriage.

17,739. (The Commissioner.) How do you know that?—Because part was fitted on, and it exactly fitted into the broken part of the second-class carriage.

17,740. Did you do that?—No, the foreman who was here along with Mr. Armit. I did not fit it on with my own hand.

17,741. (Mr. Biddis.) Did you see it fitted on?—Yes, but I did not do the action, so I cannot say that I did it.

17,742. But you saw it done?—Yes.

17,743. And it fitted?—Yes.

17,744. Immediately after that, did another man, John Robertson, was with you climb up the boom, and examine other parts of the boom?—Yes, the way the boom was hanging from the “Henry,” the one end was pretty well up in the air, and he climbed up the boom a little bit farther and found part of the axle-box, and he handed it to me—two parts of the axle-box.

17,745. Do you produce those also?—Yes, they are in Court here to (producing the same).

17,746. You could not fit those I suppose, because the whole thing was gone?—This piece belongs into here.

17,747. Do they fit to the horn plate?—Yes, this fits to the horn plate; this is the part that fits in here; this is the slide worn with working up and down.

17,748. (Mr. Barlow.) That held the axle-box?—Yes.

17,749. (Mr. Biddis.) Will you just take that photograph in your hand, I think that is a photograph of the trough in which you and Robertson found these fragments, is it not?—This is the one; I see more of it here than what I saw in the water at the time I found it; the lower end here was down in the water.

17,750. It was lower tide when the photograph was taken?—Yes.

17,751. The vessel was aground, I think?—Yes.

17,752. I want you to mark, if you can, upon that photograph whereabouts in the trough you found this horn-plate?—(Mr. Balfour.) There is one marked already.

17,753. (Mr. Biddis.) Will you let me see it, if you please.

17,754. (Mr. Traynor.) These were initiated by Mr. Meek yesterday (handing the same to Mr. Biddis).

17,755. (Mr. Webster.) Is the place marked where he found the axle-box?

17,756. (Mr. Traynor.) No.

17,757. (Mr. Biddis, to Witness.) Will you take that photograph and just mark, if you will, in red pen unless on it where you found the guard plate, and where Robertson took out the axle-box (the witness did so).

17,758. I do not know whether there was anything else found by you?—That was all; there was plenty of glass in the trough of the boom.

17,759. Did you find glass in the trough of the boom?—Any amount of glass.

17,760. (Mr. Traynor.) I have no questions to ask you.

(Mr. Balfour.) Nor have I.

The witness withdrew.

John Robertson sworn.

Examined by Mr. Biddis.

17,757. Did you climb up the boom after he had found the piece of the guard plate?—Yes.

17,758. Did you find anything in the boom?—Yes, I found pieces of the grease box.

17,759. Then you handed them to the last witness?—Yes.

17,760. Those are the pieces which have been produced in Court?—Yes.
17,761: Did you afterwards yourself try the guard-plate upon the second-class carriage to see if it fitted?—I was there when it was tried.

17,762: Did it fit?—Yes.

17,763: Have you seen any portions of the wreck of that girder which has been brought ashore since, still more recently than the portion which has been photographs?—No.

17,764: Was there a strut brought ashore?—Yes.

17,765: One of those channel struts?—Yes, one of those (pointing to the model)—one of those towards the centre.

17,766: Do you know which one it was?—I think, as far as I could make out from where it was taken up, it would be No. 5 from the end.

17,767: From the north end?—From the north end or from the south end, I believe it would be very near in the centre.

(Mr. Bartlow.) One of the central standards.

(Mr. Webster.) One of the central cross ones.

17,768. (Mr. Bidder.) Had that strut any marks upon it?—Yes.

17,769. Of what character?—It had been struck at the south side—the angle iron and covering-plate were all turned up and burst in three or four places, and the web of the strut was all broken.

17,770. You mean that the angle-iron had been bent straight?—It had been struck at the side; the angle-iron was turned out straight, and it was all split and the web of the strut broken.

17,771: If I understand you, that being the shape of the strut or of the section, this portion on the rear side of the strut had been turned out so (describing)?—Yes.

(Mr. Bartlow.) Of which girder is he now speaking?

(Mr. Bidder.) No. 4 girder.

(Mr. Bartlow.) The girder in which the break was found.

(Mr. Bidder.) No., No. 4 girder.

(The Commissioner.) The one in which the van was?

(Mr. Bidder.) Yes.

(The Commissioner.) Is it the same girder on which evidence was given yesterday?

17,772. (Mr. Bidder.) Yes, the same girder. (To the witness) What reason have you for saying it was the fifth strut?—From it being in the centre of the girder—in the centre portion.

17,773: How do you know that it was in the central portion?—You find that it has a strut on both sides of it with ties.

17,774: Was it a portion of that which was a double strut?—Yes.

17,775. (Mr. Trayer.) That girder was taken up in how many different pieces?—I could hardly say.

17,776. (Mr. Bidder.) There is one other matter that I wish to ask you about before Mr. Trayer commences his examination. Did you afterwards go and examine, with the last witnesses, No. 5 girder?—Yes.

17,777: That is the girder north of this?—Yes.

17,778. It was lying on West Ferry Beach?—Yes.

17,779. And did you look at the wrought-iron tie-bars which are bolted to the permanent way beams?—Yes.

17,780. I think there are tie-bars every 18 feet?—About that, about 17 or 18 feet.

17,781. (Mr. Bidder.) I may just mention that they were put in at the suggestion of General Hutchinson, in order to keep the gauge accurate. (To the witness) They were bars of flat iron about 2½ inches or 3 inches?—Six inches by half an inch.

17,782: Did you find any marks upon any of those tie-bars?—Yes.

17,783. (Mr. Bidder.) I may just point the attention of the Court to this, inasmuch as it is new matter to me; and it will be new matter to the Court, because it indicates to a certain extent that the carriage in front of the van had also left the rails.

17,784: (To the witness.) Have you got some of those tie-bars here?—Yes, two of them.

17,785: Just produce them—one of them will show a very distinct indentation. Do you find upon two or three of those tie-bars marks as if the wheel of a carriage had been upon them?

(Mr. Trayer.) I object to that way of putting the question. Yes, the witnesses will describe the marks that will be the proper way for him to give his evidence.

(Mr. Bidder.) I will do better than describe the marks, I will bring the tie-bars themselves. (Two tie-bars were produced.)

(Mr. Bidder.) There is the mark of a flange on one of those tie-bars; will you point it out to the Court. (The witness pointed it out.)

17,786. Those were found in the fifth girder, I believe?—Yes.

Examined by Mr. Trayer.

17,786. I asked you whether the fourth girder, between the piers Nos. 3 and 4, was in several pieces?—Yes, that was so.

17,787: Can you tell me how many?—No.

17,788: Do you know that it was separated and broken up before you raised it? Do you know how it was broken up?—Part of it was broken up at the end. They made an attempt to cut it and lift it.

17,789. With dynamite?—Yes; one part of the junction was cut with dynamite.

17,790. But how was the girder itself, from pier to pier, broken into bits?—I do not know.

17,791. You spoke about a lattice bar in the centre of the pier, upon which you saw certain marks. Was there a covering-plate at that particular piece on the strut or tie. A cover-plate riveted on to it?—Yes, there was the web of the strut and then angle-irons on each side and a cover plate on the outside; both outside and in.

17,792: Were those marks that you saw on the covering plate?—The covering plate was turned down altogether along with the angle-iron.

17,793: That was a covering-plate that had been rivetted to the iron?—Yes, part of the strut.

17,794: It was rivetted on to the struts?—Yes, this part here (pointing to the model).

17,795: The covering-plate which you say had been forced up in some way had been originally rivetted down upon the strut itself?—It is a part of the strut.

17,796: Just try and follow me. The strut was two cross-bars?—Yes.

17,797: Was not there a covering-plate outside the strut itself?—No, it is not at that; it is lower down towards the boom.

17,798: Then it was the double strut, one part of the strut was forced edgeway and the other part was as it originally stood?—Yes.

17,799: Was that bit that was turned edgeway broken at either end, or was it just a great twist in the strut?—It was broken where the mark was on it.

17,800. (Col. Foolmad.) Broken from the boom?—No, it was on the boom—it was not detached from the boom.

17,801. (Mr. Trayer.) It was not detached from the boom, but it was itself severed and broken through?—No, it was not broken through—the web was broken, and the inside was partly split.

17,802. I am not sure that I understand you yet. Will you look at the photographs?—You see inside of that is struck there, and it turned that up, the whole of it, and broke the centre web.

17,803: It turned up the edging?—It turned it up; it turned back the whole of it, and straightened out the angle-iron.

17,804: Was it the only one of those struts that you found marked in the same way?—Yes.

17,805. Do you know where the guard's van was found?—I did not see it lifted, I was not present.
17,806. Can you tell me what was the thickness of the angle-iron that had been flattened out?—I could not say exactly, but near to about three-eighths or half an inch.

(Mr. Barlow.) Can you tell us which way upwards these two pieces were found?—Place them in their proper position. (The witness placed one of the bars in position.)

(The Witness.) That was placed so; this is the east side, and that is the west side.

17,807. (Col. Yolland.) This went through the longitudinal beam?—Yes.

17,808. Was it bolted through these holes?—Yes, the spikes had been partly drawn.

17,809. But these bars went through the longitudinal beam to the cross bearers underneath?—No.

17,810. They went through the longitudinal beams, but not into the cross bearers; had they nuts underneath?—No, they were not bolted, they were simply spiked the same as railway sleepers.

(Mr. Barlow.) Now will you put the other one in position? (The witness did so.)

17,811. (Mr. Barlow.) The curious thing is that one of them seems to be bent downwards and the other bent upwards; which is the east, and which is the west?—This is the west side, and that is the east.

17,812. (The Commissioner.) Where is the mark?—There are three marks on this.

17,813. On the under side or the upper side?—One on the upper side and two underneath (pointing them out). This looks as if the flange had struck it, there is one here and one here (pointing out the same). 17,814. Those are underneath?—Yes.

17,815. How would the flange of the wheel get underneath?—If the wheel was on the rail it would slide down, underneath, and it would smash through the planking; it was bound to go underneath because the beam is on the top of the way-beams.

17,816. (Mr. Bidder.) You have worked on the railway for a good many years?—Yes.

17,817. Can you tell me this, have you seen cases where the after carriages of a train have gone off the line?—Often.

17,818. What effect has that had upon the carriages in front of them?—If they are thrown any distance it very often throws them off along with them.

17,819. In what way?—The couplings being tight, if a hind carriage goes off the line it gets what are called buffer locked with the carriage before it, and it has a tendency to throw the carriage in front of it off to the rear.

17,820. What do you mean by buffer locked?—It is supposed that the couplings of the carriages of a train are screwed close up so as to save jerking in starting and stopping, then when one carriage in the rear goes off the road it is bound to go off on the same level as the carriage that is in front, and then the buffer would get under the one in front and would have a tendency to throw it off.

17,821. You say you have seen cases where the fore carriage has been thrown off in that way?—Yes.

17,822. (Mr. Trayer.) When two or three of the hind carriages are thrown off the rails what effect has that upon the rails themselves?—It depends upon how they off.

17,823. Take it that they go off any way you like, if they go off they fall over to the outside, do they not?—Yes.

17,824. Supposing that to happen what effect has that upon the rail?—If it was common permanent way to see the rails marked.

17,825. Would it have some marks upon the rail too?—Occasionally.

17,826. Has it not the effect of bearing up the rails?—Yes, it bears them up upon a common permanent way.

17,827. Upon a common permanent way the tendency is to bear up the rails?—Yes.

17,828. If you were going to inspect a piece of railway were you had been told that the carriages had gone off the line, in what condition would you expect to find the rail at that particular place?—I would look first to see how the railway was laid down, what the sleepers were.

17,829. What difference would different kinds of permanent way make?—If it was cross-sleepers I would look for flange marks on the sleepers and the chairs.

17,830. And if they were not cross-sleepers what would you expect to find?—I would expect to find very little marks on them.

17,831. That is to say if the sleepers were longitudinal instead of transverse?—Yes.

17,832. In either case would you not find marks upon the rails themselves?—It is quite possible you might.

17,833. You would expect to find them, would not you?—Sometimes.

17,834. Not so much in the case of longitudinal as in the case of transverse sleepers?—Certainly not.

17,835. But in both cases if there had been some violent action which threw a carriage off the rail, you would expect to find naturally some marks upon the rail itself in that same place?—It would depend upon the action that took the carriage off the rails.

17,836. If the action was such as to throw it off violently, would not you expect to find some mark upon the rail?—If it was thrown off very violently it would throw it clear of the rails and sleepers.

17,837. Lift it off altogether?—Yes, above it off altogether.

17,838. Would it do that if there were a guard rail?—I expect it would.

17,839. It would not be so easily lifted out where there was a guard rail by a violent side stroke as if there had been no guard rail?—If it is raised up outside of the guard rail it would go, there is only a guard rail for keeping the wheel from coming outwards.

17,840. The object of that guard rail is to protect the train from going off the metals, is it not?—Yes.

17,841. If there is a guard rail and rail, and a violent side force is brought to bear upon the carriage, would not you expect to find more marks upon both rails in such a case as that than if there had been no guard rail at all?—No.

17,842. (Col. Yolland.) With regard to those two gauge plates, how far apart from each other were they found—were they adjacent ones?—These are adjacent ones.

17,843. Next to each other?—Next to each other. There is another astern of them, but we had not time to take it off at that time.

17,844. They were found still attached to the longitudinal sleepers?—The spikes were loosened; they had been drawn; the sleepers canted with the pressure upon the girders.

17,845. The spikes had been drawn?—The spikes had been partly drawn; you see the marks of them in the holes.

17,846. Do you know at all from what part of this fourth girders this was taken, if it was taken from that girder?—That is from the fifth girders.

17,847. Near where the engine was?—No, this front one opposite the first-class carriage.

17,848. (Mr. Barlow.) The engine had passed over the place which that occupied?—Yes, the engine had been in front of that.

17,849. ((Col. Yolland.) Is must have passed over it?—Yes.

17,850. (Mr. Webster.) Where do you say this one nearest me was found?—The one next you was got opposite the first-class carriage.

17,851. And the other one was got where?—The other one was opposite the end of the second third-class carriage.

17,852. (Col. Yolland.) What distance were those apart?—17 or 18 feet.
Mr. Waddell called again.

Further examined by Mr. Bidder.

17,864. Did you see also these tie-bars on the top of the fifth girder?—Yes, I went with Mr. Robertson and made a careful examination of the tie-bars. I had a telegram from Mr. Armit to make a careful examination, so I took Mr. Robertson with me and we went to Broughty Ferry and made a careful examination of these tie-bars between the way-beams. 17,865. How many did you find like these?—Five altogether I found. 17,866. Can you tell us which part of the No. 5 girder they were in, which part these tie-bars which we have here, came from?—This one, that is not so badly bent as the other, came from about the centre of the first-class carriage, and this one that is more bent came from about the rear of the third-class carriage, to the rear of the first. 17,867. The one nearest the Court came from the third-class carriage?—No, from about opposite the first-class. 17,868. In the rear of the first third-class?—Yes. This one came from the first-class, in the rear of the third-class, and the other one came from the third-class in the rear of the first-class. 17,869. And therefore just at the south end of No. 5 girder?—Yes, pretty near the south end of it, I think, according to the position of the carriages as they lay in the carriage. 17,870. I believe you also went to see if there were any traces on the girders behind, No. 2 and No. 3 girders?—I examined all the ties of the way-beams very minutely and carefully. 17,871. In No. 2 and No. 3 girders?—Yes, all that I could see. 17,872. Did you find any markings there?—I found no markings; in some cases I found the tie-bars twisted with the collapse of the booms; in some cases the beams are not in the least collapsed beyond about an inch, but the ties are bent in an upward bow position, and when I gave orders to take that tie-bar off where it is bent, the one that is nearest to you, I took the measurement of the permanent way, and I found it only to be half an inch out of gauge. 17,873. It had preserved its gauge within half an inch?—Yes, the gauge is 4 feet 5½ inches. 17,874. How was it where the other one was?—In the case of this one, the one end was cut, and the way-beam was collapsed; it seemed to have bent a second time at the one end of it. 17,875. Did you see anything of the strut which was brought up from No. 4 girder which the last witness said was the fifth strut, and which had the angle-iron flattened?—No, he asked me to come and see it at the time, but I did not want to wet my feet in about 15 inches of water. 17,876. Have you ever had any experience of the effect of the after carriages of a train going off upon the fore, carriages?—I have experienced an axle-breaking in a train running at a speed of about 25 miles an hour. I was travelling in the train myself when it broke, and the axle breaking is liable to throw one of the wagons of the train off the road, or two of the wagons of the train off the road; perhaps all of them behind might be thrown off together. (Mr. Bidder.) That is not quite what I want. 17,877. (The Commissioner.) I think you said you found this axle-box, and the guard plate, as you call it, and plenty of glass inside the boom, did you not?—Yes, plenty of glass inside the trough of the boom?—17,878. Mixed with sand and shingle?—Yes. 17,879. Was there plenty of sand and shingle in it?—Yes, any amount. 17,880. All mixed up together?—All mixed up together. There was very little shingle; it was mostly sand.

Mr. Thomas Napier Armit sworn.

17,881. I believe you are by profession a shipbuilder?—I am. 17,882. But you have been engaged for some years past in wreck raising?—I have. 17,883. And is the operations of raising the wreck of the Tay Bridge you have acted as manager for Mr. Waddell?—I have. 17,884. And have all the operations which have been carried on there, gone on under your superintendence?—The whole. 17,885. As we know, up to the present time you have lifted a considerable amount, I think something like 1,500 feet in length of girder altogether, have you not?—Yes, about that.

17,886. How many feet distance would there be between that and the place you took these from?—Thirty-six feet.

(The Commissioner.) Are you referring to the same photograph that we have here? (Mr. Webster.) Yes, it is very like this girder, but it is not the same. (Mr. Traynor.) The witness says that that is 96 feet in advance of the place where these two were taken. 17,887. (Mr. Barlow.) Did I rightly understand you to say that the middle strut of the girder was broken through, or did you say that the only partly broken and the angle-iron turned up?—The inside is partly split, and the angle-iron and the covering-plate is turned up, and the web of the strut is cracked. 17,863. The rest is unbroken?—The outside is not broken or touched at all appearance. (Col. Yolland.) Not separated? (Mr. Barlow.) Fractured, but not separated. (Mr. Bidder.) I will just recall the last witness, because I am told he can corroborate the bending of these tie-bars.
them?—Yes, we had to cut the booms here and there, and we used dynamite for that purpose.

17,890. A good deal has been said with reference to that. It has been suggested that when you use dynamite, the dynamite might do a great deal more than fulfill the purpose for which you used it, and destroy portions of the girders and the carriages for a good distance round?—That is a mistaken impression.

17,891. I believe you had had a very long experience in the use of explosives under water?—Yes, have.

17,892. Did you ever use gunpowder when you first commenced ship raising? Afterwards I used gunpowder as being more effective than gunpowder, and afterwards I adopted dynamite as being still more effective, and doing its work entirely in its place, not scattering; gunpowder scatters, and so does gunpowder, but not to the extent that gunpowder does.

17,893. Was it upon your recommendation that dynamite was used in the present case?—A dynamite agent had come to the spot, and I advised Mr. Waddell to have dynamite as being the best explosive for this sort of work.

17,894. Just explain what sort of charges were used, and how the dynamite was applied, and in what way it worked?—A charge was used to sever the boom at a joint, at a cover plate, by sending a diver down with perhaps 2 lbs., or 3 lbs., perhaps on some occasions, of dynamite in a waterproof bag with a detonator inside of it, and a copper wire; he took it down, and when he had tied it close down on to the boom or plate, or whatever it was to be cut, he came to the surface, and then we fired it with a fractional battery.

17,895. Did he tie it above or below the boom?—In cutting a boom we jam it into the trough of the boom, so that it will operate all round.

17,896. Anything farther off than 3 or 4 feet would not be damaged?—No, even in some cases 2 feet might escape; dynamite is a treacherous thing, and you cannot always for a certainty say what will be the result of an explosion. I have used more dynamite at the Tay Bridge than I had over used in any other case before. We see that all throughout, the explosions have not extended more than from 3 to 4 feet. In some cases we have cut a plate, punched a hole right out of it, and left the plate intact, punched it out as if it had been done by a cutting tool, and the rest of the plate you might have put your finger upon without getting it injured.

17,897. You have seen that drawing which is being held up on the wall?—Yes.

17,898. You know what it refers to?—Yes.

17,899. It represents the portions lately recovered of the lower or eastern girder; No. 4 girder—that is so.

17,900. To what extent are the fractures there on the twistings of those parts due, if at all due, to the dynamite; will you just point out upon that drawing where the dynamite has acted?—Nowhere that I see.

If I saw the photograph I could tell you.

17,901. You know the left end of that is at the north side, where it joined on to the next girder?—Yes, I am aware of that, but there is no dynamite in that whatever.

(Mr. Webster.) None at the north end.

(The Witness.) The charge of dynamite exploded here (pointing it out).

(Mr. Webster.) Where the two things are put together at the top of the picture is the place he indicates.

(The Commissioner.) There was a charge of dynamite there where they were separate.
TAY BRIDGE DISASTER:

17,916. When you say "this," you mean the south end of the lift?—Yes, the south end of the lift; and when it came to view, and was just out of the water, it broke in the lifting.

17,917. (The Commissioner.) Which broke.—The bow of the wooden pontoons, and the two upper booms?—Yes, I did not know whether it was broken or not, but when it came to the surface a break was observed.

17,919. (The Commissioner.) Do you mean the upper boom or the lower boom?—I am speaking of lifting the whole thing—I am only speaking of what we broke. From this I observe that this boom, and this boom here, the two upper booms as the girder lay, were broke.

17,920. (Col. Volstead.) That would be the western girder?—Yes, the original western girder.

17,921. (Mr. Bidder.) As the bridge originally stood?—Yes, I did not then heave it at any more. I skated off the wooden pontoons and shifted along to get a better hold of the end beyond the break. It was a case of all night and all day work; and after we had shifted, at about an hour and a half of flood tide the whole of these chains ruptured, and we brought this top member back the western side, and left the bottom boom on the ground. A post here about hold, and I think this anchor bar here. I sent a diver down to cut that, which brought about this (pointing to the right-hand corner of the top of the drawing on the wall). This broke here besides.

17,922. That is the tie between the two pontoons?—Yes; the tie between the two pontoons broke. The whole of the girder broke between the two pontoons. That portion which the wooden pontoons were attached swung to the eastward, sending the west side of it in that direction (describing), and in discharging one of these tins with four carriages of dynamite, a very small charge, we sunk the pontoons, and they settled down here.

17,923. The pontoon bottom being just above the charge?—Eighteen inches from it.

17,924. With reference to all these operations that you have described which were unsuccessful so far as raising the lower part, did you in the course of those operations do anything to the lower part of the girder that would account for the fractures and twisings that we see there?—I do not believe it.

17,925. In point of fact, if I follow you rightly, you did not succeed in moving the lower part of the girder?—Never hinged it.

17,926. I ask you that because the witness Thurs said yesterday it was possible that damage had been done to the lower girder during these operations?—I heard his evidence, but it was wrong. I do not know how he could have come by his evidence.

17,927. In your judgment that was impossible?—Impossible: (Mr. B. Of.) What does he say was impossible?—

17,928. (Mr. Bidder.) That this unsuccessful attempt to move the thing as a whole caused the damage that is shown to the lower girder. He says that is impossible, because they never succeeded in raising the lower girder. (To the witness.) That is what I understand you to say?—That is so.

17,929. Subsequently to that, before you lifted any more of No. 4 girder, you went to No. 5?—Yes.

17,930. Before you did any more to No. 4, you lifted No. 5 girder, did you not?—We did.

17,931. When you lifted No. 5 girder you deposited it on the beach at West Ferry, did you not?—Yes.

17,932. Did you examine the state of the permanent way and the tie beams in No. 5 girder?—I did not at that time; we did not beach No. 5 girder with the carriages until a week after it was lifted. The ties were then not to hand, the spring tide.

17,933. Then after that did you go back again to this portion of No. 4 girder with the carriages on it, which was still at the bottom?—Yes.

17,934. What did you do; will you just explain what you did?—I sent the divers down to see if the second-class carriage and the van could be lifted, and they found them perfectly open for lifting. Two divers went down, Dewey and Thurs being attached to the second-class carriage, and Dewey to the van. Dewey reported to me that the van was lying on the top, and he thought his carriage ought to be lifted first, but I decided that as Thurs was nearest to the best; that is to say, nearer to the lifting chain, we would lift the second carriage first. We accordingly hove it up, and have the van up the same night, and the third-class to the north of it, on the same night. I then lifted this piece of No. 4, and this was broken here as I stated. I then lifted this piece, thus (lifing in fragments), and there were other portions from this west side which were beached at Tay Port, sleepers and rails and pieces of the boom.

17,935. (The Commissioner.) Are those two pieces on the drawing pieces of the west boom?—No, the east boom.

17,936. (Mr. Bidder.) Those were lifted on what day?—On the 19th or 20th, speaking from memory, I think it was about that.

17,937. You, of course, saw those fragments when you lifted them and brought them into harbour?—This (pointing to it) was the first that was lifted, and I was struck with its appearance, and I once ran it into Dundee, to be photographed, I thought it was important.

17,938. I will draw your attention to the left-hand portion of the diagram. You see these twisings of the first suspension bar and the tie, and the twisting or bending of the second suspension bar, are those in your judgment, the consequence of anything done by you in the course of lifting?—No, certainly not.

17,939. Did you see the marks upon the girder, which are indicated upon the plan by red lines?—I was the first to observe them.

17,940. I did not hear what you said just now. My friend tells me that you said you thought it so important, that you went into Dundee to have it photographed?—Yes.

17,941. Will you just describe those marks—are they distinct upon the girder?—They are black, an impression made by passing your finger over them you can feel that there is more than the paint—that even the iron bears a grace, there are hard grases, the heads of the rivets are very hardly rubbed, in passing your finger over you can feel a distinct hollow, and over the heads of the rivets there has been a very hard grace indeed.

17,942. Did you notice what Mr. Mack described as one corner of the covering-plates being turned up and the rivets gone?—Yes, I assisted him to pick out some of the pieces.

17,943. Have you formed any opinion, from the appearance which you saw there, of how that could have caused?—Yes, I have.

17,944. What is your opinion?—That the rear of the train must have done that, I should imagine the second-class carriage.

17,945. What I want more particularly to get at is this, is there any way in which you can conceive that to have been done after the bridge had fallen?—No.

17,946. Anything in your process of handling of the train?—No. This is in the rear, and I have found still further south of this some damage. This seems to be the tail-end of the damage—the real damage occurs here (pointing to the model).

17,947. Are you referring to what was spoken to by the last-witness, the stumps further south?—Yes.

17,948. Have you seen that?—Yes, I lifted it.

17,949. What must do you say it is?—On No. 6, No. 5 from the north.
17,982. (Mr. Picker.) That is the contra bay?—Yes.

17,983. (Mr. Bidder.) That has only been very recently lifted, I think?—I lifted it some time ago. I lifted it after I lifted the carriages—it was as easy as pie—and it did not dry on the ties, but I lifted it in the warehouse on Wednesday last, I think.

17,984. It has not been possible to photograph it, because of the state of the tide. The craft, the "Emery," in lifting the girder which she did, was drawing fully 12 feet of water, and we took it in, and we could not take it in any further than the draught of water she was drawing would let us, still I went and examined it before coming up to London, and I saw these things, and I left instructions with my assistants to still further examine it and try and lift some further parts of it for the show.

17,985. Just state in your own way, what you observed in the case of that strut?—The iron of the strut seems to have got a blow that opened it up like that (smacking his hands and opening them). The angle and covering plate of the strut.

17,986. Was it flattened out?—Opened out.

17,987. In what direction, as the bridge originally stood, must that blow have come from?—From the south.

17,988. Having regard to the appearance of it, must it have been a blow of considerable violence to do what you see has been done?—It must have been a head blow to the top of the strut.

17,989. I believe you were not present when the axle-box and guard plate were found in the trough of this girder?—I was not.

17,990. Did you subsequently see the portions of the guard plate?—They were given up to me.

17,991. Did you try them in order to ascertain whether they were sound?—Yes.

17,992. What was the result?—The guard plate fitted on the second-class carriage. I do not know about the axle-box.

17,993. Have you any doubt that the guard plate was a portion of the guard plate of that carriage?—None whatever.

17,994. In the position in which that girder was lying, could that guard plate and that axle-box have got into it after the bridge had fallen and in the process of your lifting?—That seems simply impossible.

17,995. There was a good deal of sand and débris in the trough?—So they tell me. I did not see it.

17,996. That would have washed in and out as the tide went up and down?—Yes, with an easterly breeze we would find this boom pretty clear, and with a westerly breeze we would find it sodden.

17,997. The tide would not be strong enough to wash axle-boxes about?—No, there is not much water between that sort.

17,998. If I recollect, at the time of the accident, the tide was flowing down, was it not?—I do not know. I was not there.

17,999. You afterwards recovered the hind wheels of the second-class carriage, did you not?—Yes, Thomas, the driver, found them.

17,100. And they were raised to the surface?—Yes.

17,101. Was there anything to remark about them?—The axle was bent, and the outer end of the axle was also bent.

17,102. Was there anything noticeable about the wheels themselves?—On the inside there were rubbings like charred timber on the inside of the wheel. You could not call it anything else.

17,103. Later on you went again and examined further, I think, the way-beams and the tie-bars in No. 5 girder?—Yes.

17,104. The one that was north of the girder that we have been talking about?—Yes.

17,105. As it lay upon the beach at West Ferry?—Yes.

17,106. Did you see these beams in position, which are now in court?—I did; but they did not strike me at the time—not until I had been shown the marks in London the other day. I saw them all like that, but it did not strike me that anything had occurred to them, as it does now.

17,107. Can you tell me this, were the tie-beams at the north end of No. 5 girder and the permanent-way in the same condition as at the south end of it?—Will you repeat your question?

17,108. I am talking of the north end of No. 5 girder—that is the farthest from the guard's van and the second-class carriage. Were the tie-beams and the permanent-way found in the same way at the north end as at the south end?—The tie-beams were in position at the north end, at the south end they had fallen together. These tie-bars were not so much twisted up at the north end as at the south end. Altogether the girder was more complete at all its parts at the north end than it was at the south end. At the south end and it was very much wrecked. Dynamite had been used at both ends.

Examined by Mr. Teather.

17,109. I understood you to say that dynamite in its operation is more local than any other explosive you have used?—That is so.

17,110. I want to see if I quite understand you. Do you mean it only shatters things which are in immediate juxtaposition with it?—Perhaps you will understand me better if I say this—In destroying a vessel, for instance a vessel on a bar, an obstruction which a conservancy board has got to get out, I should use gunpowder because it shatters. I would not use dynamite because it cuts—the effect is only local.

17,111. Would it have a disturbing effect, to some extent, round it, though it did not operate in cutting or shattering anything immediately round it?—There is a bubbling of water comes up immediately after every explosion.

17,112. Naturally enough, but what I want to know is this—take, for example, that there is one of these bars lying within a few feet of the place where your charge is fired, would it have any effect whatever in turning it over, for example?—No, I could cut one of these rivets out and not disturb it with dynamite. I could not do that with powder or gun cotton.

17,113. The fourth girder between piers 3 and 4 was taken up in how many pieces?—The first lift was a portion of No. 3 and up to hereabouts of No. 4, that was beached at the ferry. This end was very much broken, the west side was most broken, that is one bit, to here is two and thus came up in several fragments (pointing to the model).

17,114. It had been lying in fragments, had it; you did not cut it up into fragments with your dynamite?—No, we found it like that.

17,115. The result of what you did showed you that before you began to meddle with the girder between piers Nos. 3 and 4 it was in several pieces?—It was.

17,116. (The Commissioner.) Before you touched it at all?—Yes.

17,117. (Col. Yolland.) Are you speaking of the east or the west girder?—I am speaking of the whole girder between piers Nos. 3 and 4.

17,118. (Mr. Teather.) I am endeavoring to raise the part of the girder you have spoken of, which was nearest pier No. 4, you told us you had tackled to it and you worked at it something like 24 hours in your endeavour to raise it without being successful?—Yes I had 79 hours at that bit altogether.

17,119. And you were straining upon it with your machinery and with your cable boats with as much force as you could?—We were not.

17,120. How much then; were you straining much upon it?—That end was loose; this and never left the ground (pointing to the model).

17,121. You ultimately cut this end with dynamite?—Cut it free.

17,122. Before you cut that end free had not you been tugging at it to raise it?—No.

17,123. One of the witnesses yesterday said that was so?—They were wrong; after we cut the post...
immediately under that I put on one tug to tow this upper member, which was free, as I expected it would be after having cut the post, and I towed it to the eastward, and towed it, I dare say, seven minutes at the very outside: I saw that one of those T angle bars still held out, and I stopped the tug. This tide was by that time on the ebb, and the greater remained to the eastward, where it had been towed. In cutting that tie-bar we sunk the pontoons, so that instead of 24 hours towing and pulling we had at the very outside seven minutes.

17,992. When you cut one of those bars that was seen to get away the upper part of the girder which was lying uppermost?—Yes.

17,993. The witness yesterday misinformed me upon another point, or I must have misunderstood him, for I understood him to say that it was at that point the girder was holding, and you cut it out there (pointing to the model)?—It was here (pointing to the model). The girder was held at the joint at the lower west boom.

17,994. Had you to cut it before you got it up?—We took this away and left this for I gdem him to my which was lying uppeoplost on the strnt—The strut the had... had turned up?—The plate and the angles

17,995. There was nothing at that joint that prevented you carrying away the bit that was lying at the top of it?—They were all gone; the chains had parted.

17,996. You were able to carry off the top part of it without cutting anything with dynamite at the lower part?—Yes.

17,997. Was it in this part of the pier where that plate had got the blow that opened it out?—Yes.

17,998. About the centre?—Yes.

17,999. Was that a plate that had been riveted on the strut—was it a cover plate that had been riveted on the strut?—The strut has a centre web with top and bottom angle bars and a plate riveted on to the outer flanges of the tangle bars.

18,000. Was it the plate that was riveted on that had been turned up?—The plate and the angles together.

18,001. The rivets remained still in?—Yes, they may be disturbed now.

18,002. They were not displaced—they were still in their rivet holes?—Yes, I believe so; it did not occur to me to look to that.

18,003. Have not you examined it with your eyes?—Yes, but there was 6 inches of water upon it.

18,004. How high would that plate or angle-iron, which was so disturbed, be above the level of the permanent water?—I think about 6 or 7 feet.

18,005. You see the plate that is marked with the red scores, was it as high above the level of the rails as that?—No, it was down below (pointing to the diagram).

18,006. Four or five feet below?—Four or five feet below.

18,007. Were the edges of that angle-iron, which were displaced, dragging from the effect of a blow?—Yes.

18,008. Were they indented?—The thing itself has an indentation.

18,009. It is two wedges in fact, and one of them is forced up?—It is like this, it has a blow here, and it is turned over this way.

18,010. Are there any indentations upon the metal itself showing that it has been twisted up with the force of a blow. Has the metal here been indented or displaced?—I did not observe it; it may be, I cannot say that it is, where it is indented is fractured.

18,011. What is the extent of the fracture—could you put the blade of a knife into it?—Yes, about that.

18,012. Did you try it?—No.

18,013. Was this which you saw 6 or 7 inches below the water?—Yes, I felt it with my hand.

18,014. Was Mr. Mock with you when you made the examination?—No, he was not.

18,015. Do you think that the metal could have been forced out of position in the way you describe by a blow from a piece of wood?—No, I should think not; it may have been—I cannot tell.

18,016. Can you suggest any kind of wood that would do it?—The edge of a carriage might do it.

18,017. (The Commissioner.) The wood at the edge of a carriage might do it?—The corner of a carriage might do it.

18,018. (Mr. Trayner.) Do not you think that if any carriage that ever was built came against a piece of iron like that, it would shiver into pieces before the iron, instead of bending the iron in the way you describe?—I do not know that; the carriage would certainly get the worst of it.

18,019. This is mere theory; you have never seen the strength of iron and wood tested in that fashion?—I never saw wood confronted with iron.

18,020. You never saw anything that suggested to you that wood brought with violence, that is to say, the body of a carriage brought with violence against a piece of iron of that strength would have the effect you have seen described, you have never seen anything of the kind which leads you to think it?—I have a conviction that some of the carriages went foul of the girder from what I see all along.

18,021. I want to get at the ground of your conviction and I want to know if you have had any experience of iron and wood being brought into contact, and whether you have ever seen wood smashing up iron in that fashion?—I have not.

18,022. What made you think it took place in this particular case, a thing that was unprecedented?—Many strange things do occur.

18,023. There is one other matter I want to ask you about, you say in the inside of the trough of No. 4 girder you found a part of the horn plate?—A part of the horn plate was found there.

18,024. When the bridge was standing in its position, what trough would it be in which that was found, the eastern or the western trough?—The eastern trough, the bottom trough.

18,025. What is the depth of that trough?—About 18 or 19 inches, I should think.

18,026. And the width?—It is about square, 18 inches square, thereabouts, I never measured it.

18,027. The dimensions of the piece of iron which you have described as being found in it would be what?—About 16 inches long.

18,028. And how broad?—About 3 inches broad.

18,029. If that had been in the girder before the bridge gave way, would it not have fallen out of the girder when the girder went over probably?—I cannot tell.

18,030. Do not you think it likely, if a piece of iron that size was lying in the trough of the girder before the girder went by the side, that when it did go, the tendency would be for that piece of iron to fall out?—I cannot tell; I do not know.

18,031. You have an opinion; what is your opinion about it?—That it would not, seeing that it did not.

18,032. (The Commissioner.) Have you any other reason than that?—No.

18,033. (Mr. Trayner.) That is assuming it was in the trough before the bridge went over the side. —Yes.

18,034. Apart from the fact that it was found in the girder, which I am quite willing to take, you have no other reason for supposing that it was improbable that it would fall out when the thing was captured?—I do not think it was likely at all, it was a considerable weight.

18,035. If it had a considerable weight, do not you think it would have a tendency to roll when the side of the girder was?—No, being a flat thing it would lie flat.

18,036. Those beams when first shown you you say did not impress you. Nothing occurred to you upon looking at them at first?—I did not look there. At that time I did not think that anything but the second-class carriage, and possibly the van, had been off the rails, therefore I did not look for indications of the whole of the train having been off.
18,037. Were not these found near where the second-class carriage and the van were found? — No. One of these was found where the first-class carriage was found, and the other was found where the third-class carriage, in the rear of the third-class carriage.

18,038. You see two bent beams of the same kind in this photograph at the north end of No. 5 girder; you see there a similar buckle to this? — Yes.

18,039. The other one is so much like the one nearest me of the two on the floor? — Yes, there is a similarity; it is not unlike it.

18,040. Did you see any more of these? — There were five of these they informed me. There was one of these tie-bars on a pair of rails, which led me to inspect my assistant to look for these.

18,041. You said just now that you had not looked at these particularly, because at that time you thought nothing had gone off the rail but the second-class carriage and the van. From whom did you originally get that notion that the carriages had gone off the rail at all? — To tell you the truth, originally there were so many stories that I did not believe anything.

18,042. Who told you that the carriages had gone off the rail originally? — I have no notion; but when I heard that thing I thought there must be something in it, and it grew upon me from the time I heard of it.

18,043. Do you know this, that immediately after the disaster took place Sir Thomas Bouch expressed the opinion which appeared in the public prints that the second-class carriage and the van left the line? — Yes.

18,044. You knew from the first that that was his view? — Quite so.

18,045. (The Commissioner.) Do you understand you to say that he never suggested that to you before you got there? — I went down to take charge of the operations that Sir Thomas Bouch gave that as the cause of the disaster.

18,046. (Mr. Biddell.) But you said you did not attach much importance to it yourself till you raised these fragments? — Yes.

18,047. (Mr. Tregoner.) Did you afterwards form an opinion that something more than those two carriages had gone off the line? — Yes, I did.

18,048. What is your opinion about it now? — I believe the whole train has been off.

18,049. (Mr. Biddell.) Do you mean including the engine? — Not including the engine or the tender.

18,050. (Mr. Tregoner.) Since you have got that impression, you formed an opinion as to what part went off first? — I think the second-class carriage would go off first.

18,051. Why? — I have read the evidence that has been brought forward in this Court.

18,052. And is that your verdict upon it? — No, I am not pre-judging, but I have been made aware that the second-class carriage was the lightest and the first that would be likely to be blown off, and I find it is the most smashed up.

18,053. Have you anything else to add in support of the view you are giving besides the lightness of the carriage and its being very much smashed up? — Any grounds for supposing that the second-class carriage went first off the line at that point? — And also finding those charred pieces of timber, inside the wheel where it has evidently been running, or with the axle across the way-beams; and this is another reason for my believing that the whole train has been off — the whole of the axles are bent across the way-beams.

18,054. Off the rails? — One wheel upon the permanent way and another outside.

18,055. That you think led to the bending up of the axles? — Yes, I do.

18,056. Will explain how that is; to bend an axle you must have compressing power on each side, must not you? — If you bring these carriages on here you very soon bend the axle.

18,057. You think the wheels going off, I suppose, on the easternmost side, and running along for some distance would have, the effect of bending the axles in the way we see in the photograph? — When they are thrown off the line they are bound to come down. The wheels must fall 28 inches.

18,058. Do you take into account that when the second-class carriage went off the line — if it did go off the line — the couplings between that and the carriage in front of it were still entire? — I should think they would still be connected.

18,059. Do you not think that the connexion with the carriage in front of it would have a tendency to keep it on the line as against any other force that was driving it laterally off the line? — No, I should think it being off the line it would take the carriage in front off.

18,060. When it got off? — Yes.

18,061. The force driving it off the line would be counteracted by the force of the coupling connecting the carriage in front, would it not? — So it would, but if the buffers of the second-class carriage got under the couplings, or even the framework, or the other buffers in front of it, it would very soon turn it over, and the same thing would occur all along.

18,062. From what you have described as the appearance of the way-beams, what distance do you suppose this second-class carriage ran after it left the metals? — I do not think that any of them ran more than about their own length.

18,063. Does your answer imply this, that in your opinion every one of the carriages, except the engine and tender, ran its own length, or about its own length, after it had got off the metals? — Yes.

Re-examined by Mr. Biddell.

18,064. You told my friend that No. 4 girder was in several pieces? — Yes.

18,065. In point of fact, the southern part was all in one piece, was it not? You have described it as having been lifted first with a portion of No. 3 girder? — We found it that way, and we lifted it as we found it.

18,066. That included nearly half the girder? — No. (The Commissioner.) The three first bays.

18,067. (Mr. Biddell.) Which was most broken, the northern or the southern end of the girder? — The northern.

18,068. As to the axle-box and the guard plate; suppose the guard plate did not get into the trough of the boom, or, having got in, fell out again before the girder got to the bottom, of course it must have deposited itself somewhere in the bottom of the river? — That is natural.

18,069. Can you imagine any possible way in which that bit of guard plate, having been once deposited in the sand of the river, could have got into that trough? — No, I cannot.

18,070. My learned friend asked you about these planks on the floor, did you afterwards find a tie-bar on No. 4 girder similarly bent to that? — In the photograph which you hold in your hand there is a tie-bar.

18,071. Was that upon No. 4 girder? — That was upon No. 4 girder.

18,072. Did you have it photographed? — I did.

18,073. Whereabouts is No. 4 girder would that be? — About here (pointing to the model).

18,074. In the second or third bay? — Thereabouts.

18,075. I do not know whether it is within your knowledge that one of the bodies that was found was that of a man with his coat taken off? — It is.

18,076. (Mr. Tregoner.) I see that tie-bar on No. 4 girder seems to have been broken way; it is entire in its length, and has been torn away from the other side? — The other side is gone.

18,077. This is the spike hole here? — It looks like it.

18,078. And the part of the permanent way to which it is attached seems to have had a great wrench too? — Yes.

18,079. Is that the guard rail that is in most bent? — I do not know.

18,080. You do not know the guard rail from the other? — I do not, not in that.
Examined by the Commissioner.

18,081. I think when you got up the second-class carriage, two of the wheels were wanting, were they not?—Yes.

18,082. Were they afterwards found?—They were.

18,083. Where were they found?—They were found, I should say about from 50 feet to 55 feet south of No. 4 pier. They would be perhaps some 6 or 8 feet behind where the second-class carriage was found, to the south.

18,084. They were inside the girder, were they?—They were inside the girder.

18,085. You have told us that you discovered some marks on the eastern side of the girder, at about 6 or 7 feet above the permanent way, which you supposed had been done by a portion of the second-class carriage?—Yes.

18,086. Of course you know what a second-class carriage is?—Yes.

18,087. What do you think would be the effect of its coming in contact with the girder?—It would be smashed all to pieces.

18,088. These marks are at the fifth bay?—Yes.

18,089. That is at the height of 11 feet 2 inches from the permanent way. How do you account for that?—I cannot tell how it was. Perhaps the train jumped up. I believe to some eccentricities in a train.

18,090. You believe, therefore, that that mark on the fifth bay was due to some eccentricity of the train?—Yes.

18,091. And could not have been caused except by some eccentricity of the train?—I do not know of anything in our operations that could have caused those marks.

18,092. I am not asking you about your operations, I am asking you about the marks upon that fifth bay. You have told us that you believed that the mark on the fifth bay was caused by the second-class carriage coming into collision with the eastern girder, and you have told us that that would knock it all to pieces. I want to know what part of the second-class carriage could have caused that mark at a height of 11 feet 2 inches on the fifth bay?—It might not be the second-class carriage, it might be the carriage ahead of it.

18,093. How could it be the carriage ahead of it, if we do not think any carriage more than its own length?—This is just about the length of a carriage ahead. The end of the first-class carriage was found here; 3 or 4 feet beyond the joint of No. 3 and No. 4 girders.

18,094. Was it not standing upright with its roof?—The side of it is all shaken to pieces.

18,095. Was not the roof standing and was not it on its legs?—The roof was gone.

18,096. Was it not standing upright?—No, I believe it was tilted a little.

18,097. Practically speaking it was upright, it was not on the rails?—Not on the rails, it was lying across the girder.

18,098. It was not on its side?—No.

18,099. It was standing on its wheels?—Yes, tilted a little.

18,100. It could not have been found standing upright unless the air got inside of it, which lifted it up as it fell over?—Very likely.

18,101. Therefore that could not have made these marks?—These marks are at a height of 12 feet 2 inches?—It would have passed along here (pointing to the model).

18,102. With respect to this guard plate and the axle, you know, I suppose, that at the bottom of the pier there is a quantity of large rubble stones which have been put down there?—Yes.

18,103. What size are they?—They are of various sizes.

18,104. Some of them are very large?—Some are as big as a man's hat.

18,105. And you know also that the tide is so strong there that it severs them away sometimes, does it not?—I do not think any of them have been severed. They may at the first when they were laid.

(The Commissioner.) There is evidence in Mr. Noble's statement about a hole having been secured.

(Mr. Bidder.) But it is appeared that the sand was undermined from under the stones, not that the stones were swept away.

18,106. (The Commissioner.) However, there is a very strong stream there?—Yes, but no stream to float a stone or sweep a stone away.

18,107. A stone or a piece of iron would move in the bed of the river without floating would it not?—In the case of rubbish you have a lot of sand, and if you undermine it it is bound to tumble.

18,108. You are taking that from what Mr. Bidder has just said, but from your own knowledge, apart from the sand being washed away, have you never heard of a large piece of stone being washed away, a large rock being washed away by such a strong stream as that of the Tay?—I have known cases in a highland loch where the breaking of a dyke would carry away large pieces of stone. I have known stones swept away through the breaking of a coffin-dam but not in such a force or five knot current as the Tay.

18,109. A four or five knot current could not wash this plate into the trough?—No; it would be impossible in my belief.

(Mr. Bidder.) If you will look at the strength of currents requisite to move heavy bodies you will find it utterly impossible.

18,110. (Cot. Yolland.) Can you say whether any dynamite was used for breaking the girders before you got there?—Mr. George Waddell had attempted one shot upon a portion of the girders. There is a photograph showing the girders as they lay before any one touched them. That is the portion that used to show up at dead low-water spring-tides.

18,111. In which span?—Opposite No. 2 pier. One shot had been fired previous to my taking charge of the work.

18,112. Can you state from your own knowledge what was the state of the top and bottom booms of the eastern girders before you began to use dynamite at all?—First, as regards the top boom, was it broken or fractured, and if so, into how many parts?—The top booms were not greatly broken.

18,113. Were they cracked?—They were cracked; these are the general bottom booms. We had more chains to put on to this girders in consequence of the frequent occurrence of breaks. We had over a dozen chains.

18,114. I want to know what was the state of those two booms before you began to use dynamite at all?—They were more broken than any other girders I had come across.

18,115. As regards the top boom of the eastern girders, was that broken through?—I mean the top boom of the eastern girder then lying in the bed of the river?—I think not.

18,116. It was cracked, perhaps?—It was cracked, perhaps. I think it was not broken.

18,117. That was the top boom?—Yes.

18,118. With reference to the under-boom, was that broken at all before you began to use dynamite?—Very much.

18,119. Was it fractured right through?—Yes.

18,120. Will you take the stick and point out whereabouts it was fractured?—I cannot pretend now to show you where the fractures occur, but I can state that we had more chains hanging between these booms on this girders than on any other lift we made. I cannot tell you where the breaks were, but we had more chains, and the chains were close together all along the whole boom.

18,121. Was the bottom boom actually fractured, or only cracked; was it broken through before any dynamite was used?—Yes.

18,122. Was it broken into two pieces, or three parts, or four, or more?—I do not know. I did not examine how many cuts there were.

18,123. How many actual fractures through the bottom boom were there before you began to use dynamite?—I cannot tell you how many, but so many...
18,126. (Mr. Biddes.) Did you lift the No. 3 girder?—I did.

18,127. Was the northern end of that No. 3 girder much broken?—It was not very much broken, but the piece attached to it, which was the southern end of this, was considerably broken on the side on the west side.

18,128. This diagram which has been put in represents what the divers found before you began your operations?—They were not my divers.

18,129. At any rate some divers, and it appears to show, that the girder was broken at that place, that is, in the middle part of its length; is that consistent with what you found?—At this portion it was very much broken; at No. 4.

18,130. They show four breaks within 60 feet of the pier?—Portion of No. 3 was a short bit, and we had breaks there (pointing to the model), and in No. 4 there were as many.

18,131. Did you find any of those bent tie-bars at that place?—The way beams and rails are there in a complete state of collapse—caisped, all thrown down on the eastern side. The sleeper and these tracks are, way and beam fell sightwise on this eastern side.

18,132. There is no suggestion that the carriage was off the lines there to cause that breakage?—No, we could see no traces of the carriage having been off the rail there.

18,133. How do you account for the amount of breakage that you found there?—Possibly the columns might cause the damage, through its falling down through the columns.

18,134. Some of those breaks are a great way from the columns?—One cannot tell where a column would come down.

18,135. You cannot form any opinion how that breakage arose?—No. (The Commissioner.) You said that the engine and the tender did not go off the rail?—I do not believe that the engine and the tender had been off the rail.

18,137. But the girder is very much broken where the engine and tender are?—I heard that the girder is very much broken there.

18,139. That is a very long way from any columns?—Fifty-five feet to the south of No. 6, I think, it is very much broken there.

18,139. Is it quite beyond the reach of any columns?—I could not say that it was quite beyond the reach of any columns, there must be columns pretty close up to it, it is just possible that there may be columns there, I saw none. I was examining the engine and I saw no columns about it.

18,140. You raised the fifth span?—I went down and examined it myself.

18,141. And you found it, broken all round about the engine and tender?—Yes.

18,142. Both the upper and the lower beam?—I found what was originally the top lying right over on the top of the engine, before I could lift the engine I fired away these up and down posts of the top. They were lying coated right over on the engine within two feet of the engine, and tender, I fired away these or four of them with the ordinary shots that we used throughout. The tender came up without a single scratch.

18,143. But what I am asking you is this, before you fired those charges you found the girder very much broken?—Yes.
Mr. T. N. Armit
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(The Commissioner, to Mr. Bidder.) Would you like to ask him any question upon that?

(Mr. Bidder.) What I should suggest would be, that having before him the tracing of the train, whether he is now able to form a judgment as to what was the cause of those markings.

18,158. (The Commissioner.) Knowing that the guard's van was below the second-class carriages, can you account for all those markings?—It is very possible that the guard's van caused them—very possible—I should say very likely.

18,159. (Mr. Trukey, through the Court.) If the van was still on the rails, and tilted over by the wind, can you form any opinion as to how much that would diminish the height of the place at which it struck?—If it was on the rail tilted over, it would very likely come below that, but, as I have said before, I should not be at all astonished if it jumped up.

18,160. (The Commissioner.) What you call the eccentricity of the train?—Yes.

(The Commissioner.) Will there be any other person called, besides these witnesses, who have seen the fragments since, because otherwise it may possibly be necessary either that Mr. Law, or the Court itself, should look at them. Is there anybody on behalf of the company, under whose control all this is, who might be produced to give evidence about it?

(Mr. Balfour.) Mr. Drummond, the locomotive superintendent, has seen all the carriages, and he can describe their condition accurately.

(The Commissioner.) He is hearing the evidence.

(Mr. Balfour.) Yes, we thought it right to bring into the Court all the things when the evidence began, in case the Court wished to ask him anything.

(The Commissioner.) I think we should. The opinion of Colonel Yolland and Mr. Barlow is that some person of the kind should be called.

Mr. Dugald Drummond recalled.

Further examined by Mr. Trukey.

(The Commissioner.) Mr. Drummond has made a special report upon this case I see.

18,160. (Mr. Trukey.) Yes, Sir, Mr. Drummond's general report and that sketch contain most of the information that we shall elicit from him. (To the witness.) I may take it from you in the outset, that the figures in this sketch representing the surface of the carriages and their weight and so on are accurate.

—Yes.

18,161. And the marshalling of the train as shown on this sketch is also accurate?—It is now also accurate, the first one was not.

18,162. (The Commissioner.) This plan is the plan that has been given in connection with the report?—Yes.

18,163. (Mr. Trukey.) You have made a report, dated 16th April 1860, addressed to the solicitors of the North British Railway Company, upon the state of the train and the carriages which you yourself examined?—Yes.

18,164. And the statements in this report, and the statements which are noted on the sketch put in, are correct in point of fact?—They are all correct.

(Mr. Bidder.) I have not seen those remarks. When you ask if all the remarks are correct, if I do not know what the remarks are, I cannot cross-examine upon them.

18,165. You will have plenty of time to look at the notes if you wish. (To the witness.) How high was the second-class carriage above the level of the rail?

—A little over 10 feet.

18,166. From the level of the rail to the top of the roof?

(The Commissioner.) At the side, I suppose.

(Mr. Trukey.) At the side. The roof was slightly arched. I am going now to the highest point of the roof.

(The Witness.) About 10 feet 5½ inches or 10 feet 6 inches.

(Mr. Balfour.) We thought probably the Court would wish that, and so we telegraphed to Mr. Drummond to come up.

(Mr. Bidder.) If anybody is going to be called by the company or by the Board of Trade upon this part of the evidence, I should like to know when it is going to be done, because I cannot keep those witnesses indefinitely in town.

(The Commissioner.) Would you be prepared to examine him now?

(Mr. Balfour.) I have not done what you were going to put forward. I propose to ask leave to recall Mr. Cochrane and Mr. Law, and to put to them one or two questions in direct opposition to the opinions expressed by Sir Thomas Bouch, which were not opened in the cross-examination of Mr. Law or Mr. Cochrane.

(The Commissioner.) That is another question. The question we are upon is whether Mr. Drummond should be examined now.

(Mr. Barlow.) While the subject is fresh in our minds, we had better have Mr. Drummond, I think.

18,167. If you take it from the level of the rail, how much less was it to the edge of the side, leaving out the bulge of the roof?—About 6 inches less.

18,168. (The Commissioner.) The height of the second-class carriage above the side at the side would be about 10 feet, taking it to the edge of the roof?

—Yes.

18,169. (Mr. Trukey.) In what condition did you find this second-class carriage; it is all gone, I believe, but the sole plate?—All but the under frame.

18,170. At the north end of it how did the buffer or coupling stand?—Every coupling at the north end was broken through the centre of the shackle.

18,171. (The Commissioner.) Do you mean the coupling with the van?—The coupling with the third-class carriage. The coupling with the carriage in front was broken in the centre of the shackle, and the east side chain hook was broken also through the centre of the hook. The west side was correct.

18,172. (Mr. Barlow.) Unbroken?—Unbroken.

18,173. (Mr. Trukey.) The west side chain?—And also the west side buffer socket was broken.

18,174. (The Commissioner.) Were the couplings attached?—They were separated when I saw them. What condition they were in when they were lifted, I do not know.

18,175. (Mr. Barlow.) Would you give us the buffers next?—The buffer socket on the west side was broken. The buffer on the east side was all right. I think. The buffer head was made of timber; it is that that was broken. I think you will see it in the photographs; it was broken on the inside. The buffer socket and the buffer head, the wooden fitting that is on the buffer head, was broken on the west side.

18,176a. (Mr. Trukey.) And on the west side it is all right?—On the east side it is all right. You will see it on the photograph (pointing out true).

18,176. With regard to the wheels, there were four wheels on the carriage originally, were there not?—That is so.

16,177. Were any of them attached to this frame?
work when you saw it?—Yes, the cause towards the
fourth end of the carriage were underneath.
18,178. (Col. Yolland.) The leading wheels re-
maining—is it so?
18,179. (Mr. Trayner.) Were they still attached
ear the framework?—They were.
18,180. In what state was the axle?—It was bent.
18,181. Was it bent upwards in the centre?—Yes;
you will find it so in the photograph.
18,182. The third wheels and what pertained to
the axle and everything else, was gone, I believe?
—That is so.
18,183. Can you tell me what was the character of
the construction of that second-class carriage; was it
heavy or of a lighter carriage?—It was a very lightly
constructed; in fact it was the only light carriage, both in construction and of itself,
that was in the train.
18,184. You have heard the evidence upon this
theory of the carriages going off the line and breaking
through the girders?—I have heard of it.
18,185. What opinion have you formed upon this
matter; assuming that the second-class carriage went
off the line and that the foremost portion of it, or the
front part of it, struck against one of these struts,
what do you think would be the result?—My opinion
is that if it was so, the rear end of this carriage would
go across the girders, across the line.
18,186. And the result of its going across in that
way would have been to expose which side of it to the
blow?—The east side, the east buffet.
18,187. (The Commissioner.) If it was struck on
the top, forward, at the east side, that would send the
rear of the carriage towards the west?—I may put it
in this way also; that if any part of the body of this
carriage had struck any part of the girder, it would
have had very little effect upon the under portion of the
carriage, because it is so light in construction
(about three-eighths of an inch), that it would have
knocked the body all to spunks.
18,188. You mean that if the blow had been given
in the east side, then it would have shifted it in that
way?—That is, if the blow had been given to the
under frame instead of to the top.
18,189. Would it have cleared all off?—It would
have cleared all off; that is my opinion, knowing the
18,190. (Mr. Trayner.) The first view that you
had is this; that if the fore part of the carriage came
against the lattice, you think if the carriage was
strong enough to resist that, it would have turned at
an angle?—That is so.
18,191. Presenting the easternmost side of the
carriage to the advancing carriage?—Yes, to the
brake van.
18,192. If that had happened, on what part of the
second-class carriage should you have expected to find
the greatest amount of damage?—On the east side.
18,193. In point of fact, on which side do you find
the greatest amount of damage?—On the west side.
18,194. The east side of the framework is entire?
—The east side is so.
18,195. The west side of the frame is all smashed?
—That is so.
18,196. Supposing that the first-class carriage came
in contact in this way that I have suggested with one
of these lattices, do you think that the carriage
would have been strong enough to have resisted that
impact so as to have sent it round?—I do not think so.
18,197. You think it would have gone off at once
like matchwood?—It would have done so, I am sure.
18,198. Supposing that the first-class carriage had
been tilted by the lateral force of the wind, so as
to bring its easternmost corner in contact with the
lattice-work, how much must it have gone outward
in order to touch the lattice?—That is, how much it
would have fallen below its natural level on the rails?
18,199. Just so—do you think about 3 feet would it
have been lowered?
18,200. (Mr. Bidder.) That is rather ambiguous;
what do you mean when you say that "it" must have
been lowered 3 feet?—The top edge of the carriage.
18,201. (Mr. Trayner.) The ambiguity was in
your own mind, Mr. Bidder, and not in the question.
(To the witness.) If that carriage tilted over by lateral
pressure, how much would that have reduced its height
from what it would have been, if it had been standing
perpendicularly on the rails?—From 2 to 3 feet, I
think.
18,202. And therefore, if it did strike the lattice-
work, it would have struck it, as you think, between
7 and 8 feet from the level of the rails?—That is so.
18,203. Can you conceive that carriage in any way
not running alongside of the girder, but tilted over or
thrown over from the railway, that it could have struck
the girder at a height of 11 feet above the rail?—I
cannot understand it.
18,204. Do you accept that jumping theory of Mr.
Armit's?—No, I do not accept it at all.
18,205. Can you conceive of any way in which that
carriage, tilted over by the natural force of the wind,
could have made a mark upon the girder 5 or 6 feet
above the level of the rail?
(The Commissioner.) 6 or 7 feet, the evidence was.
(The Witness.) If it was possible that the carriage
had tilted over and touched any portion of the girder,
I believe there might be the slightest suspicion of a
mark, if it was inspected immediately afterwards; but
that would be all, because my opinion is that the body
of this carriage was so weak of itself that it would
stand very little compression in that direction.
18,206. (The Commissioner.) Would you repeat
that answer, which seems rather an important one?
If the body of the carriage had struck any portion
of the bridge whilst running, I believe that it would
have gone to matchwood, and would have left no indications
at all on the girder.
18,207. (Mr. Trayner.) Do you think that
that second-class carriage, even if it was up at that hight,
could have struck upon the outer plate with such force
as to leave splinters of its own wood between the
plates that were riveted?—I do not think so; not at
11 feet.
18,208. At any number of feet, do you think that
the carriage could have driven splinters of itself in
between those two riveted plates?—I do not think so.
18,209. How do you account for the bending of the
axles?—The only solution of the question that I can
get is, that after the girder went over, the longitudi-
inals in which the rails were fixed had sprung together,
and the minor rails, or guard rails, being higher than
the outer ones, had caught as they sprung the flange
of the tire back and front, and it had been in,
because I find that all the axle-boxes were about the
same radius at or near the centre, and the wheels that
are under the van, and the wheels that are under
the second-class carriage, stand with that bending to
the bottom of the carriage, or upwards from the centre
of the wheels.
18,210. (Col. Yolland.) All the wheels?—Yes.
18,211. (Mr. Trayner.) The whole length of the
train?—No, only those that are left in. I am dealing
with the second-class carriage and the break van.
18,212. The wheels that are there are bent in
towards the centre, and your opinion is that that
was occasioned by the nipping of the rails, the time
when the girder took its cut?—At some portion
of the time when it was canted over until it reached
the water. It was occasioned by the nipping of the
latticework.
18,213. (Mr. Barlow.) Bringing the two longitudi-
nals nearer together?—Yes.
18,214. They being fixed upon a series of transverse
iron beams?—The beams were fixed that way, but we
found the day after the accident took place, that many
of those longitudinal beams were down at the ferry
three miles away. These are the longitudinal timbers,
ot the wrought-iron beams.
18,215. What do you imagine to have occurred to
shift the longitudinal timbers?—Nothing could have
occurred, only the weight coming down in this direc-

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Mr. D. Drummond. 4 May 1860.
tion on its side (describing the same). The weight of the girders falling on its side could have mopped the longitudinal.

18,216. (Col. Yolland.) Do you imagine that these bends in the tie-rods were caused by the slipping of the longitudinal also?—That is my opinion, because these tie-beams are held from the outside. There is nothing to support them, as if it had had the line or not?—I only think that any of the carriages left the rails until the girders had left their place on the pillars.

18,224. These are traces of the axles of the wheels of the second-class carriage as found (handing some traces to the witness)?—Yes.

18,226. Are they accurate?—Yes, they are taken from them actually as they are.

Examined by Mr. Bidder.

18,236. You say you do not think that any of the carriages had left the rails until the girders had left the pillars; is that an opinion arrived at after carefully considering all the conditions of the question?—After carefully looking over the state of the plant when found and examined by me.

18,237. It is simply an opinion formed from examining the carriages?—That is all.

18,238. Have you carefully considered at all the evidence that has been adduced here?—In what way? There has been so much evidence.]

18,239. That opinion was formed by you before you had heard any of the evidence which has been called here upon the subject as regards the condition of the girders and other matters presented to bear upon the question?—I have not examined the girders in any way at all.

18,240. Will you attend to my question, if you please. Was that opinion formed before you had heard any of the evidence given here with reference to the condition of the girders and other matters bearing upon the question?—That is so.

18,241. I want to test the care with which you have carried out this matter and given your evidence. You tell us that the second-class carriage had a height above the rails of 10 feet or 10 feet 6 inches at the top of the roof?—That is so.

18,242. And that in turning over to come in contact with the girders it would lose about 8 feet of its height?—From 2 to 3 feet, I said.

18,243. Is that the result of calculation?—It is not.

18,244. Would you be surprised to hear that it would only lose 6 inches?—Yes, I should be surprised to hear that.

(The Commissioner.) It would lose more than that. I have worked it out to be about a foot, assuming the height to be 10 feet and the distance from the girders to be 4 feet.

(Mr. Bidder.) It is about 2 feet 6 inches.

(The Witness.) I assume the carriage to be 7 feet wide.

18,245. If you will turn to drawing No. 5 of Mr. Law's, you will find the carriage shown in the girders, and the scale being a quarter of an inch to a foot, as near as I can see it, from the edge of the girders to the edge of the carriage is 2 feet 6 inches. If you take a perpendicular height of 10 feet to the edge of the roof, and a horizontal motion of 2 feet 6 inches, I think you will find that there is a loss of somewhere about 6 inches.—At what width did you take the carriage?

18,246. I do not take the carriage to be any width at all. If you will refer, you will see Mr. Law's section of the girders and the carriage. I scale it from Mr. Law's own picture.

(Mr. Traynor.) This is not the second-class carriage in Mr. Law's picture.

(Mr. Bidder.) What is it?

(Mr. Traynor.) It is the first-class carriage.

(Mr. Bidder.) I do not know how you know that.

(Mr. Traynor.) Pardon me for asking how you know that it is the second-class carriage. It does not appear on the picture, that is, as a second-class carriage.
18,247. Neither does it appear that it is a first-class carriage. (To the witness) Is there any material difference in the width of the carriages?—I think there is about four inches difference in these carriages.

18,248. Do you know what was about the width of the second-class carriage?—The width of the second-class will be about—

18,249. Do you know what it was?—I do not know to an eighth of an inch, but I know to within an inch of it. The outside would be about 6 feet 11 to 7 feet.

18,250. The carriage drawn by Mr. Law is shown as having a width of 7 feet 9 inches, or 7 feet 10 inches, or 8 feet, as the new carriage. Mr. Law.

18,251. And there are projecting eaves on each side, which makes it, over 8 feet?—That carriage is 7 feet 6 inches, if it is the first-class carriage outside.

18,252. Do you know what was the width of that second-class carriage at the eaves?—It would be about 7 feet 7 feet 6 inches.

18,253. Have you ever measured it?—I have not measured that particular carriage.

18,254. Then you do not know?—I do not know, because it was not there for me to measure it.

18,255. You are merely speculating what it would be likely to be, without knowing the fact?—Without knowing the fact, as the carriage is not there to measure it.

(The Commissioner.) I think it does make it only about 6 inches. My assumption was that it was 4 feet from the girder.

18,256. (Mr. Bidder.) That would make it of a good deal more. (To the witness.) Take it now, and see how much it is about 6 inches. Why, you get into the witness box and give a reckless statement that it is 8 feet without having taken the trouble to verify the calculation as to, on an important inquiry like this?—I was mistaken in my figures this morning, I took 4 feet from the side of the carriage to the side of the bar of the girder.

18,257. But that will not do. Supposing that you did take 4 feet, that would not have landed you anywhere near 3 feet in less of height, because with 10 feet in height and 4 feet you would still have something over 9 feet left?—I did not give that evidence, I only gave it as my opinion that it would be so.

18,258. Do you think it was becoming of you in an important inquiry of this kind, you being called to contradict the evidence and opinion of other witnesses, to give your evidence without taking the slightest trouble to ascertain whether it was accurate or not.

(Mr. Bidder.) I do not think that you have any right to say that. This gentleman is not called to contradict anybody's evidence. He is called to give evidence as to certain matters which are within his own province and his own knowledge.

(The Commissioner.) I thought at the time that he was going to say that it was a mere guess.

(The Witness.) I feel the importance of every one giving evidence here so truthfully as they can possibly give it, for the purpose that every one shall be able to draw some conclusion as to the cause of this accident, and I made the statement with reserve, giving it as my opinion, not as having actually measured the thing that was to be shown.

18,260. (Mr. Bidder.) Will you pardon me, for reminding you that in your evidence this morning you gave it as your opinion, if you please, that the height of the carriage, as shown over would be some three feet, and that consequently the height of the carriage would not account for the marks that have been indicated on the girder?—That is so.

18,261. And you gave that opinion in contradiction to the opinion of those who have stated otherwise, without having taken the slightest trouble to make any calculation to ascertain whether the fact was so or not?—That is not so.

18,262. What calculation have you made, because no calculation could have led you to three feet?—It was not calculated. I took the height of the girder as 10 feet from the edge, and I knew that if that mark which was on the drawing showed 11 feet from the rail level, it was not possible that it could get to there at all.

18,263. I am cross-examining you about the 11 feet, I am cross-examining you about your own evidence?—And that is what I gave it on, the information which I have already received at this Court as to the height from the rail level to the marks on the girder.

18,264. You are rather trying to lead me away, but I am not going to be led away?—I am not doing so.

18,265. You stated in your evidence (which, let me remind you, is upon oath, and upon an important inquiry), that the tilting of the carriage would lose 3 feet of its height, and that therefore any marks made by the carriage would only be at a height of some 7 feet on the girder. Am I to understand that you did that without making any calculation whatever to ascertain what the fact was?—That is so.

18,266. May I take that as a fair example of the care with which you have investigated this question upon which you are now giving your opinion.

(Mr. Traynor.) That is not a question which Mr. Bidder has any right to put, and it is a question which the witness is not bound to answer.

(The Commissioner.) You would not answer that question. The witness himself, when he stated that about the 3 feet, said at the same time that it was a mere guess, and I think if we are to treat all witnesses who come forward in this way, we shall never get to the end of the inquiry.

(Mr. Bidder.) I must claim the right of a certain discretion as to the way in which I put my questions in cross-examination, and you will find, Sir, when you refer to the shorthand writer's notes to-morrow, that it was given as a piece of positive evidence by the witness.

(The Commissioner.) And he stated that it was without any calculation having been made.

(Mr. Bidder.) I am at a loss to understand upon what ground the question is objected to. The witness is a gentleman who comes forward as a skilled witness, and he gives evidence of having carefully examined all the carriages, and of having considered the subject, and then he winds up his evidence by giving it as his opinion that the carriages had not left the bridge, or that the left the bridge. That is an opinion given by a gentleman, who is supposed to have a certain amount of skill and scientific knowledge, upon a matter of considerable importance in this inquiry. It is my duty to cross-examine that gentleman to test the value of his evidence, and to find out the amount of weight that is to be attached to his evidence, and I am perfectly entitled to ask him that if the carriages had left the bridge, or not. That is a fair example of the care, or want of care, which has characterised his general consideration of this question.

(Mr. Traynor.) I object to the question, and surely it will not be argued that it is a fair example of the care, because Mr. Bidder, after making a speech upon something totally different from the relevancy of the question put to the witness, concludes by saying that surely it is relevant. Sir, it is quite fair for Mr. Bidder to comment upon this evidence as he thinks right when the evidence is concluded, and he may say that Mr. Drummond gave his evidence without having either made sufficient inquiry or instructed himself in such a way as to enable him to give an opinion that...
Mr. D. Drummond.

4 May 1880.

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\[ \text{18,285.} \]

\[ \text{18,286.} \]

\[ \text{18,287.} \]

\[ \text{18,288.} \]

\[ \text{18,289.} \]

\[ \text{18,290.} \]

\[ \text{18,291. (The Commissioner.)} \]

\[ \text{18,292.} \]

\[ \text{18,293.} \]

\[ \text{18,294.} \]

\[ \text{18,295.} \]

\[ \text{18,296.} \]

\[ \text{18,297.} \]

\[ \text{18,298.} \]

\[ \text{18,299.} \]

\[ \text{18,300.} \]

\[ \text{18,301.} \]

\[ \text{TAX BRIDGE DISASTER:} \]

\[ \text{the strength of the structure that-it goes against at} \]

\[ \text{a high velocity.} \]

\[ \text{I do not suppose that a tallow candle} \]

\[ \text{would go through a wrought-iron beam, supposing that} \]

\[ \text{you fired it at it.} \]

\[ \text{18,281. I am not quite sure about that; it is a} \]

\[ \text{question of velocity.} \]

\[ \text{As I darsey you know, a lead} \]

\[ \text{bullet will go through an iron plate?-I do not know} \]

\[ \text{from my own knowledge.} \]

\[ \text{18,282. But you seriously put it forward as your} \]

\[ \text{view that the greater the velocity the train the less} \]

\[ \text{will be the chance of any injury upon the iron?}-That} \]

\[ \text{is my opinion.} \]

\[ \text{18,283. If it were going very slowly indeed it might} \]

\[ \text{damage the iron?—It would be very much more ready} \]

\[ \text{to do it.} \]

\[ \text{18,284. I just wanted to see the grounds upon which} \]

\[ \text{your opinion was based. You also said that you} \]

\[ \text{attributed the bending of the axles of the carriages} \]

\[ \text{to the nipping together of the way-beams?—That is so.} \]

\[ \text{18,286. Do you mean the coming together of the} \]

\[ \text{way-beams before the girder fall, or after its fall,} \]

\[ \text{or during its fall?—Either after or during its fall.} \]

\[ \text{18,287. Were the axles of the carriages in the} \]

\[ \text{fore-part of the train bent?—They were all bent that we} \]

\[ \text{found; there were two or three of the axles of the} \]

\[ \text{wheels found a little bent.} \]

\[ \text{18,288. Did you see No. 5 girder in which these} \]

\[ \text{fore carriages were found?—I did.} \]

\[ \text{18,289. Did you notice that the way-beams had not} \]

\[ \text{come together?—I noticed that they had come a little} \]

\[ \text{together.} \]

\[ \text{18,289. To what extent; did you measure them?—} \]

\[ \text{I did not measure them.} \]

\[ \text{18,290. The photograph tells us that substantially} \]

\[ \text{they have not come together. I do not know whether} \]

\[ \text{you heard the evidence of Mr. Waddell this morning} \]

\[ \text{that they were within half an inch of their gauge.} \]

\[ \text{Do you see sufficient coming together in that} \]

\[ \text{permanent way to account for the bent axles which you} \]

\[ \text{speaks of?—I believe the axles were bent before they} \]

\[ \text{got that length; these two carriages at the rear end of} \]

\[ \text{the train.} \]

\[ \text{18,291. I am not talking of the carriages at the rear} \]

\[ \text{end of the train. Do not lead me away to something} \]

\[ \text{else. I am talking about carriages which were in} \]

\[ \text{that girder, and which you say had their axles bent;} \]

\[ \text{I am testing your theory, you know.} \]

\[ \text{18,292. (The Commissioner.)} \]

\[ \text{18,293. (Mr. Bidder.)} \]

\[ \text{Now, I hand you the} \]

\[ \text{photograph of the bridge to the rail level is quite sufficient to allow that} \]

\[ \text{to spring in.} \]

\[ \text{18,294. Do you mean that they had come back} \]

\[ \text{again to their original position?—Not all of them.} \]

\[ \text{I believe that these things have sprung together.} \]

\[ \text{18,295. And recovered their original position?—To} \]

\[ \text{a certain extent, that is my opinion.} \]

\[ \text{18,296. Are you aware that there are packing pieces} \]

\[ \text{between the two way-beams of something like six} \]

\[ \text{inches thick of timber?—That is at the bottom of} \]

\[ \text{them.} \]

\[ \text{18,297. And that those must be broken or removed} \]

\[ \text{before they can come together?—No, I do not think} \]

\[ \text{they would, because the distance from the sill of} \]

\[ \text{the bridge to the rail level is quite sufficient to allow} \]

\[ \text{that to spring in.} \]

\[ \text{18,298. (Mr. Bidder.)} \]

\[ \text{I do not know whether you have a} \]

\[ \text{copy of the photograph before you, Sir.} \]

\[ \text{18,299. (The Commissioner.) We have a plan here of} \]

\[ \text{Mr. Law's. The photograph shows it better.} \]

\[ \text{(To the witness.) I should like you to explain to the} \]

\[ \text{Court how these rails could have come together before that planking was} \]

\[ \text{either started or broken, or in some way got out of the way.} \]

\[ \text{You see there is planking both between the permanent} \]

\[ \text{way-beams and also between the outsides of} \]

\[ \text{them.} \]
the beam of the bridge?—Yes; but I do not believe that the planking would be tight enough inside to prevent it from springing.

18,302. Take the way-beams; how could those two way-beams possibly come together while that planking was there between them?—It is quite possible that if the planking had been up to the very top, it would not have sprung so long as the planking remained there.

(Mr. Barlow.) As a matter of fact these way-beams are bolted to the girders, are they not.

(Mr. Bidder.) Yes, they are bolted to the fish belly girders.

(Mr. Barlow.) I do not see myself how they are to come together when they are so bolted.

18,303. (Col. Yolland.) The longitudinal timbers would be bolted to the cross beams?—Yes.

18,301. (Mr. Bidder.) I want to test the value of your opinion. Just explain how it is possible that these things could have come together and then sprung back to their original position after the bridge had fallen, so that anybody looking at them would imagine that they had not come together?—My opinion is, this bridge fell on the weight on the two sides, either in getting over or on coming in contact with the water. The inside part of this bridge, to spring and catch the tides on the inner flange and the outer flange.

18,302. Does it occur to you that there could be no other weight until it had got to the bottom and whilst it was falling?—There would be no weight so long as the two were going at the same velocity.

18,308. And therefore the thing could only happen when it got to the bottom of the river?—I should think that it would be very difficult to tell what happened while this was going down.

18,304. Does it not occur to you that what you suggest as the thing to nip the way-beams together, the weight of the upper girder squeezing down the other, could only come into play after the thing had got to the bottom of the river?—Or in contact with the water.

18,305. You think that the resistance of the water would be enough to do it?—I should think so.

18,306. Does not the position of the carriages that have been show that by that time they had got away from the rails altogether?—I do not think so. I think the carriages had left the rails before they got to the water. It was the force of the water, in my opinion, that brought the carriages on to their wheels again.

18,307. You think that the force of the water squeezed these permanent way-beams together, and that they have since recovered their position?—Anybody examining them would see that they had been together.

18,308. On the photograph?—No, on the girder itself.

18,309. Have you examined them on the girder?—I have to a certain extent.

18,310. Have they started from the cross-beams?—They seem started; the permanent way seems started.

18,311. Have the longitudinals of the bolts been born or bent?—I cannot say about their being bent, but they are not short. The beams are there all the same.

18,312. Did you measure the gauge?—I did not measure the gauge.

18,313. Did you take any trouble to ascertain whether they had come together by the hundredth part of an inch?—I did not.

18,314. Then in that evidence you are giving your opinion without any observation or measurement whatever?—That is so.

18,315. I will not put the question that has been objected to before; I will leave the inference to be drawn.

(Mr. Barlow.) May I ask which girder is represented in this photograph?

(Mr. Bidder.) No. 5. (To the witness.) You said, if I followed your evidence aright, that if the second-class carriage on the first tile over it would, in your opinion, be on the east side of the girder, and the rear of the carriage towards the west?—That is, if the bottom portion of it struck sufficiently to resist the impetus that it got, it would turn round, in my opinion.

18,317. In the ordinary course of things, would the guard's van be coupled up, buffers to buffers, close in contact with the carriage in front of it?—That is so.

18,318. And under those circumstances would there be any room for the rear end of the second-class carriage to pass to the windward, so to speak, to the westward?—Yes.

18,319. Would it not inevitably be caught by the guard's van as soon as it tilted over to leeward?—It would.

18,320. And if it was caught by the guard's van, how is it possible that the end of it would get past the guard's van to the westward?—Because the couplings are sufficiently long to allow the buffers to slip past one past the other.

18,321. I am afraid you do not follow me, we assume that the second-class carriage has got a tilt over to the eastward by the wind?—That is so.

18,322. So that its eastward buffer would have slipped to the eastward of the guard's van buffer?—It would have slipped to the west, I should take it.

18,323. Pardon me, do me the favour to follow me for a minute. The first effect of its tilting to the eastward would be that the buffer on that side would have a cant to the eastward apparently?—It would be so.

18,324. And it would be therefore to the eastward of the buffer of the van?—That is so.

18,325. If the tilting goes on further until the edge of the carriage catches the lattice, if anything arrest the carriage, will not the guard's van be in to the end of it immediately?—On the east side, because the west side would be above the buffer on the west side, if it was tilted in the manner you describe.

18,326. Can you tell me whether the buffers of the second-class carriage were on the same level as those of the guard's van or not?—I could not tell you whether they would be on the same level as those of the guard's van or not, they would be within an inch or so, we have our standard, 3 feet 5 1/2 inches.

18,327. It is suggested to me that they are a little lower?—They may be an inch or so, but that would be dependent upon the variation after working. Our standards are all alike, 3 feet 5 1/2 inches from the centre of the buffer.

18,328. Do you know at all what would be the average speed of these two carriages at 25 miles an hour?—No, I have not calculated it. It would depend entirely whether in that rate described as 25 miles an hour the weight is concentrated in a solid body or not.

18,329. Do you say that the average depends upon how the weight is concentrated?—No.

18,330. Have you considered what the average speed of those two carriages would be?—No, I have not.

18,331. Have you taken any trouble to make any calculation with a view of ascertaining what would be the effect of the sudden arresting of the momentum of these two carriages by the lattice work of the girder?—I have not.

18,332. Have you taken any trouble whatever to calculate whether it would be sufficient to destroy the tie-bars or not?—I am quite sure that the tie-bars would destroy the carriage.

18,333. That is not my question. Have you taken any trouble whatever to make any calculation or estimate with a view of forming a judgment as to whether there would be sufficient force to destroy the tie-bars?—No, I have not, because I did not know what the force was to begin with.

18,334. You give a confident opinion, without making the calculation?—I do, from my knowledge of the construction of the carriage.
Further examined by Mr. Traftnor.

18,335. The permanent way was covered with planking.—That is so.
18,336. In the photograph of the girder as recovered, you saw that the whole of the planking is gone?—It was all gone as far as I could see.
18,337. And so far as that helped to keep these longitudinal beams in position, it was away?—It was.

Examined by the Commissioner.

18,338. I think you are the manager of the railway?—No, I am the locomotive superintendent of the company.
18,339. Then you have a pretty intimate knowledge of the construction of carriages, I suppose?—Yes.
18,340. And I suppose you have as good a knowledge as the persons who have been produced before you, the divers and others, as to what the effect would be of a carriage coming into contact with girders?—I should think so.
18,341. That question was not put to them, but it was put to you; but you suppose that you answer, I presume, would be just as much entitled to respect as theirs?—I should think so.
18,342. The theory that is put forward is that the train in some way or other (I am not confusing myself as to whether it was one, two, three, or four carriages) came into collision with the eastern girder and broke it, and that that brought the bridge down?—Just so.
18,343. Supposing, for instance, that that were so, and that the girder fell down in that way, carrying, I suppose, the columns with it, would you or would you not suspect that the girder itself would fall near the base of the pillar if the girder broke first?—I should think so.

(Mr. Bidder.) Will you let me suggest to you, Sir, that unless the witness has given the subject consideration, it is extremely unfair to put that question. I am bound to point out to you that you are doing gross injustice in putting such a question, because unless the witness has given careful consideration to the question, if you put it to him off-hand, and got an affirmative answer from him hastily, and it goes down upon the notes, it is supposed to have a certain weight, whereas it is entitled to none. If you had asked the witness if he had considered it, and if he felt that he was in a position to give an opinion, there could have been no objection.

(The Commissioner.) I shall pursue my line of examination, if you please, because it relates to a very important fact in the case, upon which, I think, this witness, who has made these plans, and who has seen the girder, is probably better able to give evidence than anybody else.

(Mr. Bidder.) I do not for one moment object to the importance of the question if you will prefix it by ascertaining whether he has considered the subject.

18,344. (The Commissioner.) I do not know whether any gentleman there has a copy of the plan which has been given to us by the company. (To the witness.) Would you take that plan in your hand; you know that the high girders were divided into three continuous girders?—I am told that that is so.
18,345. Do you not know it as a matter of fact?—Not from my own knowledge.
18,346. You may accept that from me; you may also take it for granted that at the pillar, which is marked 31, on that plan, there is a fixed bearing, do you see that?—I see it.
18,347. And that right and left of it there are roller bearings. You know the construction?—Yes.
18,348. And you know where the expansion joint is at No. 26 and No. 33.—I do not from my own knowledge.
18,349. Then No. 56 has another fixed bearing, has it not?—I observe that.
18,350. No. 29 has another fixed bearing?—That is so.

(Mr. Bidder.) You see, Sir, the witness knows nothing about it.

(The Commissioner.) But these are facts which are admitted in the case.

(Mr. Bidder.) And you are proposing to the witness, who knows nothing about it, who is simply locomotive superintendent and not an engineer, these things about which he knows nothing, and without an instant's consideration you ask him to give an opinion upon a matter which is of the greatest importance in the case; I do formally protest against the extreme injustice of such a proceeding.

(The Commissioner.) If his opinion is entitled to no weight, it will have no weight with the Court.

(Mr. Bidder.) Then, Sir, I submit that the Court ought not to elicit it.

(The Witness.) I think you have made a mistake there, I have not, I have not seen this plan before, nor have I given the construction of the bridge any consideration.

18,361. (The Commissioner.) Did you not send in this plan?—No, all that I have gone into is the carriage plant. I have not considered the bridge in any way at all.
18,362. (The Commissioner.) If that be so I withdraw the question. I understood that this plan had come from you. It was given in by the company. You have only examined the wreck of the carriages, have you?—That I have.
18,363. And also the wreck of the girders?—No, I only examined them casually to find out if I could possibly do so, whether this engine left the rails.
18,364. You have been on the spot?—I have been on the spot.
18,365. But you have not examined exactly how the girders lies?—No, the only thing that I went to Dundee to examine was the condition of the plant, and the condition of the engine as to the regulator and the reversing levers.
18,366. You have sent us in a formal report about it, and therefore we concluded that you had examined carefully into the whole position of the train in the girder, and the position of the girders and everything?—I have examined the carriages, but nothing more than that.
18,367. (Col. Polland.) I think you stated that you had made an examination with a view of endeavouring to ascertain whereabouts the engine or some of the carriages left the rails?—Yes.
18,368. Can you tell us, with reference to the engine, whether, for instance, you are of opinion that it left the rails before it finally stopped?—I am of opinion that it did not. If you take this photograph here you will find two indentations in the rail about 18 inches in front of the third-class carriage that was next to the tender.
18,369. That is the point where you believe the engine left the rails?—That is the point where I believe the engine left the rails. I have measured the distance between those two points, and found the exact centre of the wheel base of the leading and training wheels of the engine.
18,370. What length would that be—7 feet 7 inches.
18,371. What did the least amount to?—It was bent towards the east side; the length would be about 18 inches between the two chairs.
18,372. Was the top of the rail scorched or indented at all?—No, not that I could see.
18,373. That is so much for the engine. Have you formed any opinion with reference to any of the carriages leaving the rails?—None at all. I could see no marks which would give any indication as to when the carriages left the rails.
18,374. You are not prepared to tell the Court anything respecting the state of the girders before they were operated upon by the dynamo?—No, nor afterwards.
18,365. We understand certainly that you were conversant with the position of the girders in every way?—Oh no; it was only with rolling stock.
(Mr. Trayner.) This gentleman never went down below water to see them.
(The Commissioner.) No, but there were times when they could be seen above water.
(Col. Yolland.) Some one must have had knowledge or had information conveyed to him on which this plan was drawn.
(Mr. Trayner.) That plan has been prepared by Sir Thomas Bouch's assistants. I know nothing more about it.
(The Commissioner.) We understood that it came from the company, and now it seems that it comes from Sir Thomas Bouch.
(Mr. Trayner.) Sir Thomas Bouch's assistant, as I understand, having got the fullest information he could from the divers and others working below water, put it up to the best of his knowledge.
(Mr. Bulder.) Although we believe it to be substantially accurate, there are one or two things in the recent proceedings which show it to be not quite accurate. The guard's van was on the second-class carriage, and the third-class carriage had a space between them and the second-class carriage.
(Mr. Barlow.) It would be desirable to have a correct plan put in, or to have that one corrected.
(Mr. Bulder.) That was done by a diver below putting a string upon a certain point, and then the line being drawn as near as could be straight above, and the assistants marking where it was, doing the best they could. We have every reason to believe it to be substantially correct, but there are some errors in it.
(Col. Yolland.) I rather think the understanding when we were at Dundee was that before dynamite was to be brought into operation for pulling the girders to pieces so as to enable it to be raised, all the facts should be ascertained respecting the girders as to where it had been broken, and the Court understood that information would be laid before us.
(The Commissioner.) I must say that I thought that we were to have that certainly.
(Mr. Trayner.) If you look at the report of what took place at Dundee you will see what was said. I will give you a reference as to what was said.
(The Commissioner.) The application was made to us at Dundee, I think, Mr. Trayner.
(Mr. Trayner.) At the end of the third day's evidence this was in the Commission:
Colonel Yolland suggests whether it might not be possible to have the girder raised. Colonel Yolland: All I mean to say is that if it is determined to raise the girders by blowing certain portions of them to pieces, it will be necessary that the actual state of the girders at those parts where the gunpowder or dynamite is applied should be accurately ascertained before the dynamite is applied.
Mr. Balfour: That will be certainly done. And throughout I took leave to make this observation—Do not let it be assumed that in the meantime the Board of Trade will give any authority for blowing up this pier, which is a matter of great difference to the Bench; we should not say anything new, and so on. The diver, the only man who knew anything about it and Mr. Peddie, prepared this plan, and no one else, as Mr. Balfour suggests to me, could have prepared it. Mr. Law tells me that he has been asked for and obtained the permission of the Court to allow the engineers to go on using the dynamite before it was done.
18,366. (Mr. Barlow, to the witness.) I suppose that you, as belonging to the locomotive department, do not venture to infringe upon anything belonging to the engineering department?—I do not.
18,367. You will not undertake to say anything about girders and piers and things of that sort; but you can speak as to engines and carriages?—Just so.
18,368. But there is a certain ground upon which both the engineers and the locomotive superintendent come, and that is about when a train leaves the rails?—That is so.
18,369. They are both in the habit of studying that point?—They are both in the habit of studying that point; they are obliged to do so.
18,370. You do not think that any of the carriages had left the rails until the girders had left their places?—That is my opinion.
18,371. Have you ever known a carriage to be blown off the rails or upset by the wind?—Never.
18,372. Not on exposed viaducts or embankments or anywhere else?—No.
18,373. Neither light carriages nor heavy ones?—Neither light carriages nor heavy ones.
18,374. Will you tell us in what state you found the engine?—The steam shut off?—The steam was not shut off.
18,375. Were the brakes applied?—No, they were not.
18,376. Was there anything to indicate that there had been time to do anything after the appearance of the accident?—There was every indication that there was no time for acting. The reversing lever was standing at the third notch from the centimetre, or six notches from the full forward gear; the regulator was standing full open, and the brake screw on the tender was full off; the brake screw on the brake van in the rear of the train was also off.
18,377. Those would be indications of great suddenness in the character of the accident?—They would be indications of great suddenness. The first thing for a driver to do if there was anything wrong would be to shut the regulator if he felt any jolting with his engine, and the next thing would be to apply the brake. They have to do it often while the engines are slipping in wet weather that it is the first thing that they attempt to do; in fact, they do that before they attempt to put on the brake.
18,378. What did the brakes on the train that had this train?—It had the Westinghouse automatic air brake.
11,379. Would that be worked by the driver?—By the driver.
11,380. Not by the guard?—On this guard's van we had not had it fitted. We had hardly the whole of them done, but not this one.
11,381. Then the only person who had control of the train was the driver?—He was the only person.
11,382. Had the brakes been applied or not?—I could not tell. The screw brake we could tell, but the other we could not. We find on the average that the air brakes will hold from half an hour to twenty minutes. I do not think they would hold long, because the whole of the carriages which had the brake fitted were so destroyed, with the exception of the one next to the tender, which was not destroyed at all, that I do not think it would have been of any service whatever.
11,383. There was nothing in the position of the handles which would enable you to form an opinion as to whether the brakes had been applied or not?—Nothing at all.
11,384. You mentioned that most of the axles in the carriages were bent?—That is so.
11,385. How did you find the axles of the engine?—I have not got the engine lifted, but in moving the engine forward I know that the axles are bent close to the boss of the wheel.
11,386. But not much bent?—Not much bent, but they are bent.
11,387. How about the tender?—The tender is a perfect almost as it was before it went down. It is that with which one of the foot boards is carried off and the tank is burst on the west side for about 12 inches. I think there has been a flaw in the plate and the water has made a slight crack, but nothing to do the tender any damage, in fact it is not scratched at all.
11,388. It is free from damage?—Yes.
11,389. (Col. Yolland.) If the wheel of a carriage in falling come against the ground on one side after a fall of 80 feet instead of falling upon all four wheels
would not that alone be sufficient to bend the axle of the carriage?—In my opinion it would be if it was on dry ground, but not through the water. Falling for that distance on the ground I should expect that the axles would have broken, but not going through the water.

18,390. (Mr. Barlow.) If they fell the height of this room in the open air they would be bent, would they?—Yes.
18,391. If they fell 100 feet into water, do you think there would be a similar result. There was a fall of nearly 100 feet from where they came to where they went?—I find that the open-spoke wheels are just as much bent as the solid boss wheels; they are all solid disc wheels with the exception of the tender and the second-class carriages.

(Mr. Barlow.) I have no more questions to ask the witness, but I should like these photographs to be described, particularly with reference to the form in which the permanent way appears upon them, and with reference to this bending of the ties which has been brought before us this morning. If these came anywhere near a junction pier, there may be a reason for some of this bending that we find upon them.

Can you describe what they are and to which end they apply.

(Mr. Trayner.) We will have that done, Sir, by somebody who knows about it.

The witness withdrew.

(The Commissioner.) Is there anybody else who could give us information about the girders or their position, because we are all very anxious to know exactly the state of these girders before they were blasted with dynamite. That was one of the conditions upon which we allowed dynamite to be used. You see the difficulty in which we are placed.

(Mr. Bidder.) I think I have given you the exact places in which dynamite was used as regards these eastern girders.

(The Commissioner.) Yes, I see you have.

(Mr. Bidder.) I do not know whether any of the witnesses can throw any more light upon it, if I call them. They are in the room.

(The Commissioner.) They have been examined, and we have got what we can out of them.

(Mr. Balfour.) We do not know of any one who can give more information. Apparently each diver works over a very limited space and sees only a very short way; and we have had all the divers, and we know of no one else who can give further evidence upon that point.

(The Commissioner.) And many of them also have been working in thick water.

(Mr. Balfour.) So that apparently it is a very obscure subject.

(The Commissioner.) And you, Mr. Trayner, have no further evidence to call.

(Mr. Trayner.) No, Sir; I have no further information upon the subject.

(Mr. Bidder.) My next witness will be Dr. Pole.

Dr. William Pole, F.R.S., sworn.

Examined by Mr. Bidder.

18,392. You are a civil engineer?—Yes.
18,393. And you are a fellow of the Royal Society of London, and also of the Royal Society of Edinburgh?—Yes.
18,394. And a Member of the Council of the Institution of Civil Engineers?—Yes.
18,395. I believe you have had a great deal of experience in connexion with the designing and construction of iron bridges?—Yes.
18,396. And you have made the subject of the behaviour of cast and wrought iron a matter of special study for many years?—I have.
18,397. I believe that you were engaged in connexion with the Britannia Bridge, over the Menai Straits?—Yes.
18,398. Yes, we were not actually engaged in superintending the construction, but we were consulted by Mr. Robert Stephenson in connexion with the design for that bridge?—Yes, not the designs as they were being made, but afterwards with a view to the calculation of the strains for the book which was published under Mr. Stephenson's authority, and which gave a full and complete account of the methods and all the calculations on which the strains were founded. I understood that matter entirely for Mr. Stephenson.
18,399. And you did make a very complete investigation of the strength and other properties of that structure?—I did. There was a work published by Mr. Edwin Clark, the superintendents of the bridge, under Mr. Stephenson's direction and with his authority, and Mr. Stephenson wished that book to contain a complete account of the principles upon which the bridge had been constructed and full calculations as to its strength and Mr. Stephensons engaged me to undertake that and to write those portions of the work, which I did.
18,400. At that time I think you may say that all wrought iron bridges were a novelty?—Yes.
18,401. And many new questions of which engineers had but little practical experience cropped up in connexion with the introduction of wrought iron for the purpose of bridges of large span?—That is so.
18,402. Such as, I think, the question of the continuity of girders?—That was a new principle then; that was the first large bridge in which it was applied.
18,403. And that was one of the questions which at that time you investigated in connexion with that bridge?—Yes.
18,404. Since then have you had frequent occasion to pursue similar investigations in connexion with other iron bridges of large span, either in testing them, or in calculating them, or in designing them?—Yes, I have.
18,405. I do not think your work has been so much testing in the direction of measuring deflections as in making designs for bridges?—I have made designs for small bridges, but not upon a very large scale; my work has been chiefly in making calculations, but I have designed some bridges.
18,406. In 1873 you undertook, as we know, in conjunction with Mr. Barlow, the examination of a design for a bridge over the Firth of Forth?—Yes.
18,407. And not very long ago you were engaged by the Government to examine and report upon the Chelsea Bridge before its transfer to the Metropolitan Board of Works?—Yes, that involved full calculations of the strength of the bridge.
18,408. As regards the study of iron generally, you were a member, were you not, of the committee which was appointed some years ago by the Government to make investigations as to the use of iron for defensive purposes in war?—I was.
18,409. I believe a long series of very elaborate experiments of a very novel character were undertaken by that committee upon the use and behaviour of iron, and which led to a great extension of the knowledge of the profession upon the subject?—Yes, and upon a very much larger scale than had ever been undertaken before.
18,410. And I believe you have embodied your experience in a well-known work on iron as a material of construction, which is adopted as a standard textbook now?—Yes, I have written such a work.
18,411. You also in your practice have had very large experience of iron generally for railway purposes, have you not?—Yes, I have had to do with the preparation and superintendence of ironwork for railways on a very large scale for many years, and during
that time it has been my business to look to its application to bridges as well as to other parts of railway work.

18,412. (The Commissioner.) Practically or mathematically?—Practically. I had the practical supervision of ironwork for railways on a very large scale, and I have been engaged practically in connexion with ironwork for 50 years. I was brought up in an iron shop, and there has scarcely been a year or more in practice that I have not practically to do with ironwork, so that my knowledge of iron and of its application is not theoretical only, but practical.

18,413. (Mr. Bidder.) You hold at present an engineering appointment under the Board of Trade, do you not?—I do; but that has nothing to do with what I have just been speaking of.

18,414. Were you in the month of January of this year applied to by Sir Thomas Bouch to investigate the circumstances attending the fall of the Tay Bridge?—Yes.

18,415. Previously to that I believe you had no connection with the bridge?—No, not at all.

18,416. Or with its design?—Not in any way.

18,417. And you knew no more about it at that time than the rest of the public?—No, I had never seen the bridge.

18,418. I believe it was in consequence of a request which was made by the Court of Inquiry at Dundee for certain information that you were asked by Sir Thomas Bouch to go to Dundee and visit the site of the bridge, and inspected the ruins generally?—Yes; I only made a superficial inspection; I was there one day; I did not attempt to examine into the details, but I saw the ruins of the bridge.

18,420. (The Commissioner.) In what month was it?—I think it was in February.

18,421. (Mr. Bidder.) You do not pretend to have made an exhaustive examination of the details of the different pieces of iron?—No, I was not engaged for that purpose, and I did not pretend to do so. I had not time, and it was no part of my business to do so.

I was only there one day.

18,422. After that, did you, conjointly with Mr. Stewart, give your very careful attention to the investigation confided to you with a view of answering the questions which had been asked by the Court as regards the strains upon the bridge and other matters that were suggested?—I did.

18,423. And the result of your investigation was embodied in that letter to Sir Thomas Bouch of the 22nd of February which has been printed and which is before the Court?—Yes; I do not know whether that has been put in, but I have a copy of it here.

Perhaps you will allow me to give a copy which has been corrected, as the copies which I have seen are not quite correct.

18,424. (Mr. Trayner.) Will you let us know what the corrections are?—They are verbal corrections.

18,425. (Mr. Bidder.) Are there any alterations in the figures?—No, there are no corrections in the figures of any consequence, except in the table on page 9, in answer to the four questions, Nos. 10, 11, 12, and 13. It is simply that it is not quite clear which of the figures in the column refer to tension and which to compression under the pressure of 40 lbs. The asterisk which is put to the 40 lbs. ought to apply in No. 1 to the figure 1 for the windward 18-inch column; <9 for the two 16-inch columns: <3 for the two 14-inch columns beyond. Then there seems to be a similar correction in the last line of all, where the figures 8, 2, 8, and 10 should have asterisks to indicate that those are tension. That would be understood, I think, by anybody who understands the table, but it is not quite clear.

(Mr. Trayner.) The copy that the Court has is quite right.

(Mr. Bidder.) I am afraid the Court has not got it quite right, because that would look as if all the tension were on the bolts.

(Mr. Barlow.) According to this copy, take, for example, No. 1, having 40 lbs. pressure, three of those results are tension and one is compression, and the same with regard to No. 2.

(Mr. Bidder.) That is right, that is what I intended to be represented.

(The Commissioner.) The tension on the bolts is over three of the columns.

(The Witness.) That is so. That is not clear in the copy that I have, and I think that the Court might be under the same misapprehension.

18,426. (Mr. Bidder.) Is there anything else?—Nothing else, except some verbal corrections. I did not know that it was already formally put in.

18,427. And you are quite prepared to explain your views as to the whole of it?—Yes, if required.

18,428. I think a good deal of it does not bear directly upon the question of the strength of the bridge?—A good deal of it contains the results which the Court required, but which, I suppose, there is no question about, and which need not be repeated. I should think, such as weights and so on; they are agreed to, I believe, in a great measure.

18,429. And the sectional areas of the beams of the girders?—Yes.

18,430. (Mr. Barlow.) I think all the main elements are agreed to. There are some points, perhaps, which are not agreed to about the manner in which they act. The surfaces and the weights are agreed upon, but the results that come from them are not altogether agreed. I think?—We took pains to get the data out from the drawings (of course the data were not known), and I believe there has been no question as regards the accuracy of our calculations.

18,431. (Mr. Bidder.) Mr. Stewart and you, with reference to the strength of the bridge as designed by Sir Thomas Bouch, pursued an entirely independent mode of investigation of your own, I think, did you not?—Mr. Stewart and I together did. We did not work independently; we worked together.

18,432. But you worked an entirely fresh calculation apart from anything that had been done previously by Sir Thomas Bouch or by Mr. Stewart?—Yes, we made use of nothing that had been done before; we calculated the whole entirely a fresh, as if it were a new design.

18,433. And based upon the most accurate data that you could obtain?—Yes.

18,434. Of course there are two distinct main elements of the bridge that you have to consider, first the girders, and secondly the piers?—Yes.

18,435. And in each case I think you considered their strength with reference to two different questions, that is to say, the loading that the bridge may be liable to and the pressure of the wind?—We did.

(The Commissioner.) I think it may perhaps save you trouble, Mr. Bidder, if the Court expresses an opinion upon that point. So far as the girders themselves are concerned, and their strength, the Court has no doubt whatever that they were sufficiently strong. No doubt has been thrown upon that by any portion of the evidence that has been given in this case.

18,436. (Mr. Bidder.) That would enable me, no doubt, to shorten that portion of the examination of Dr. Pole. (To the witness.) I had better ask you this; both as regards the girders and the piers, you have confirmed your calculations to the 15 high spans?—Yes.

18,437. I need not ask you very much about the girders after the information which has just been given by the Court. You had arrived, I believe, by your own calculation at a similar result, that the girders, as girders, were abundantly sufficient for any load or any stress that could be put upon them?—Amply so. The
Mr. Palot. 

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 improving the most admirably designed, and they were, certainly, fully equal to any strength that could possibly be required, either as to loading or as to wind pressure; and I may say a little further and say that I think any engineer looking at the drawings of the girders could not fail to be struck with the great care with which every part had been designed even to the minutest detail. If they were examined, I am not on the test of the examination thoroughly in every respect. Of the girders, we heard, of course, perfect designs, designs which were prepared for the purpose, and which corresponded in every particular, so far as I could understand, with the girders as actually erected, and therefore we had no difficulty in calculating them. My judgment upon them was not only as to the strength, but, as to the merit of the design, was certainly very favourable indeed.

18,438. There is one question which probably, as it is not covered by the question of the efficiency of the girders, I had better ask before I go further on to the piers and the question of wind pressure generally. I dare say, you have heard it suggested that those girders--except on certain piers, simply rested upon the rollers upon the summit of the pier, and that they might with heavy wind force, although the girders themselves were perfectly safe, blow off or slip at any rate and shift their position laterally upon the top of the pier, and so alter the distribution of weights upon the piers, having you considered that?--Yes, we considered, not only the strength of the girders, but every way in which they could fall, either by blowing over, or any other accident. We satisfied ourselves that the strength was sufficient in every way. The continuous girders, of course, fastened brady to one of the piers at its centre, and therefore it cannot blow away or slip upon one of the other piers. It cannot be fastened, because it has to slide by the expansion and contraction, but if there rests upon rollers, and the friction upon those rollers is far greater than the wind force would overcome, and in addition to that there are theflanges of the rollers, and I certainly fail to see how any wind that one can suppose would blow the girders off the piers.

18,439. Mr. Barden.) What were the rollers made of?--Mr. Stewart can tell you better than I can.

18,440. Mr. Barden.) I think they were made of cast-iron, sir. (To the witness.) Putting aside the flanges of the rollers altogether, what was the weight of the girders upon each pier, and what was the friction due to that weight; how does it compare with the wind force that could be brought to bear upon it?--I do not know that I have the figures, but I know that we calculated it.

18,441. The weight of the girders, I think, I have got in your report as 286 tons. That is given in our report.

18,442. What would be the friction due to that apart from any question of the flanges of the rollers?--It would be about one-fourth.

18,443. That is to say about 70 tons?--About 70 tons. I have not the figures, but we satisfied our-
TWENTY-SECOND DAY.

Wednesday, 5th May 1880.

Dr. William Pole, F.R.S., recalled.

Mr. Bidder. I think you may take it that every one of those is No. 5.

Mr. Barlow. But we want to know which is north and which is south.

Mr. Webster. The water pipe is always the east side of the girder.

(The Commissioner.) Where the carriages are standing on their wheels, of course, are all No. 5.

(Mr. Webster.) Yes.

Further examined by Mr. Bidder.

18,460. I think as we left off last night we were just going to discuss the question of the piers, the girders we were relieved from further discussing, the first question I will ask you with reference to the piers is this: I presume, as in the case of the girders, you have to consider the sufficiency of the piers in two aspects; first, with regard to the load, and secondly, with regard to the wind?—Yes.

18,461. I will just take that which I mentioned first, namely, the load; have you considered the sufficiency of the piers with reference to the load apart from any question of wind?—I have.

18,462. What is the result of your investigation in that respect?—The piers in that respect had to sustain the weight of the girders and the moving load. Now, I do not think that I can do better in regard to the moving load than refer to our answer to Question 9, because this question directly applies to that. The question put to us by desire of the Commissioner was to give (a) the estimated maximum pressure in tons per square inch upon the columns near their bases arising from the dead weight of the structure and (b) the additional weight of the engines and train.

Then I will read out our answer to (a) and (b), in the answer we have taken into account the effect of continuity in varying the pressure on the piers; and (c) is right that we should do that, because the effect of continuity is to throw a greater pressure on a certain pier than would come upon it if the girders were ample and independent. It was from the fact that I did not like that into account because I believed, and I still believe by the evidence, that the girders were continuous. Mr. Law doubts it, but that is a matter upon which the Court will form their own opinion; at any rate, we were led to believe that the girders were continuous, and I believe that that was Mr. Grothe’s impression too, and I may say I can hardly think that a question of that importance should have been left doubtful when there were so many people about the bridge who would have known the fact, and when such elaborate preparations had been made for ensuring the continuity by calculating with great precision the angles at which the girders must be lifted to ensure the proper continuity. We have taken that into account, and the result is what I am now going to read—(a) With uniform dead weight of the structure only, the pier most strained is the one between an extreme span and the adjoining intermediate one. That pier bears considerably more than the dead weight of one opening. Adding to this the weight of the portion of the pier above the bearing piers, we find that the maximum pressure on the columns near their base, arising from the dead weight of the structure, will be 14 tons per square inch of metal. Since cast iron of average quality has for its crushing-stress about 40 tons per square inch, it certainly appeared to us that the margin was very ample indeed; that if it gave about one-eighth as the maximum crushing-weights coming upon the wind, without taking into account the effect of the wind. That is to say, the maximum working weight was only one-eighth of what the metal would take.

18,463. I do not know whether it would be convenient to follow that up with the wind pressure, or to come back to it after we have considered the question of wind pressure?—The question of wind pressure is a very important thing indeed.

(Mr. Barlow.) Perhaps I might suggest that at this stage you might put a question about the effect of the inequality of the thickness.

18,464. (Mr. Bidder.) I was going to do that. (To the witness.) You are aware that it appears that some of the columns in this bridge were cast with unequal thicknesses on different sides?—Yes.

18,465. It was said in one extreme case that on one side the thickness was as little as half an inch and five-eighths; I think Mr. Law said that at one point he measured it half an inch—I have observed that myself.

18,466. There were two columns that were five-eighths; I will ask you to give your opinion as to whether such inequality, having regard to the calculations you have made, would in any way imperil the safety of the bridge?—So long as the pressure was fairly down the column, I do not think it would matter at all, it could only matter in the case of some—show irregular pressure coming upon that part of the column in which there was that inequality, in which case it might weaken it; but I do not see anything of that sort that could be expected to come, and therefore I may say generally that I do not think the fact of there being that inequality, although an undoubtedly defect which we were prepared to have examined if we had seen it, could have had any effect in bringing the bridge down. So long as the pressure is straight down the column, the existence of a place anywhere where there was a diminution of thickness so long as the section of the metal was not reduced to an unsafe amount, I do not think could have had any effect upon the strength of the columns have declined.

18,487. Before we go to the wind, taking the load, does the bracing perform any important part in carrying the load when there is no lateral wind strain?—Theoretically, no. If the forces were, as they are assumed theoretically to be, directly down the column, there could be no influence to bend the column at all; and therefore the bracing would be of no use. But that is theory; practically we know that in a long column, through irregularities in the line of pressure, or irregularities in the elasticity, or irregularities of some kind, there is a slight tendency for the column to bend, and therefore in struts or in columns bearing a compressive strain, there must always be braced; but under ordinary circumstances the strain upon the bracing would be very slight indeed. It is more a matter of precaution to prevent them going out of the straight line than as a matter of taking up any calculable stress. There are many cases in bridge building of various kinds, and they must; when they are of any length, be always braced; it is a practical necessity which we know by experience must be attended to. But as a matter of theory, if the pressure passes directly along the line of the strut, there need be no tendency for it to pass out of the straight line, and therefore we cannot calculate, if the forces were...
directly down these columns, that any of those should have any positive strain upon them at all.

18,458. I gather that they do perform practically a certain function; that is, counteracting any tendency of the columns to be deflected—that is what I understand.

18,459. But in performing that function there is no action of moment whatever thrown upon them?—No, no strain that can be calculated; it is merely to provide against irregularities that must exist.

18,460. A regulating office, if you may say so—Yes; one could not attempt to calculate the stress upon those struts and ties; at least, I do not think I could; supposing there was nothing but the dead load on the bridge, it should not know how to apply that theory to it.

18,461. There was a point raised by Mr. Law; I do not know whether it was put as bearing upon the question of overturning the bridge, but still, as it was alleged to, I will just ask you a question upon it—I intended to have mentioned that Mr. Law distributes the pressure on the columns in rather a different way from what we do. I do not think it is of the slightest importance, because Mr. Law makes the pressure actually less than we do; but in any case, the pressure is so insignificant and so much within the margin, that I should hardly take up the time of the Court in discussing it.

18,462. (The Commissioner.) That is to say, the downward pressure, the weight of the superstructure of the columns, and the live load?—Yes; Mr. Law calculates it in a different way. I do not think that it is a very complicated question of how it is distributed, and particularly when the wind comes in, and it has caused a great deal of anxiety and trouble. I cannot see what Mr. Law said, alike to the point of view, but at the same time I think it would be taking up needlessly the time of the Court to discuss it, because it is a matter of utter insignificance as it appears to me.

18,463. (Mr. Barron.) The margin is so large that it appears to you hardly worth while discussing it?—I think so. I merely say that having heard what Mr. Law says, and giving, of course, all weight to his views, I rather adhere to my own, at the same time, admitting that it is a complicated question.

18,464. (Mr. Bidder.) Upon the subject of wind, your attention has been drawn to the subject of wind on many occasions, I believe, previous to this inquiry?—Yes.

18,465. I should like you to say generally what is your opinion upon the subject of wind pressure?—I can state what was known before the witnesses appeared here.

18,466. You mean what was known to engineers upon the subject of wind pressure?—Yes. The first thing I may mention which was known to engineers generally about wind, was some information obtained from Smeaton. I need not say that Smeaton was not only a great engineer but an eminent philosopher, and he treated all his engineering questions in a philosophical spirit. He investigated about 1769 the power of air and wind to turn water and to turn millstones. At this time musical air and wind had not come into use, and those were the two principal mechanical powers; and he made a very elaborate philosophical investigation of the nature of those powers, and he wrote a paper to the Royal Society upon it. It may omit all he said about water, and merely tell 'you about what he did. He studied the force and power of the wind to turn mills, and made a great many elaborate experiments.

18,467. (The Commissioner.) In what have you before you from the "Transactions"?—This is the original paper, at least it is a copy of the paper published in his works. He gave a good deal of attention to it and he made a great many elaborate experiments on the force of wind, and he inserted in that paper a table which he describes as containing the velocity, and force of wind according to their common applications. He says in regard to the table this: "The following table was communicated to me by my friend Mr. House, and appears to have been constructed with great care from a considerable number of facts and experiments, and having relation to the subject of this article, I here insert it as he sent it to me." Now Smeaton, we well know, would not have given it that authority unless he had had full confidence in it. That table contains an enumeration of the common applications of the force of winds, and puts against those applications the force in pounds per square foot which those winds might be assumed to exercise, and I will read a few of them. What are called high winds, he says, exert a force of 4 to 6 lbs. a square foot. What he calls very high winds exert a force of 7 to 8 to 10 or 9 3/4; and a storm or tempest he describes as exerting a force of 12 to 14, that being equivalent to a velocity of 60 miles an hour, and I believe the relation between pressure and velocity agrees pretty well with what was given by Mr. Scott here. There are then three further items, but in regard to them he says, "I must observe that the evidence for those numbers where the velocity of the wind exceeds 50 miles an hour does not seem of equal authority with that of 50 miles an hour and under." Then those three are, a great storm, which is marked as giving 17.1 lbs. per square foot; a hurricane, which is marked as giving 31.49 lbs per square foot; and the last is a hurricane that team up trees, carries buildings before it, etc. That, I presume, must be a tropical hurricane, not the same thing that occurs in these climes.

18,468. (Mr. Trayner.) Does it happen in Scotland?—I am not aware of it. It occurred to me that that could only have referred to tropical meteorology. That is marked as the highest possible (it being one about which he entertains a doubt), at 49.2 lbs. a square foot. But I believe it is not as a very authoritative one; it has been reprinted and referred to times without end in all sorts of engineering books, and I believe it has furnished and does furnish in engineering note books the chief and, in many cases, the only authority for judging of the force of wind according to its nominal velocity.

18,469. (Mr. Bidder.) If you turn up any encyclopaedia of the present day you will find that table?—I think so, and certainly any engineering note-book which engineers use has it in.

18,470. I think one of the earliest railway bridges in which iron was employed for very large spans was the Britannia Bridge—Is it so?

18,471. And that, as we know, was erected in a locality notoriously subject to very violent storms?—Yes.

18,472. The Menai Straits, over which it was carried, have hilly sides, forming a sort of funnel for the wind, so to speak?—Yes; it is near the high mountains between which the straits form a gully.

18,473. I believe considerable attention was given by Mr. Stephenson in connection with that bridge to the subject of the wind?—Yes.

18,474. And the master was observed very closely by his assistant, Mr. Edwin Clark?—Yes.

18,475. I think some valuable experience was gained by Mr. Clark in that bridge on those great ways, which bears upon the subject, was there not?—Yes.

18,476. Perhaps you will refer to anything which you consider material as bearing upon this inquiry?—Mr. Clark says, at page 465 of this book, "During the violent gales of February last, the heaviest that have occurred for many years, except the ones received on the bridge; you may omit all he said about water, and merely tell you about what he did. He studied the force and power of the wind to turn mills, and made a great many elaborate experiments.

18,477. (The Commissioner.) You are speaking now of the Britannia Bridge?—Yes. In lateral motion, as well as in the vertical, the bridge was subjected to considerable lateral disturbances which were comparatively slight upon the bridge, but were almost as great as those upon the Britannia Bridge. It was not, however, as much as we should like to have it. It was not as much as we should have liked it to be; but it was so, and it was in that manner.
"parts of the length which presented a breadth side to the gale. It was impracticable to pass along the top of the tube except by clinging to the windward edge, and even in this position the distress of those with disgustful people was very great."

18,478. Before you leave that, that observation on the part of Mr. Clark would seem to be in accordance with what the Astronomer Royal described in his Report of 1878—namely, that the violence of the severe gales was extremely local indeed. The one certainly corroborates the other very strongly, and I confess it impressed me very much that the Astronomer Royal should, without knowing anything of this (for I doubt whether he had ever heard of that passage), by his observations on his own gauges, have come to the same result as had been established by experiment by Mr. Clark a quarter of a century before.

18,479. From what was observed in the case of the Britannia Bridge, the gusts were small locally as compared with the whole length of the 450 feet tube.

18,480. Does it appear what was the limit of wind pressure that was assumed as practically to be prohibitive for bridge design?

Mr. Clark. A high figure. Mr. Clark gives a full history of the design of the bridge, and he gives an account of the earliest ideas which Mr. Stephen

son had about it, and he says this:—"Secondly, with respect to the effect of wind, the pressure of a "structure such as this, was taken at 46 lbs. per "square foot, which, excepted horizontally would "amount to a pressure of 277 tons on each tube, or "831 tons over the whole span, which, though con "sidered as being much overrated was yet not in any "way, likely, to prove injurious to the combined "tubes, more especially on account of the play of the "wind when it was not uniplanar, and its action "peculiar. That was only Mr. Stephenson's idea, it does not appear that he ever allowed for such a pressure in designing the bridge; on the contrary, we have evidence further on in the book, which I will proceed to read, showing what his idea actually was about the pressure of the wind when he came to design the bridge that is found in page 789, where the calculations of the bridge are fully given. One heading is "Strength of the tube to resist the lateral force of wind," and then it goes on:—"The Britannia "and Conwy bridges being from their exposed "situation subject to the frequent action of violent "winds, it is desirable to inculcate in what is termed "the necessity to resist pressure in a lateral direction." Then follow the calculations of the strength of the bridge, and then the data are expressed in this way:—"Now a violent storm exerts a force "of about 20 lbs. on every square foot of surface exposed to its direct action." So that Mr. Stephenson must have had in mind that when he first took his figure of 46 lbs. on the square foot, that he reduced it in considering the structure itself to 20 lbs. I think that is clearly deducible from what is in print here."

(Mr. Barlow). I do not know whether it is the proper time to ask this question now, but if the lateral deflection was 1 inch it would be easy to ascertain whether there was a deflection that was 1 inch, and we should then have the effect on the tube of a great storm. If that is not ready now perhaps it might be got ready.

18,481. (Mr. Barlow to the witness). Is that in the book?—I am not quite sure whether it is given.

18,482. That 1 inch was deflection, was it?—I am not quite sure.

18,483. "Lateral motion amounted to 1 inch." I suppose that is deflection. It is a little ambiguous.

(Mr. Barlow). It says, "The tubes were but little affected; although one or two was resting at each end "only on tiles of loose planks, at an elevation of "100 feet, and was neither connected laterally nor "longitudinally with the neighbouring tubes, which "must necessarily quadruple its lateral strength. It's lateral motion amounted under these circumstances "to about 1 inch."

18,484. (Mr. Barlow). That may not be deflection?—No, I know it is calculated. The deflection under the action of the wind is very small indeed.

18,485. (Colonel Holland). Is the 1 inch actual movement or a bending in the centre?—I cannot say; I do not know anything but what the book says.

18,486. (Mr. Bidder). I think from the data of that bridge down to 1873 there is nothing further to be gleaned either from literature or experience that throws any further light upon the subject of wind pressure?—No, I know of nothing more until the Forth Bridge came under consideration. I know of nothing that an engineer could have turned to, to guide him, but what I have read.

18,487. Generally, according to your own experience, what had been up to that time the ordinary practice in the engineering world in dealing with questions of wind?—I agree with General Hutchinson that it was never paid any attention to at all—nothing was allowed for it. It was supposed that it would be covered by the ordinary margin, and particularly in girders of open work, where the wind could not get so much as to make that pressure, but there were thousands of plate girders, but there was certainly no allowance ever made for it.

18,488. We had in Sir Thomas Bouch's evidence the other day the statement that in the case of girders under 200 feet span, the wind was not considered. That represented, as I general, I might say the universal experience of the profession?—So far as I know it did.

(The Commissioner). Under 100 feet; was it not? (Mr. Bidder). No, sir, 200 feet.

(The Witness). Of course, when large structures were built, the question of the wind attracted attention, as it did in the designing of the Menai Bridge, and as it did also in the case of the Forth Bridge; but for small structures I do not think any engineer took it into consideration. He supposed that any action of the wind might be covered by the margin allowed.

18,489. According to your knowledge and experience, there was no arbitrary Board of Trade rule, or anything of that kind?—No, so far as I know, there was no allowance made of the kind.

18,490. In 1873, as we know, Sir Thomas Bouch's plan for the Forth Bridge came under special consideration, being a proposal of a very exceptional character?—Yes.

18,491. And the design for that bridge was submitted to four engineers to report upon, for the benefit of the companies interested in the construction of the bridge?—Yes. They were, I believe, the late Mr. Bidder, Sir John Hawkshaw, Mr. Thomas Harrison, and Mr. Barlow.

18,492. And the duty of investigating in detail the calculations for the design was undertaken by Mr. Barlow and yourself?—Yes. I was asked to help to the four engineers in that matter.

18,493. Assisted, I believe, by Mr. Stewart?—Assisted by Mr. Stewart.

18,494. In discharging that duty, I believe, it was felt that the question of the wind, having regard to the large span attributed to it, required special consideration?—Yes, we stated so in the commencement of that part of our report with regard to the effect of wind; also alluding to the exposed position in which it was placed.

18,495. It was with the view of arriving at just conclusions upon that point that the Astronomer Royal was consulted by Mr. Barlow and yourself before reporting upon the structure?—Yes.

18,496. The report of the Astronomer Royal has been drawn attention to, and been read already. I do not know whether there are any points in it that you would like to draw attention to now?—No; I may merely say that we did not rely upon that report alone. Mr. Barlow and myself went to Greenwich Observatory and had a long consultation with the
Astronomer Royal upon the point, who had before us all his records and discussed them with us very fully, and he explained to us there what he afterwards put in writing and explained those points so satisfactorily that I think I can answer for Mr. Barlow as well as myself when I say that we entirely concurred in his opinion. He showed us the grounds upon which he held his opinion, and we certainly thought it was well founded.

18,497. He came to this conclusion, "Adopting this consideration, I think we may say that the greatest wind pressure to which a plane surface like that of the bridge will be subjected on its whole extent is 10 lbs. per square foot."—Yes.

18,498. The question I want to found upon that is this. Assuming that was a well-founded conclusion with regard to the Forth Bridge, do you see any reason why a different figure should be applicable to this Tay Bridge? I point your attention to this, that it has been suggested that the Forth Bridge was longer than any individual spans of the Tay Bridge, of course it was as we know that each span was 1200 feet?—The only reason why the figure should be increased in the case of the Tay Bridge is because it would be the smaller dimensions, and therefore the probability of a greater action of the wind, also the smaller distance from the pier to the bridge. In the case of the Tay Bridge, I suppose two spans must be taken, because, unless the wind blew over two spans it would not exert its full force on one pier, and the two spans would be nearly 600 feet as compared with the 1600—1800 of the Forth Bridge; and in respect of that smaller distance it may have been considered that the action of the wind makes some increase in the force to be provided for.

18,500. I put it in this way. Assuming 10 lbs. as being sufficient, to provide for in the case of the 1600 feet span, or rather the utmost which you should expect, over the surface of the 1600 feet span, the dimensions due to its being a smaller span per foot that a 300 feet span would be nothing like double—Do not know. I have no means of forming a calculation, but I confess that when I heard that 20 lbs. was estimated for this bridge I thought, judging by previous data, that it was ample.

18,501. In your judgment, according to all knowledge and experience of professional and scientific men, and the best information obtainable at the time when this bridge was designed, was 20 lbs. per square foot for wind an ample allowance for such a structure?—I certainly think so, and I think that would have been the opinion of engineers generally, as far as I know what such an opinion would be. We have heard nothing to the contrary that I know of, and therefore I do not know what weight I could attach to any different opinion.

18,502. You have that figure of 20 lbs. to the square foot as the figure to be provided for investigating the strains upon this bridge, have you not?—Yes, I have.

18,503. Although I believe you have extended your calculation to higher pressures, which you have qualified in your report, by describing them as excessive pressures?—We were desired by the Commissioners to do so, and of course it was our duty to give all the information they desired. At the same time we have marked against those "excessive;" to show that according to our information they were beyond the pressures for which the bridge was designed.

18,504. In applying your calculations to the bridge, of course the question of the surface exposed to wind pressure had to be investigated?—Yes.

18,505. And that you have, I think, done under the fifth head of your report?—Yes, that I think there is no question about.

18,506. I believe you have adopted practically the same view that you took in calculating for the Forth Bridges, and the same view that Mr. Law takes in this case, namely, that the windward girder is half sheltered by the windward girder?—Yes; we were led to adopt that in the case of the Forth Bridge for this reason. The Forth Bridge consists of two roadways, at a considerable distance from each other; and we reckoned the full pressure of the wind upon the windward girder of each roadway, and half of the pressure upon the leeward girder. As the one roadway was a long way off the other we reckoned full pressure upon the windward girder of the second roadway, and half on the girder beyond, so that made in all three times the wind pressure on the front surface; that being exactly the same principle as we have adopted here, it being in that case three times (instead of 14) for the double road. We calculated the Forth Bridge upon that principle, and that is the principle we have continued to use.

18,507. Of course it is a very difficult thing to say how much pressure comes upon the back girder, but we have made the best estimate we could, and I think Mr. Law agrees with it.

18,508. Having so estimated the surface of the girder, I suppose of course you have also dealt with a light passenger train as being the weight which was actually on the bridge at the time when the bridge fell, and also the worst possible case for the bridge?—Yes, that is so.

18,509. You have calculated out the stresses upon the different parts of the pier, we need not trouble ourselves with that part of the problem; but that is the different parts of the pier, and I think it is at page 9 under head 17 the report "Light Passenger Train"?—That refers only to the girders. Those (that refer to the piers are questions 10, 11, 12, and 13.

18,510. The ultimate result of the stresses is given at the end of your report, is it not?—That is as regards the truth of you; the result for the pier itself, and for the columns is given in under the headings 10, 11, 12 and 13.

(Mr. Trayner.) It is at page 19 of the Court's copy.

(Mr. Bulder.) Before I go to the results, I will ask you a question or two more with reference to the mode in which you have arrived at the results.

(Mr. Barlow.) Which of the wind tests are you speaking of, those in the pier or those in the girder?

18,509. (Mr. Bulder.) Those in the pier. I understood that it was not necessary to go into the girders. (To the witness.) You have gone very carefully into the question of the girders in every aspect?—Yes.

18,510. Will you just explain the principle you have adopted in calculating the duty that is to be performed by the different portions of the pier in the case of a high wind?—In the first place the calculation is made with the pier as a whole. The object of this bracing is to bind the several parts of the ironwork firmly together so as to resemble, to a certain extent, a mass of solid material; and the simplest problem is whether a pier so constructed is liable to overturn by lateral pressure. That is a very common engineering problem which has to be solved in all piers and retaining walls, and all structures where there is a side pressure combined with a weight, and the mode of solving that problem is very simple, and is one about which there can be no mistake. There is a certain vertical force, namely, the weight of the pier, and what it carries, this that tend to keep the pier down, and there is a certain horizontal lateral force, namely, the wind which binds it all over, and for the purposes of calculation this force may be considered as all collected at one point. These two forces are then compounded in the usual way, and if their resultant falls at the base of the pier within its solid structure, the pier is stable and cannot overturn.

18,511. Without any holding-down bolts?—Yes, without any holding-down bolts; the holding-down bolts are not wanted in that case. We made our calculations, taking into account the most unfavourable case, namely, that of a light passenger train standing upon a pier, as that gives the greatest force of wind and the least weight to resist it. The total vertical load due to the weights of the pier, the gir-
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18,512. (Mr. Bidder.) You state under head 13 of your report that under that condition which you say is the most unfavourable that can happen, the pier will be stable without bolts until the wind pressure reaches about 344 lbs. beyond which it must be tied down. I think in that we took the centre of the column as being out of the pier; here I have taken the outside of the column.

18,510. (Mr. Law.) I have not treated it in that way, but it comes to the same thing.

18,516. They do not come into tension?—No. Possibly there might be tension upon them if they were there which would relieve the compression upon the other side; but that is a matter of elasticity, and depends upon the very complicated question of how the load is distributed over the 6 feet of the pier, but the pier would be stable without them, it would have no tendency to turn over. And if I may interpolate a remark, I may say that I quite agree with Mr. Law, at question 12,821, that the appearances are quite conclusive that the pier did not give way by overturning as a whole, and therefore the stability in that particular may be considered as established.

18,517. The next thing you had to do was to calculate the strains to prevent the pier going over, if I may use the phrase, parallel-ruler fashion?—We give in this report the stresses on the bases of the columns. I do not know whether you think it worth while to go into that.

18,518. I beg your pardon, I had forgotten that?—We have given them, and we have given also some explanation of how we arrived at them.

18,519. Perhaps you had better give us them; it was my omission not to have asked you about that. Taking the pressure of the wind at 20 lbs. to the square foot, the extreme stress with a light passenger train standing on the pier upon the leeward column is 88 tons to the column.

18,520. That is the compressive force?—Yes.

18,521. The ordinary limit of iron being 40 tons?—Iron of average quality.

18,522. I see your table shows that even if you take those excessive pressures, even 40 lbs., it does not rise above 88 tons per square inch?—No, that is supposing the whole compression to be taken upon that column (pointing to the model), the load falls upon the outside of the pier; and, therefore, supposing the whole of the compression taken upon that column, we make it 88 tons per square inch. That is allowing nothing for the bearing power of the concrete. If the concrete was good it would materially assist the iron, I think, because its bearing power, I think, would be very great.

18,523. You have added this to the end of that paragraph: "We must again state that we cannot believe the two pressures we have marked excessive could ever occur over the whole surface of the pier, larger, and train standing on the other day by the Astronomer Royal and the other gentlemen, who were called upon the subject of meteorology, would modify my opinion if I had time to consider them, but that must be left for the Commissioners to decide. I cannot give my opinion as to how far one's opinion ought to be modified by the evidence we have heard here.

18,524. (The Commissioner.) All that you are now stating is apart from the evidence which has been given in this case?—Yes, I have not considered that; I heard it, but I have not considered it, and I do not know what weight I should attach to it if I had time to consider it.

18,525. (Mr. Bidder.) I do not know whether there are any new facts that we have had here with regard to wind that are not recognised and taken account of in the report of the Astronomer Royal in 1873?—I think not.

18,526. I think he mentioned here the other day that the wind pressure rose to 40 lbs., and he pointed to that as a fact also in 1873?—Yes. I do not see that there are any new facts, but of course it is a startling thing to hear him say that bridges should be designed to bear a pressure of 120 lbs.

18,527. I do not know whether you have had time to calculate what would happen to the majority of large engineering works if that calculation had to be applied to them.

18,528. (Mr. Barlow.) I did not understand the Astronomer Royal to say that he suggested 120 lbs. now in the sense in which he suggested 10 lbs. on a former occasion. When he said 120 lbs., I take that to be including all contingencies, taking a margin of strength.

18,529. (The Commissioner.) What he said was thus: "I recommend that all calculations for the strength of the proposed structure, and especially for the approach (transversely to the bridge, or longitudinally to the "valley" of the bases of the pier be founded on assumption of pressure not less than 120 lbs. on the "square foot.""

18,530. (Mr. Bidder.) We have now dealt with the pressure upon the columns, and with the tensile strain upon the bolts. The weight which you give the maximum is very far within the margin of safety, is it not?—Yes.

18,531. With a pressure of 40 lbs. I see it is 3½ tons to the inch on the outside windward column, and 8½ tons on the outside leeward column?—Yes. In the case of 40 lbs. pressure with a light passenger train, we estimate that the tension on the bolts would be three tons per square inch, two of them here and one there (pointing to the model).

18,532. You have taken no credit in any of these calculations for the bearing power of the concrete inside the columns?—No.

18,533. (Mr. Barlow.) I do not consider the bearing power of the concrete inside the columns separately, have you not?—To stresses on the ties.

18,534. That of course involves the stresses on the ties?—Yes; I have not calculated what the resistance would be to the columns overturning separately,
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18,532. You have proceeded to consider what would be the strains upon the ties, which prevented the thing becoming a separate structure to speak of?—Yes, that is the point; as long as these ties hold their object it is to prevent the columns tumbling over separately.

18,534. As long as the ties are in tension and holding the structure is a whole?—The structure is a whole.

18,535. In what way have you proceeded to investigate the strains upon the ties, assuming a lateral wind pressure?—That is a very complicated and difficult problem, and I have thought it over a great deal.

We have explained in answer to question 16 how we have arrived at it. "The stress on the diagonal ties of the pier are difficult to calculate, seeing that the strains are borne by the constant resistance of many bars in different positions." I may explain that the action of the wind is to produce a shearing force. We have taken the weight out of the question now entirely, for it has nothing to do with it. It produces a shearing force tending to push this aside.

We estimate what that shearing force would be at the top of the lowest tier of columns, and we have calculated the tension in the ties in that tier, and the most strained:—First, we assume a certain small lateral motion of the top plane of the lowest tier of columns produced by a horizontal force applied thereto. Secondly, we calculate geometrically what extension this will give in each tie, and we find the stress corresponding to such extension. Thirdly, we resolve these various stresses into components of force causing the motion of the top plane. Fourthly, we find what resistance the six columns will offer to an amount of bending corresponding to the lateral motion assumed. Finally, by adding together the resolved stresses of the various ties and the resistance of the six columns we obtain the total horizontal force corresponding to the assumed small lateral motion which gives us the relation between any horizontal force applied to the pier and the stress on any given tie.

18,536. You have gone to the top of the bottom tier of columns as I understand, because at that tier you would have in addition to the wind force of the pier the wind force of the whole of the upper part of the pier?—Yes.

18,537. Did you take into consideration that in the upper tier you had a less wind force to deal with, and therefore less shearing action?—Yes, as the ties are all of the same dimensions we have taken these as the most strained.

18,538. You have the greatest lateral force at the top of the bottom tier?—Yes.

18,539. You have taken that as being the most unfavourable, the case in which there is the greatest strain in the tie, have you?—Yes, that would be the case that would have been the most likely to break. I may say, I think we have consulted frequently since we made this report with persons who, we think, are good judges, and we have generally had it admitted that this mode of doing it was as fair a mode as could be adopted, and one likely to give the true strain, although I do not know that that problem has been worked out before, because it is so difficult to arrive at a solution of it, on the account of the number of bars at the different angles which have to be taken into account.

18,540. (Mr. Barlow.) And the obliquity of their planes?—Yes.

18,541. (Mr. Atter.) Of two-thirds of them. I wish to know if you have given the result in a final table at the end of your report?—Yes.

18,542. You give it both ways, without a train and with a light passenger train over the pier?—Yes.

18,543. That shows that with a wind of 20 lbs. with a light passenger train over the pier, you get upon the section a maximum tension of 679 tons per square inch?—Yes.

18,544. That is taken upon the smallest section of the tie?—Yes, that is taking the smallest section of the tie, deducting the bolt hole.

18,545. That is equal to, I think, about 11 tons, is it not?—About 11½ tons on the whole tie.

18,546. (The Commissioner.) That is for 40 lbs.?—Yes. By another independent calculation I make it 6½, a little less. We have given it here as 7½, but I repeated the calculation, and made it a little less.

18,547. (Mr. Bidder.) It is a question which you say is a very troublesome question, and one in which it is not easy to arrive at the final result. I think your result is not the same as Mr. Law's?—I understand that Mr. Law did agree with us, but I am not sure.

18,548. I think not?—Then I am wrong, for I thought he said he agreed with us.

18,549. You have also given it for the excessive pressure of 90 lbs. and 10 lbs.?—Yes, as desired.

18,550. And you have shown what it amounts to per square inch in those cases?—Yes.

18,551. What is it?—10½ for 30 lbs., and 13½ for 40 lbs.

18,552. I want to know what would be the strain upon the whole tie?—It would be 22½ for 40 lbs., just double the 20 lbs., over the whole tie. If we take the 20 lbs. at 11½, we may take the 40 lbs. at 22½ tons.

18,553. (Mr. Bidder.) Whilst I am upon that, I might ask you this. A good deal has been said about the tie-bars and the cotters and the lugs in connection with the tie-bars. Going back to 20 lbs. of wind, you have 6¼ tons to the square inch of metal upon the minimum section of the tie, deducting the bolt hole?—Yes.

18,554. What do you say with reference to that?—It is more than we are in the habit of allowing, the limit being generally 3 tons.

18,555. (Mr. Barlow.) That is with 20 lbs. of wind?—Yes.

18,556. (Mr. Bidder.) That is on the sectional area of the tie?—Yes, excluding the bolt hole, taking it as we are accustomed to take all these bars which have bolt holes through them taking the net section, deducting the bolt holes.

18,557. Taking the strength of the iron at the stipulated minimum in the specification, it still shows less than one-third of the breaking strain of the iron?—We should take the breaking strain of the iron at 21 tons, and this is less than a third, giving a margin of strength of 3 instead of 4.

18,558. (Mr. Barlow.) That is to say, a factor of 3?—Yes.

18,559. (Mr. Bidder.) Are you aware what the breaking strain of the iron, as shown by Mr. Kirkaldy's experiments, was?—I do not recollect, but I think over 2½ tons.

18,560. Twenty-five tons, I think?—I think the iron was uniformly over 20 tons, as far as I can recollect.

(The Commissioner.) I think it varied from 19 to 28.

18,561. (Mr. Webster.) Yes.

18,562. (Mr. Bidder.) Practically, we know that Mr. Kirkaldy's tests show that the iron was as regards its breaking strain in accordance with the specification. With regard to cotters a good deal was said by Mr. Law to the effect that the cotter having a very small bearing surface, only $\frac{1}{2}$ by $\frac{1}{2}$ an inch, the metal would be upset, and he pointed to that as an element of weakness. The tests have shown, I think, that under a very heavy strain the metal would be upset, compressed a little but not much, and the strain does not appear to have damaged the holding strength of the cotters at all.

18,563. That is what I wanted to ask you. Mr. Law said that he had measured one of those cotters that had been tested at Mr. Kirkaldy's, and he found, I think, that there was a fracture of metal to the
18,561. You have an ultimate compression, according to Mr. Law, of 14th of an inch under the breaking strain of the tie, but that would be much less, of course, with the strain that you are calculating here—I think in cases where the iron is not likely to give out, more pressure may be put on, and the experiments do not seem to have shown that the iron has given out in the case of the cotter to any extent to lead to the destruction of the bridge. That has given somewhat under the heavy strain that pulled the bar and I do not deny, but I do not gather from the result of those experiments that small surfaces contributed in any material degree to the weakness of the general structure.

18,562. (Mr. Brindley.) There were two cotters, were there not?—I think in some cases there were two cotters and one gib, and in some cases two gibs and one cotter.

18,563. (Mr. Bidder.) I think I am right in this, that in none of Mr. Kirkaldy's experiments has there been any failure of the cotter—I think not, nor at the cotter hole—I think not, but I am not sure; I speak under correction.

18,564. (The Commissioner.) What do you mean by "at the cotter hole"? The cotter might give, and also the metal beyond the cotter hole.

18,565. The cotter got indented, but none of them gave as far as I understand. In mentioning the cotter hole I meant the portion of the bar beyond the cotter hole. One way of giving way by that being torn away, and there is one case, I think, not in Mr. Kirkaldy's experiments, but in the bridge itself, where I happened to see that.

18,566. (Mr. Bidder.) You have calculated your strain taking a certain lateral motion, of the head of the column, a geometrically corresponding extension of the tie-bar, and the tensions arising in the tie-bars, and the resistance to fixture of the columns in those two cases?—Yes.

18,567. Am I not right in this, if in course of its lateral movement, and it is supposed, say 16th or 14th of an inch, thereby permitting a further extension of the tie by the same strain the effect would be, would it not, that proportionately the head of the column would be further deviated laterally?—Yes.

18,568. Comparatively free to move would be perhaps the right phrase, until the tie-bar came into full tension again? The column would move a little.

18,569. (The Commissioner.) The column would move over until the tie got into tension again?—Yes, assuming the tie-bar got slack.

18,570. (Mr. Bidder.) What I mean is this; in your calculations you have assumed a certain lateral displacement in the head of the column, and a geometrically corresponding extension of the tie-bar?—Yes, the tie-bar being always strained.

18,571. Then there would be a certain tension corresponding to that extension; and then a certain resistance to fixture on the part of the column and those you have calculated?—Yes.

18,572. If under those circumstances you imagine the gib to yield by compression 14th or 14th of an inch, or whatever you like, what would be the result?—The columns would bend a little more and would do a little more work.

18,573. (The Commissioner.) The columns would bend a little more?—And would do a little more work in maintaining the pier.

18,574. (Mr. Bidder.) And pro tanto, would relieve the tie-bar?—Yes.

18,575. (The Commissioner.) The column would do a little more work, you say?—Yes. I may say with regard to the resistance which act to support the force of the wind, supposing the tie to be brought to this direction—on this tie-bar, (passing to the model)—and that one and one, and the corresponding ones on the other side, and also taking into account the force required to produce fixture of these six columns standing rigidly on their bases, they would bend a little over, and would therefore assist to meet the force of the wind. If these ties, supporting it to take place in all of them, were allowed by the compression of the column to extend a little more, the columns would bend a little more, and consequently by that bending, like a spring, they would give a little more resistance. That is the answer to Mr. Bidder's question.

18,576. A little more resistance is what?—A little more resistance to the force of the wind. It takes some strain to bend a column over, and that strain is effective pro tanto in opposing the force of the wind and resisting it.

18,577. Do you mean a bending of the column itself or a displacing of it?—A displacing of it at the top, which means a bending. I suppose that the lower part of the column is firmly tied down with bolts. If the columns were loose there would be no such thing. The column is supposed to be firmly bolted down, so as to have the power of bending when the force of the wind is brought to bear upon it.

18,578. You are assuming that it is permanently fixed at the bottom?—Yes.

18,579. (Mr. Bidder.) In your calculation you assume the column to be firmly rooted to its base?—Yes, I do.

18,580. And, of course, an iron column firmly rooted to its base resists fixture at the top?—Yes.

18,581. So long as the base was immovable there would be very considerable resistance to any lateral displacement at the head?—Yes.

18,582. And that resistance will increase as the displacement increases?—Yes, quite so.

18,583. There is another point in connection with this which it is necessary to take up. That resistance which you have taken into account in these calculations of yours, is far within the limit of the holding down power of the bolts, is it not?—Yes.

18,584. That is to say, as calculated by Mr. Law or by yourself?—I have calculated it myself. The bolts will resist that so long as the tie holds.

18,585. The resistance is correct, and you are given credit for on the part of the columns is far within the resisting power of the bolts to hold down?—That is so.

18,586. And therefore, for the purpose of your calculation, the bolts are firmly rooted to the base?—I have assumed them so, and I think they are so.

18,587. That you are satisfied of?—Yes.

18,588. That being so, as you have just pointed out, the effect of any slight yielding on the part of a gib, or on the part of a bolt, or anything which permits of a slight further lateral displacement of the column, is
18,569. To throw a greater strain upon the column and a less strain upon the tie-bars?—Yes.
18,590. (Mr. Barlow.) Less in proportion?—Yes.
18,591. (Mr. Barlow.) I must ask you another question upon this subject. Are the resistances of columns to flexure, which, according to your calculations would obtain, such as would in any way imperil the integrity of the columns?—I have not calculated that, but I should think not. It is only a slight thing for the 30 lbs. I think it is only a little more than the half of the columns. I have calculated the force to bend it, but I have not calculated the force to break it.

18,592. One other point in the attachment which Mr. Law, referred to, the tie-bar is held at its end by a bolt 1½ inches in diameter?—Yes.
18,593. Have you investigated the strength of that bolt—1½ inch; that is two, assuming the shearing strength of the same as its tensile strength would require about 40 tons, it would require a double shear, that is, stronger than the tie-bars.
18,594. Now, with regard to the lugs, what do you make the area of metal in the lugs? They vary, but I think they are, generally speaking, more than 9 inches. I asked for some examples, and I do not think I got any examples in which the sectional area of the two combined in the weakest place through the hole is less than 9 square inches.
18,595. On which the tension of 11½ tons for 20 lbs. of wind would have to come?—Yes.
18,596. That is, within the limits of safety?—I take the mean tensile strength of good cast iron to be about seven tons per square inch, that would give nine times seven—56 tons—as the calculated breaking force of the tie-bar lugs.
18,597. (Mr. Barlow.) What did Mr. Kirkaldy's experiments show it to be?—I think 20 to 27.
18,598. That is about a third of the calculated weight?—Yes; I am merely stating what an engineer would calculate those lugs to be able to bear in designing the bridge.
18,599. (Mr. Rodger.) As a matter of fact, they did break with 23, 24, and 25 tons at Mr. Kirkaldy's that is a long way beyond your strain of 20 lbs. of wind?—It is more than double.
18,600. I want to draw your attention to another matter. In connection with the lugs, and that as to the conical holes. We are told that in the case of some of the lugs there was a taper in the holes?—Yes, I know the form of the holes.
18,601. Sir Thomas Beech said that he would not have allowed a conical hole if he had known it. Will you just give your views upon that subject?—I hardly know without experiment what the effect of a conical hole would be. I think Sir Thomas Beech said if the difference in size was not very large, the bolt would by bending, adapt itself to the surface and bear equally throughout. Whether that would be so I do not know; I cannot give any opinion as to what the effect of the conical hole would be without experiment made for that purpose. I would agree with Sir Thomas Beech that I would rather have had the bearings plain and fair. I have not taken any account of the conical holes in considering the design, because I cannot suppose that they were designed so. I have taken the strength, as the engineer would have been justified in considering it in making the design.
18,602. (The Commissioner.) Apart from any defects?—Yes.
18,603. (Mr. Rider.) I want to ask you one or two questions generally upon that. As I understand in your judgment and of course I am confusing myself to the piers, the girders being out of the question—the design of these piers, as a design, was quite sufficient to carry the loads that the bridge had to carry, and to meet any force of wind that could reasonably be estimated?—Yes; 20 lbs. of wind with a large margin.
18,604. And you have satisfied yourself that the design was ample for 20 lbs. of wind?—Yes.
18,605. Applying your calculation to the things as constructed, and taking the results of Mr. Kirkaldy's tests upon the tie-bars and the lugs, which with tensions of 21 and 25 tons—assuming that those results are correct, as representing the actual state of the bridge in your judgment, would it give way to any static force of wind that could be expected to come upon it?—No, I cannot think that a static force of wind could have been expected to come upon this bridge which would have anything to do with the top of the columns. I have calculated the force to bend it, but I have not calculated the force to break it.
18,606. Even taking into account the diminished breaking strain of the lugs, which, as you have pointed out, is so much less than reasonably it ought to have been?—Yes.
18,607. What would you say was more probable as being the explicable cause of what happened to the Tay Bridge?—As I cannot think that a static force would have broken down the bridge—any static force that as far as I know could come upon it, I think the rupture must have been caused by the superaddition to the static force already existing of something like a shock of some kind. The bridge had been already strained considerably by the wind, as nobody denies; and if I am right in being unable to find any static force that was sufficient to rupture it, I can only conclude that there must have been something superadded, and the most reasonable supposition to my mind is that some thing should have caused the nature of a shock, and I am led in a great measure to think that that is rendered probable by the fact that which struck me at the very first moment I looked at the bridge, and that is that it is almost universally the cast iron that has gone and not the wrought iron. I do not know the details, but the fact impressed itself very strongly upon my mind that in all the broken cast iron it was broken by a rupture of the cast iron and not by any fracture of the ties themselves; and since we know that cast iron gives way so much more readily under shocks than wrought iron and will resist static pressure very well, it occurred to me as an explanation worthy of consideration whether there might not have been a shock in addition to the static strain which broke those lugs.
18,608. Have you in connexion with this part of the case, carefully calculated the wind pressure that would have have been sufficient to overturn the second-class carriage, which, as we know, was the lightest carriage in the train, upon the bridge at the time of the accident?—We have calculated that, and we have given it in our answer to question 6. Although we were not asked that question we thought it desirable to mention it, and we gave there our opinion that 28½ lbs. per square foot would overturn a second-class carriage in the open, and 30½ lbs. per square foot allowing for any windage of the bridge. Mr. Law has pointed out that in our calculation there were two elements which we did not consider. In the first place, that we did not allow for there being any passengers in the carriage. He tells us that there were eight, and he points out also that there was a 'little force exercised by the wind in keeping the carriage down and fair.' I have not taken any account of the conical holes in considering the design, because I cannot suppose that they were designed so. I have taken the strength, as the engineer would have been justified in considering it in making the design.
18,609. (The Commissioner.) Apart from any defects?—Yes.
18,610. (Mr. Rider.) I want to ask you one or two questions generally upon that. As I understand in your judgment—and of course I am confusing myself to the piers, the girders being out of the question—the design of these piers, as a design, was quite sufficient to carry the loads that the bridge had to carry, and to meet any force of wind that could reasonably be estimated?—Yes; 20 lbs. of wind with a large margin.
18,611. You say under all those circumstances a pressure of 33 lbs. of wind overcomes the stability of
the carriage?—Yes, I make it so. Mr. Law makes it so more. We have gone into the calculation very carefully, and that is what we make of it.

18.612. (Col. Yolland.) That is, under shelter—Yes, allowing for shelter.

[Mr. Webster.] It corresponds with the 30.2 which Mr. Law gave.

18.613. (Mr. Bidder.) There being, as we know, a very heavy storm raging at the time this train passed over the bridge, would it not be natural to assume that you might, and would, have considerably average pressures on a limited space, like the side of a carriage, than you could possibly have over large areas like two of these girders?—Yes, Mr. Edwin Clark's observations and the Astronomer Royal's theory both tell us that.

18.614. Have you heard the evidence that the windward wheel of the carriage was grinding against the guard rail, and producing a stream of sparks from it?—Yes, I understand that was observed.

18.615. Have you anything to say with reference to the effect of that?—I think there might be, owing to that, some tendency on the part of the carriage to mount the guard rail. That is a very unusual action. They generally bear a little against the wind, we are under ordinary circumstances. The flat part of the flange would bear hard against the rail by the pressure of the wind, and we know that it bore so hard as to cut the rail almost to pieces. That flat surface grinding against the guard rail, when the carriage was dragged so tightly, might give some tendency to the carriage to mount the rail.

18.616. Putting that on one side, if your calculations are correct, and especially bearing in mind that you get a higher pressure upon a limited space than a large one, the overturning point of the carriage is reached; is that to say, the point at which the carriage would turn over, long before you reach the point of the danger to the bridge in wind pressure?—Yes.

18.617. Assuming that in point of fact the two last carriages, we will not take into consideration at present what has been said about the possibility of the others having left the rails—assumed that the two last carriages, that is to say, the second-class carriage and the guard's van, left the rails and came into collision with the leeward girder, have you taken into your consideration whether the effect of that impact would be such as to imperil the safety of the bridge, already under tension, in the way in which it was?—I have already answered that question upon that point.

18.618. How do you deal with that question of the effect of the impact of a body like that upon the girder, the train going at a high velocity?—During the experiments on iron armour, which, as I said, lasted many years, it was very frequently necessary to consider the effect of impact of heavy bodies moving at high velocities, and we had occasion very often to use a formula which we gave. It is a formula very well known, based on ordinary mechanical principles; and I can, perhaps, put the substance of it in words. Every heavy body in motion carries with it a certain definite amount of mechanical power or work. This exact amount of power or work has been expended in giving the body its velocity, and exactly the same amount of power or work has been expended again by the body, before it can come to rest. Therefore, in calculating the effect of shot, if we measured its velocity by a machine, we should know its weight, and we could tell what amount of mechanical power or work had been put into it by the gunpowder; and we should know what that amount of power or work would have been upon the plate, or whatever was struck. And we were able in that way to calculate the effect of shot more accurately than by any other mode. We tested the correctness of this formula by the new thermo-dynamic theories. In some cases we found the quantity of heat given out by shot in striking, and we found it to agree very well with the amount of work that ought to have been in the shot. Applying this principle to a railway train we may say that in ordinary cases it is very applicable. In getting up the velocity of a train there is a certain amount of work put into it by the action of the engine over a certain space, and when the train is brought to rest that exact amount of work is expended on the breaks before the train can be stopped. In this case, assuming the two carriages to have got off, they possessed in themselves a certain amount of work which must be expended somehow and somewhere, before the carriages could be brought to rest. Now we can all agree that amount of energy is.

The amount of work stored up in a body is equal to half the square of the velocity. (The Commissioner.) You mean what it would have been to say, W. V.2

18.619. Supposing the two vehicles to weigh 15 tons and to be going at the rate of 23 miles an hour, or 57 feet a second, we find that the quantity of work stored up in them is 390 foot-tons—that is, before they could have been brought to rest. Before the matter in them can be brought to a state of rest, there must be work done somewhere or somehow which is sufficient to raise 320 tons one foot high. That is a matter of mathematics which cannot be disputed.

18.620. (The Commissioner.) Whether the vehicles, or whatever they may be, are made of iron or wood?—Yes, if they weigh 15 tons we must have that quantity of work done. That may be expended in various ways. It may be expended in doing damage in various directions. If there was no break to take it up it must all have been expended on the structure somewhere, or on the bodies of the carriages themselves; and supposing there to be no wind blowing, the impetus of the carriages would have carried them forward, and in all probability the work would all have been expended in a forward direction. But here, taking the supposition that the carriages went over, and got off the line, we have a heavy wind driving them against the eastward girder, and it is, I think, highly probable in fact that a portion of it must have been expended in some way upon that girder. A portion of it, perhaps, might have been expended in breaking the girder, or breaking some portions of the girder, but I do not say so much upon that as upon the general fact that a portion of it must have been expended upon the girder, tending to drive the bridge over in the same direction that the wind was setting.

18.621. (Mr. Bidder.) And if these bandings and distortions of portions of that girder that were referred to yesterday, and the markings upon it, are indications of the effects of a collision between those two carriages and the girder, in your judgment, under the circumstances, is there sufficient to account for a shock that would bring the bridge down?—I think so.

18.622. (Tell me if I rightly summarise what you have been saying. First, taking the bridge as com-
Dr. William Pole.

5 May 1680.

TAY BRIDGE DISASTER:

18,624. Such a pressure would not upset the bridge?—No, there is no proof of that at all.

18,625. Indications of the way in which portions of the bridge have given way lead you to infer the probability of a shock as being the cause of the fall of the bridge?—Yes.

18,627. According to your estimate and judgment, if the last two carriages did leave the rails and come into collision with the ledward girder that was a sufficient cause to produce a shock adequate to account for what happened?—I think so.

Mr. Webster stated that he had no questions to ask Dr. Pole.

Examined by Mr. Thayner.

18,628. You have had great experience, I have no doubt, in making calculations for structures somewhat similar to the Tay Bridge?—Yes.

18,629. And you also told us that you have had very considerable experience practically in ironwork?—Yes.

18,630. Have you ever constructed a bridge anything like this?—No, nothing like it. I have designed several bridges—among others I designed a large bridge a few years ago for Japan. It is a low bridge, and of a different character to the Tay Bridge. There are no high bridges and no large girders.

18,631. Apart from that bridge in Japan can you tell me of any bridge in this country that has been erected according to your designs?—No. I have made some designs for bridges in Ireland.

18,632. I will ask you a few questions, first, upon the fall of the bridge. In your report which you addressed to Sir Thomas Bouch I find this passage at the top of page 13, under heading 5: “For these reasons in designing the bridge, a maximum wind pressure was assumed acting over the surface of a span and pier equal to about 20 lbs.” Again, on page 22, under heading 24, you say: “It has, however, been ascertained in the answers to the last question that up to a wind pressure of 20 lbs. per square foot for which the bridge was designed.” Will you tell me from whom you got that information?—From Mr. Stewart, who was working with me.

18,633. You have given us some very interesting and no doubt correct account of what was known prior to the erection of this bridge, generally, by engineers upon the subject of wind pressure, and I think you said that Smeaton’s tables gave you the best information upon that subject, and the information that was generally acted on?—Yes.

18,634. Smeaton’s tables gave you for a storm or tempest only 12 lbs., and as the very highest hurricane that tears up trees and throws down houses 49 or 2?—Yes.

18,635. You said you thought that was tropical?—Yes.

18,636. But you know, I suppose, that there have been hurricanes in this country which have had the effect of both tearing up trees and throwing down houses to a large extent?—Tearing up trees is a common thing, but throwing down houses I have not known.

18,637. Did you hear Mr. Scott’s account of a whirlwind that passed over Walmer, of which he exhibited certain photographs?—Yes.

18,638. Did not that fulfil all the conditions of the description given by Smeaton of a wind that would probably bear with a pressure of 49 lbs. to the square inch?—Hardly. I think that could hardly be considered a rectilinear pressure that any structure would have to withstand—it was one of the whirlwinds that the Astronomer Royal speaks of as exceptional. I do not think it could be called such a steady blowing wind as Smeaton contemplated in his table.

18,639. Has no other engineer since Smeaton’s time, and before the erection of this bridge, dealt to a higher pressure than 20 lbs. to be provided against in this country?—I do not recollect any.

18,640. Do you know Professor Rankin’s book?—Yes.

18,641. He is an authority, is he not?—Yes.

18,642. He is the authority that you refer to in your report?—Yes; I think I refer to the very passage that you are going to quote.

18,643. No, you do not. You quote him as an authority?—Yes.

18,644. In his book, which was published in 1866, I find this stated at page 184: his book is called “Useful Rules and Tables relating to Measurement, “Engineering Structures and Machines,” and he gives this rule. “To estimate the greatest probable amount of the pressure of wind against a chimney or tower, “if the edifice is square take the area of its vertical cross-section, or if round take half that area, and “multiply by the greatest known pressure of wind in the neighbourhood against an unit of area of a vertical plane surface as measured by the anemometer.” In Britain that pressure is about 45 lbs. on the square foot?—Yes; I know that. We quoted that very passage.

18,645. Will you let me see in your report where you quote it?—No, we quoted not that passage but a portion of the passage that had reference to a round surface.

18,646. Having quoted that portion of the passage which tells you how to estimate the amount of pressure on a round surface as compared with a square surface, why did you not take also the rest of his rule and take account for 65 lbs. of pressure instead of 20 lbs.?—Because they are on two different bases altogether. His rule for estimating round surfaces is founded on mathematical knowledge. His statement about the wind pressure must have been derived from some source which he has not given, it does not depend on his character as a mathematician at all. I never paid the slightest attention to that because I had never come across any facts or statement upon which that is founded. That is not a thing which he is an authority upon. He is an authority upon mathematical calculations, and that is not a mathematical calculation, it is a matter of fact. If he had said where he got his authority from we should have referred to it. I could not receive it upon that statement.

18,647. Do you think that Professor Rankin in issuing under the sanction of his name a rule relative to the ascertainmet of wind pressure, and that you have put forward a statement which he had not verified in some way for himself, or which he had not ascertained the correctness of?—I am quite certain that he thought it correct. That has attracted a good deal of attention since, and nobody could find any fact upon which it was based. We are assured that he was in error; when I say “we,” I mean engineers generally. Allow me to say that that would only apply to a single stick standing up in the air, and therefore might come under the Astronomer Royal’s gust or Mr. Clark’s gust, which we know will go, on the Astronomer Royal’s authority, to 40 lbs. in England or more in Scotland. A single gust will, of course, act upon a chimney and that would make a difference.

18,648. I think you are mistaken, this is not given with reference to a pole standing up in the air, with which a concentrated gust might come in contact, but it is a rule stated by him or data given by him, upon which certain calculation are to be made. I will read the rule to you.

(Mr. Bidder.) Do not say it is not contemplating the case of a pole.

18,649. (Mr. Thayner.) He says: “To estimate the greatest probable amount of the pressure of wind against a chimney or tower, if the edifice is square, take the area of its vertical cross-section, or if round, take half that area, and multiply by the
"greatest known pressure of the wind in the neigh-
bourhood;" and to enable you to make your calcu-
lations with regard to Britain, he says, "that pressure
is about 56 lbs. on the square foot." That agrees
pretty well with the Astronomer Royal, but I do not
believe that any engineer ever paid the slightest
attention to that in designing any structure of this
class.

18,650. Do you know whether any engineer in the
creation of a bridge, prior to the construction of this
bridge, ever took into account a greater lateral wind
pressure than 20 lbs.? I do not know of such a case.

18,651. Do you know Sir William Fairbairn's book
on the Britannia and Conway Tubular Bridges, pub-
lished in 1849?—Yes.

18,652. Is it the fact, as I have heard, that Sir
William Fairbairn made the calculations for Mr.
Stephenson's bridge with Mr. Hodgkinson?—Mr.
Hodgkinson made the calculations, I think, for the
experiments; the calculations in regard to the bridge
itself, I think, were made by Mr. Stephenson.

18,653. Do you know it or not?—Yes. I had to
investigate the whole thing, and as far as I recollect,
what Sir William Fairbairn did was to make certain
experiments on a very large scale, which were of great
use in the design of the bridge, and to assist Mr.
Stephenson generally throughout.

18,654. Sir William Fairbairn, writing to Mr.
Stephenson, said this: "If we adhere to our original
assumptions on the square foot for the "lateral pressure of the wind we shall find that the
"model tubes, if used as a girder, would have to be
"3 tons, and that a force of 16,650 lbs. or 7 3/4 tons." That is an instance of an engineer making a larger allowance for
wind pressure than 20 lbs.?—No. I have already
referred to that very thing. Mr. Stephenson, in his
early stages, took a very high pressure, 46 lbs. the
book says. That may have been 50 lbs. in Sir William
Fairbairn's imagination, but Mr. Stephenson later
adopted 20 lbs. That took a very high pressure in
the earlier stages as his idea of what the wind might
be; it is certain from the passage I read, and I have no
doubt Sir William Fairbairn refers to that when he
reminds Mr. Stephenson of the high pressure he
took.

18,655. With regard to that tubular bridge, there is
one thing, you told us which I am anxious to put a
question upon. You referred to Mr. Clark's work,
and you talked of the resistance which one of those
300 foot tubes offered to the wind. I would like to
know, if you look back, what the weight of the tube
was; it was not attached to piers, but simply lying on
something or other; I mean at the time of the storm.
—I know nothing of it beyond what the passage
says.

18,656. I cannot find the passage myself; will you
find it me and tell me what the weight was?—There
is a passage here that shows the wind power of the
Conway Bridge; that would be 1,000 tons.

18,657. Perhaps you can judge of the one by the
other; but the instance you gave was the Britannia.
—They are the same.

18,658. "Give it me approximately?—I cannot
recall.

18,659. It was a tube of 450 feet long, you said.
-I want the weight.

18,660. (Mr. Borrow.) It would be about 1,500
tons?—Yes, very likely; the Conway seems to be
1,000.

18,661. (Mr. Trwaner.) Did you mention what
was the estimated force of the wind on that occasion,
which did upset the tube? I do not think the book
states it; it describes it as being a very violent gale.
18,662. But there is no statement in figures of its
pressure?—No.

18,663. (The Commissioner.) I do not think you
read the word "very"?—"During violent gales."

"The heaviest that have occurred for many years."
18,664. (Mr. Borrow.) What is the date of that
publication?—1860; it is written by Mr. Clark; one
does not know exactly when.

18,665. (Mr. Trwaner.) What in your opinion was
the weakest part of this structure which would first
yield to pressure?—This diagonal tie (pointing to the
model).

18,666. The lowest diagonal tie?—Yes.
18,667. Is it the case that the diagonal tie, speaking
generally, are the weakest part, and that the
weakest of them is the lowest?—Yes.

(The Commissioner.) Not the weakest; you mean
having the greatest strain upon it?

18,668. (Mr. Trwaner.) That is what I mean, they
are equally strong in one sense, but the lowest
diagonal tie would be the least capable of resisting a
great pressure?—It would be the most likely to go.

18,669. At the very end of your report you have
given what with a pressure of 40 lbs. the stress on
these diagonal ties would be?—Yes.
18,670. 13 6/8 tons to the square inch; that is 12 1/2
say?—Yes.

18,671. If you take that diagonal tie as a piece of
wrought iron, what strain would it yield to?—The
average strength of wrought iron.

18,672. And that is what?—That is 20 tons to
something above dependent on the quality. No
engineer approves of iron that does not stand 20 tons; it
may stand anything from 20 tons up to 30, 40, or 50.
18,673. Under what strain would that diagonal tie
lose the limit of its elasticity?—At about half that.

18,674. Ten tons?—Yes.

18,675. That if it was subjected to a pressure of
40 tons, that diagonal tie would have been taken
considerably beyond the limit of the elasticity?—Yes;
but iron does not break by simply passing the limit of
elasticity.

18,676. I never supposed it did; but let me ask
you this, whether if that diagonal tie was exposed to
such a strain on more than one, say two or three,
occasions it would not then fracture?—No; supposing
iron to be subjected to large strains, it does not, so far
as I know, do it any permanent injury. All the result
of straining it beyond the limit of elasticity would be,
not to damage the iron so as to render it less capable of
bearing weight, but to stretch it permanently, to
give it what is called a permanent set.

18,677. Supposing it has reached its permanent set,
is it not more liable to fracture than it is before it has
reached the limit of elasticity?—Certainly not.

18,678. It might be strained up to the limit of
elasticity, and it might be put under a strain greater
that, and yet you think it would not be more liable
after that to fracture than before it was strained at all?
—No, I do not think the straining does it any harm
at all as regards its strength. All the evil done to
wrought iron by straining it beyond its limit of
elasticity is distorting it, giving it a permanent set such
that it will not recover. If it is strained up to its limit
of elasticity, when the strain is taken off it returns to its
former position. If it is strained beyond its limit of
elasticity it will not return, but it takes a permanent
set. But I have never believed, and I do not think
those who are acquainted with iron believe, that iron
that is strained between its limit of elasticity and its
point of fracture becomes weaker by that strain. There
are some remarkable experiments quoted in the
book to establish that point; it would be stretched, but
nothing more.

18,679. (The Commissioner.) It would not recover
itself?—It would not recover its former length.

18,680. It would be distorted?—It would be
stretched; it would keep straight, but it would be
stretched, and would not recover its former length.
That would be the only result of straining it beyond
its limit of elasticity.

18,681. (Mr. Trwaner.) I will ask you to look at
the last page of your report, and I will ask you how
you get at what you state there. "Fourthly, we find
"what resistance the six columns will offer to an
amount of bending corresponding to the lateral
"motion assumed." How do you ascertain that?—

There is a formula for it. That applies, with a certain

modification, to a column fastened at one end. You

will find it there (hawing to Mr. Troughton Clark's

book on the Britannia Bridge).

18,622. It is on page 272, of Clark's first volume,

I do not know that it has very much bearing upon

the question now. You have agreed with the

Astronomer Royal that 10 lbs. was sufficient pres-

sure to provide against in the case of the Forth

Bridge?—Yes.

18,623. And from that I understood you to say that

you deduced that 20 lbs. was ample in the case of the

Tay Bridge?—I do not think so.

18,625. (Mr. Troughton.) Will you tell me what are the con-

ditions which, in your opinion, render it necessary

to provide for greater lateral pressure in the Tay

Bridge than in the case of the Forth Bridge?—The

smaller bays; the smaller extent of the structure.

18,626. Anything else?—No.

18,626. Did you take into account the different sites

of the bridges, and the configuration of the coasts?

No, Sir; from what I recollect of the two places, I

should say that the Forth is exposed to quite as

violent winds as the Tay; it is a gully; it is a bottle

cut, a narrow passage, where the wind must be very

much contracted; and from what I know of the site

I should not expect the force of the wind to be greater

in the Tay than in the Forth.

18,627. I doubt whether your recollection is ac-

curate about the Forth; but at any rate you differ with

Sir George Airy upon that matter. You heard him

examine?—I do not recollect what he said about

that.

18,628. I will read it to you:—Q. Do you think

that there is the same probability of severe con-

trasted wind pressure coming westward at the Forth

Bridge—(I mean at the Tay Bridge)?—I should say

"certainly not;" it is much more open land about the

Forth than it is about the Tay. Your recollection

differs from Sir George Airy's upon that point?—

Yes.

18,629. Was there nothing else in the construction of

the two bridges that would lead you to a different

collection as to the amount of wind pressure which

each was equal to resist?—No; it is a matter that

would be provided for according to the construction.

Q. But what did you mean by the Tay Bridge being

a single line, and the Forth Bridge to carry two lines, held

separate or in a distance of some 120 feet?—That was

provided for; it is quite a general idea, and of course

was not provided for in this; but design for design, the

quantity of wood to be met has been provided for in

the design as well as it was in the case of the Forth

Bridge.

18,631. I am pointing to this; would not it have

required greater pressure to overthrow a construction

like the Forth Bridge, the site and everything else

being equal, than to overthrow this bridge?—It

depends upon the strength of the structure; it would

have been more difficult to overturn this if it had

been constructed for two lines instead of one.

18,632. Did not the distance between the two lines

 púb the Forth Bridge make it a more stable construc-

tion than this; and more difficult to overturn?—The

stability depends on the manner in which it is con-

structed. The fact of its being a very broad bridge

made it easier to give it the proper stability, but the

design is prepared to allow for the wind pressure in

any case, whether it is one line or two. A bridge for

double line is easier to make stable, and stability is

acquired with a less expenditure of metal than a bridge

for a single line.

18,633. Did you consider at all, or did you make

any calculation with reference to what was the amount

of wind pressure that this bridge should resist, or did,

you accept from Mr. Stewart that it had been designed

to resist 20 lbs. to the square foot?—I accept it from

Mr. Stewart. I thought it was reasonable, that was

all.

18,634. You were consulted about the Forth Bridge

wind pressure, but not about this?—That is so. I

knew nothing of this until long after it was built. I

knew nothing of it in its early stages.

18,635. You have said that this girder was simply

strong enough for any force that might be expected

to come against it?—Yes, the girder.

18,636. Do you agree with Sir Thomas Bouch that

if a railway carriage came against that girder, it

should be a transfer of pressure from one part to

the other, which would not then be provided for.

(Mr. Barlow.) You are taking the bridge with a

team upon it?

(Mr. Troughton.) No, I am simply asking him about

the bridge. I am asking him if two of these contin-

uous latticings or braces were taken away whether

that would render the bridge unsafe and bring it

down?

(Col. Yolland.) You mean a strut and a tie?

(Mr. Troughton.) Two continuous struts and ties.

(The Witness.) No, one strut and one tie.

18,638. (Mr. Troughton.) Not one, but two?—That

is to say, not one cross, but two crosses, and so if

the two were taken away the bridge would not stand.

(The Commissioner.) Two struts and ties.

(Mr. Troughton.) Taking the double cross.

(The Witness.) I think either of them; that is to

say, either taking away two separate ties adjoining

each other, or two separate struts adjoining each

other, would be sufficient to render the bridge unsafe,
because the strains are transferred.

18,639. It would not matter how these were taken

out, but if they were cut out, or came out in any

way, it would ruin the stability of the bridge?—It

would be unsafe.

18,640. And it would come down?—I think it

would; it might hang together, but it would be unsafe

to put anything on it.

18,641. Would it bring the bridge down; Sir

Thomas Bouch used that expression?—Yes, I think it

would; if it did hang together it would be by a sort

of happy accident.

18,642. It would ruin the bridge as a means of

transit for any train?—Yes, certainly, two of these

taken away would spoil the bridge.

18,643. Do you think a design for a bridge, the

safety of which depended on the accident or possibility

of its losing two adjacent struts, was a good design?

(Mr. Biddulph.) We must understand the thing one

way or another. I omitted to examine Dr. Pole upon

the girders upon an express intimation from the Court

that there was no question as to the sufficiency of

the girders.

(The Commissioner.) As to the strength of the

girders.

(Mr. Biddulph.) I must except to any cross-examina-

tion as to the sufficiency of the girders, qua girders

under those circumstances.

(Mr. Troughton.) I am not disputing the quality

of the girders, qua girders at all.

(The Commissioner.) The question, as I understand

it, is as to the theory.

(Mr. Biddulph.) Was the question put by Mr. Troughton as

Was it a good thing, in your judgment, to design a

bridge so that its safety would be imperilled if this

design were carried out? (At Mr. Troughton's request, his

former question was read.)

(Mr. Biddulph.) That is simply and exclusively a

question pointed to the design of the girders; it has

nothing in the world to do with the question of piers;

it attacks the sufficiency of the members of the girders.
(Mr. Barton): It seems to me to attack the sufficiency of all girders whatever.

(Mr. Bidder): My objection to it, however, is simply upon the ground that I have not gone into the question of the safety of the girders after the intimation of the Court.

(The Commissioner): The Court intimated that the girder was quite sufficient as regards strength.

(The Commissioner): That was all that I intended to convey.

(Mr. Traeyner): I am not here to contradict at all, but Mr. Bidder undoubtedly asked Dr. Pole (and I should have been astonished if he had let Dr. Pole leave the box without putting the question to him), you are quite entitled to say that the opinion of the Court is that the design was good. That may be a question that will not affect the mind of the Court, or it may be a question that will affect the mind of the Court. Surely I am entitled to ask Dr. Pole whether or not his opinion that it is a good design upon which to build a bridge depends upon the accident, or chance of its losing two of its adjacent ties.

(The Commissioner): The Court is of opinion that you are quite at liberty, Mr. Traeyner, to put this question.

(Mr. Traeyner): It is a question which bears upon what was the cause of the accident, which is one of the questions that we have to inquire into. One of the questions put to the gentleman by the direction of the other party, is that it was caused by the breaking away of one or more of these ties or struts. That is the theory that is put forward. It is quite clear that under these circumstances you are at liberty to ask Dr. Pole whether or not, with the information which he has, and with the attention which he has given to the subject, in his opinion that was a right thing. I do not know what his answer may be.

(Mr. Bidder): I bow to the decision of the Court. I only say that your intimation of yesterday, Sir, threw me entirely off my guard.

(The Commissioner): I have spoken to both the gentlemen upon the subject, and what we wished to convey was that simply as regards the strength of the bridge, as I understood and all that part. We thought it might perhaps simplify the case if we told you that in our opinion those struts had been made sufficiently strong.

(Col. Yolland): For the ordinary passage of trains?

(Mr. Barlow): Yes.

(The Commissioner): I do not know whether I expressed myself correctly, but that was my intention.

(The Witness): I may answer in a single sentence; that a great number of bridges are constructed in that way, so that the removal of one or two bars would spoil the strength, and that those designs are always considered by engineers good ones. There may be some engineers who would prefer to make the side struts of iron, as Mr. Stephenson did. There may be some who would prefer to have the lattice bars closer together. These are matters of taste; but this kind of bridge, in which the removal of two or sometimes of one bar would damage the bridge altogether, is exceedingly common; I think I may say that all these bridges are in use to this day, and if this is not a good design, they are not good designs. But the general opinion of engineers is that they are good designs, because the case of the removal of the bars is not contemplated.

18705. (Mr. Traeyner): I quite follow you; it may be quite a point of defence of the design if the design is attacked, but I suppose I am entitled to say to you that that possibility of danger would be avoided if the girder was below the train, as in the case of the Tay Bridge, instead of above it, as it is in these high girders?

18706. It would be less liable to be damaged by a train.

18707. And of course a train could not go into it?

18708. No, it could not go into it.

18709. It could not be damaged in the same way?

18710. No, and engineers generally put them down below the railway if they can. An engineer would never think of making these if he could put the girders below. It is very much cheaper and very much better construction to have a roadway on the top than in the interior.

18711. Are you of opinion that a second-class carriage of the character which you have heard described by the locomotive superintendent, had with even the assumed velocity sufficient strength to knock out two of these struts and ties?—I doubt whether it would have knocked them out altogether. I hardly think it would.

18712. Do you not think that the upper part of the carriage above the frame plate would altogether have disappeared before the impact with those struts and ties?—Oh, no! I would not say that, because the lower framework of a carriage is a very strong thing indeed, and would certainly if projected against one of these thin ties make it rather a hard thing for the tie.

18713. If you had attended to the question you would have heard that I said the upper part of the carriage above the frame plate; supposing that any part of the body of the carriage above the frame plate came in contact with any of these struts and ties, which do you think most likely, that the carriage would go into pieces or that it would have any serious effect upon the condition of the tie?—If it was projected at a considerable velocity I think it would damage the tie, but of course it would break up the carriage also. The blow must be expanded somehow, and a portion of it would be expended in breaking up the carriage. By the "body" of the carriage I understand the part in which the passengers sit. That is by no means such a hand-box thing as it has been supposed to be, and I should be very sorry to believe, having regard to the safety of the public, that this was so.

The panels are, as was properly said, thin, but there is a strong framework round it; and that must necessarily be so; and that would not break up so easily without telling its tale. If it were projected violently against one of these it would tell its tale upon the tie, and I should be very sorry to believe, having regard to the safety of the public, that this was so.

18714. Do you assume that the second-class carriage went against one of these struts with the full force of 25 miles an hour?—Pardon me, I assume nothing.

18715. Do you assume, in the answer that you have given, that it was likely to produce the effect upon the strut that you have described?—Yes; I assumed that it came end-on, in answer to the question.

18716. Do you mean by "end-on" at right angles to the strut?—No, I mean longitudinally (describing it). This gives the strongest position of the carriage to go against the strut.

18717. Given that that train had entered the bridge at the south end, at the very limited speed of some two miles an hour to take up the baton, and that it had proceeded over these 28 piers, and was getting up its speed even over the 25 miles an hour, do you think that the overrunning or tilting of that carriage by the wind would have given the carriage any chance?—I think it would have gone against the tie, and with anything like the force which as implied in a speed of 25 miles an hour direct against a subject?

18718. It would be 25 miles an hour.

18719. You have the coupons in front of keeping it down?—I do not think that is of much importance. The coupons are so easily bent; they would have very little motion along this to keep them sitting over, and they are generally rather loose; I do not think they would exercise any holding force.

18720. What would be the effect upon one of these struts if it was placed transversely, as firmly fixed as it is on the model, but directly at right angles to an object advancing at a speed of 25 miles an hour, and that object a second-class carriage of the character which we have had described?—I think it would damage
TAY BRIDGE DISASTER:

18,716. Do you think it would smash the carriage and send off the whole top or body of it?—I think it would smash it in, no doubt.

18,717. Do you think it would have the effect of entirely annihilating the struts and poles?—I do not think the body of the carriage would do that, but I think that if the lower part of the carriage, the strong part of the carriage where the great strength and weight lie, were projected against this with a full velocity it would have a good chance of breaking one of these struts.

18,718. By the "strong part" of the carriage what do you mean?—That which is called the under frame, which is of totally different construction from the upper part.

18,719. Assuming that the second-class carriage was coming from the south, and that it got off the line, and that even that part which you regard as the strongest part of the carriage came in contact with the speed at which we have been mentioning with one of these struts, do you think it would be able to utterly displace that strut by the force which it had, coming on at that speed?—I think it is possible; but it is very difficult to say. Some of the struts are not very strong.

18,720. Do you think it is at all likely that even if it did displace one strut there would be any force left in it sufficient to go the length of another strut and displace that?—There is another carriage to come after it. I cannot say. It is a matter of speculation, and I have been enough of railway accidents to know that nothing can be calculated upon which would occur. I can only form a very vague idea.

18,721. I think we are speculating now: you cannot speculate with any certainty about it.—No.

After a short adjournment.

(Mr. Traeyner.) I do not propose to examine Dr. Pole further.

Re-examined by Mr. Bidder.

18,722. Mr. Traeyner asked you with reference to that description of Simonsen's of a hurricane that threw down houses, whether you were not aware that such things had happened in this country; you visited Dundee shortly after the accident, did you not?—Yes.

18,723. Did you see any trace of houses having been blown down at Dundee?—Certainly not, with the wind of the kind was very violent.

18,724. Now, with reference to Mr. Rankin, the paragraph that my learned friend referred to in Mr. Rankin's book, I think, was a paragraph relating to a calculation of the stress of wind upon a chimney?—Yes, chimneys and towers, I think.

18,725. Which you roughly described as a pole stuck in the ground?—Yes.

18,726. Is there any relation between the stress of wind that you may have upon a particular limited space like that and that which you can have over a great extent of surface like a big bridge?—No. I think that it is the exact case that the Astronomer Royal put in his statement, that you may have high gusts on very small surfaces.

18,727. In accordance with what the Astronomer Royal said in 1873, and said again here the other day, you may have in England on the anemometer 40 lbs. or 53 lbs. of wind?—Or in Scotland probably more, as it does not appear that any anemometer ever registered 55 lbs. as far as we can tell, it is very difficult to tell how Professor Rankin got that figure.

18,728. My learned friend also read to you a quotation from a letter written by Mr. Fairbairn to Mr. Stephenson, in which this passage occurs: "If we adhere to our original estimate of 60 lbs. for the wind certain consequences follow" but, as I understand you, the subsequent calculations for the bridge show that Mr. Stephenson did not adhere to that, but went upon the basis of 20 lbs.—Certainly he sanc-

tioned the statement that the greatest force of the storm was 20 lbs.

18,729. As regards the relative sites of the Forth Bridge and the Tay Bridge, you know both sites?—I have been at both sites; I perhaps am hardly an authority as to the topography, but I recollect the great wind and pressure that you might expect at 10 lbs., on account of any favourable circumstances in the Forth Bridge site?—No; certainly he founded it entirely on the hypothesis or knowledge, or whatever it may be called, that these strong gusts were of very small area, and therefore ignored them in taking the pressure over the large surface.

18,730. That was founded, I think, upon general considerations as to the wind that may be expected in this country?—Yes, and taking into account also the wind that might be expected in Scotland.

18,731. But not with reference to any peculiarly favourable circumstances or any peculiar circumstances relative to the site of the Forth Bridge?—No; he gave credit to the site of the Tay Bridge for being subject to high winds, I think, as anything in Scotland, because he mentioned Scotland as giving a higher pressure.

18,732. My learned friend also put it to you whether, in point of fact, the Forth Bridge, being for two lines of railway at a considerable interval apart, would not be more stable with regard to wind pressure than the Tay Bridge: is my learned friend, in referring to that subject in connexion with the Astronomer Royal's Report, mixing up two entirely distinct things, that is to say, the wind pressure and the means of resisting it?—Yes, that occurred to me at the time I gave my answer, I tried to explain that, but I am afraid I did not do it very well.

18,733. The Astronomer Royal states that "The greatest wind pressure to which a plane surface like that of the bridge will be subjected on its whole extent is 10 lbs. per square foot," that can in no way be affected by the question whether the bridge that has to sustain the pressure is a single line or a double line?—No, the bridge being a double line, and being under such favourable circumstances in that respect, it was able to meet the pressure with a very small expenditure of metal.

18,734. It did not make the pressure that you had to meet any less?—No; and if the bridge had been only one line we should have been obliged to make the preparation for it a great deal more. In order to meet a certain given force of wind we should have been obliged to make the bridge much stronger than we did, knowing that there were to be two lines, because the second line enabled us to dispose of the material in a very much more advantageous way.

18,735. In fact, they were like the two members of a girder laid on its side?—Yes.

18,736. (The Commissioner.) Are they united?—Yes, they were united in the middle (Mr. Barlow). Would you just make a sketch showing that, because the condition of things is entirely different from what would arise on this bridge.

18,737. (Mr. Bidder.) So far as structure is concerned they are entirely different; I want to keep distinct that which is peculiar to the structure of the bridge?—The Forth Bridge consists of two bridges placed about 100 feet apart so that one supports the other. With such a proportion as that of course the means of meeting the side pressure of wind are very easy.

18,740. You were asked a question by my learned friend Mr. Traeyner upon another matter, whether it is not more satisfactory to put the train upon the top of the girder than inside it, and you said that where it can be done it is so; I suppose you are aware that in
this case there were conditions of headway which limited the design?—There must have been, otherwise the engineer would never have made this extraordinary exception for these high piers. That is quite obvious. He would have run the road upon the top of the girders throughout. That any one can see with half an eye.

18,741. (The Commissioner.) He must either have had a higher gradient, or he must have started from a higher point on the south bank?—Yes, he would have been obliged to raise the bridge altogether.

18,742. To raise it north and south of the high girders. If the part which is continuous to the north and to the south had been upon a level with these high girders, you say?

: (Mr. Webster.) You mean that he would have been "obliged to" give a greater headway all the way across.

(The Commissioner.) He must have commenced from a higher level, or have had a greater gradient.

18,745. (Mr. Bidder to the witness.) There were a great many considerations; for instance, as it is, the gradient, as it is, is pretty steep down into Dundee station, is it not?—Yes.

18,744. And if you had raised the railway 27 feet higher it would have been something very severe indeed?—Yes, I must say this headway to provide for, this appears to me to have been the most convenient way of doing it.

18,746. Now, I think the gradient is 1 in 78?—I think it is steep.

18,747. My learned friend asked you your opinion as to whether the second-class carriage, if projected against the seaward girders, would break two struts, and you said that you doubted whether it would break them altogether away, but in your observations as regards the impact of those carriages as a shock upon the bridge, you did not necessarily assume that the struts were destroyed, did you?—Oh, noEvent on the expenditure of energy in a lateral direction on the eastern girders, and I did not attach much weight to the possibility of the train breaking down the girders. I do not think we have evidence that it was the girders that gave way.

I would rather incline to the opinion that it was the pier that gave way. I do not think there is any evidence that you have given now that the first of course the destruction of two struts of the girders would cause it to give way, but I do not think there is evidence that that took place, and I based my opinion that the carriages in getting off the line might have caused the destruction of the bridge rather upon the expenditure of the energy in a lateral direction on the eastern girds, and I did not attach much weight to the possibility of the train breaking down the girders.

18,748. (Mr. Bidder.) I think you are mixed up about the destruction of the pier.

How is the destruction of the pier to be accounted for?

18,749. It is obvious that the pier could not be destroyed by the same force which destroyed the girders. It was a very much smaller action that upset the pier.

18,750. (Dr. William Polk.) Have you examined the pier under the microscope?

18,751. (Mr. Bidder.) Have you examined the pier under the microscope in order to measure the amount of force that could be transmitted to the pier from the piers?

Dr. William Polk. Yes, I have.

18,752. (Mr. Bidder.) Did you ever see a bridge collapse, as you say, in the case of the bridge coming down?—I do not recollect saying any such thing, you must have misunderstood me.

I gave no opinion about the evidence in regard to these carriages. I am not in position to do so.

18,753. But I mean the marks upon the pier. I took down the words you have just given, and I thought you said some such thing as this?

—I certainly did not intend to give any opinion as to what that showed.

18,754. (Mr. Bidder.) Do you not think you have seen them?—No.

18,755. (The Commissioner.) You have been here during the whole of the time?

18,756. But you consider that these marks indicate in fact that there had been a severe shock to the sides of the train?—I do not think I said so, but I think I may say so now.

18,757. Are you aware that the person who gave evidence about that, Mr. Armit, was asked, "Did you see the marks upon the girders which are indicated "upon the plan by this line, and he said, "I saw "the "first to observe them." Then he says, "I "thought it so important that I went into Dundee "and had it photographed." Then the question asked by Mr. Bidder was, "Will you just describe "those marks; are they distinct upon the girders?" He "thought it so important that I went into Dundee "and had it photographed." Then the question asked by Mr. Bidder was, "Will you just describe "those marks; are they distinct upon the girders?" He "thought it so important that I went into Dundee "and had it photographed." Then the question asked by Mr. Bidder was, "Will you just describe "those marks; are they distinct upon the girders?" He "thought it so important that I went into Dundee "and had it photographed." Then the question asked by Mr. Bidder was, "Will you just describe "those marks; are they distinct upon the girders?" He "thought it so important that I went into Dundee "and had it photographed." Then the question asked by Mr. Bidder was, "Will you just describe "those marks; are they distinct upon the girders?"

18,758. Not exactly where the splinters of wood are in, but about there, and also below it, too.

(Mr. Bidder.) He says the rivet heads are very hardly rubbed.

18,759. (The Commissioner.) He says, "In pass-
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Inger your finger over you can feel a distinct hole, and over the heads of the rivets there has been a very hard grace indeed. Should you think that such a description as that would infer such an injury to the girder as would be shown by the expenditure of very much to the extent that you have mentioned?

No, certainly not there.

18,760. Where else, then, do you think? — It would be in the lower part of the carriage, where the heavy mass of the carriage came in contact with the girder.

18,761. Has there been any evidence all in the course of the trial that the body of the carriage ever came into collision with the girder in any place at all? — I do not know, and I do not base my assertion on the evidence that there was; I say merely this, assuming that the wind blew the carriage over, I think there is then every probability that it would then have got off the line.

18,762. That is to say, you mean that it would have been inclined? — More than that. I mean, not only that it would have been inclined, but that as soon as any part of it came into contact with the girder, being in an unstable equilibrium and standing on one wheel only, then it would have been upset altogether, and would have got off the line, and would have pulled off also the carriage behind it. Then I say that, considering the heavy forces of the wind acting on those, it would have projected those carriages towards the eastward-girder. Whether there were any marks of that I do not know, but I say that I think it must and would have been the case that under that wind: the carriages, when they got off the line, must have been projected forcibly towards the eastward girder. I say that during that prosecution of the wind acting on those, it would have projected those carriages towards the eastward-girder.

18,763. Do I correctly understand you to say that you come to that conclusion after the careful examination that you have made of the construction of the bridge, and on the assumption that the workmanship was good? — Yes. I hardly think that affects the question.

18,764. Supposing that the workmanship was bad, and that the pillars were unseated at the bottom. I suppose that might be sufficient to account for it without any shock from the train? — I have not seen enough evidence to show me that any artificial force that would be likely to come upon the bridge, unless the wind was very much higher than I have any reason to suppose could have fractured this tie (pointing it out), which I suppose to be the first thing that gave us, by experiment found those to be very much weaker than they would make them. Mr. Kirkaldy’s experiments have shown that, and I suppose may be said to be due to something in the construction which does not quite correspond with what ought to have been according to the design. But, allowing for that, I still cannot see, as I said in answer to Mr. Bidder, any proof that any artificial strain was; that between the bridge down. I then think that this additional shock may have come in, that is to say, from the statical strain, and may have done what was wanted to make the fracture.

18,765. May I ask whether or not the paper that you wrote was written on the assumption that those lower parts have been unseated, and that the wind, as you have assumed? — No, we took nothing of that sort into account at all; we merely calculated on the bridge as designed.

18,766. As designed and with the workmanship good? — Yes; we assumed the workmanship to be carried out in accordance with the intention of the designer. 18,767. That is all that I asked you. Therefore it was upon that assumption. (Mr. Bidder.) Will you pardon me for pointing out that in his evidence to-day Dr. Pole has also said that, taking into consideration the strength of the tees, it does not increase the strain upon the tie.

18,768. (The Commissioner.) That I am coming to presently. (To the witness.) Do you also agree with Dr. Pole that the bolt holes should have been square? — Yes.

18,769. And do you also agree with Mr. Cochran or Mr. Brunlee that it is impossible to cast bolt holes square, and that it would be proper under all circumstances to trim them or drill them out? — No, I would not say that it was impossible to cast them square, but I would say that if you treated them to founders in general they are not likely to cast them square.

18,770. Have you had experience of that? — Yes. Moulders would be most likely to make them conceal. I think there is a very good reason why they might do so.

18,771. Under those circumstances you will also agree with Sir Thomas Bouch, I suppose, that the bolt would be likely to bend until it got a bearing upon the conical side? — Yes, it would bend certainly. If the broad end of the cone was not very large, it would then take a bearing upon the whole surface.

18,772. I think you stated that you assumed the columns to be firmly rooted to their bases, I do not mean with the holding-down bars but firmly rooted upon their bases? — Yes, I did for the purpose that I had in view, in calculating their bending.

18,773. You agree with the probability that the bolt holes of the flanges of the 18-inch columns were cast and not drilled? — I am told so. I forget, but I will take it from you, sir.

18,774. I suppose it is quite possible that the bolt holes of the lower flanges might be conceal? — Yes, it is possible.

18,775. Then if they were conceal at the base and a pressure was brought to bear upon those the bolts would be likely to give until they found a bearing upon the sides? — No, the pressure is entirely in another direction.

18,776. I mean a lateral pressure? — Yes, and there would be no lateral pressure upon them then.

18,777. A horizontal pressure upon them then, would it not? — I think not. A wind pressure would not act here (pointing to the model). It would act here (pointing to another part of the model).

18,778. Why would it not act at the bottom of that column? — It might.

(Mr. Bidder.) Will you allow me to suggest, sir, that you are introducing new matter in the re-examination of the witness which has never been suggested from the beginning of the case until now. It places us in unexampled difficulty.

(The Commissioner.) I cannot help that. We must find out the facts not to be brought to bear upon the bridge.

(Mr. Bidder.) You must forgive me for pointing out what is necessary. If it were Mr. Trueman re-examining and suggesting new grounds of objection in the re-examination of his own witnesses, of course I should object, and I should be in a position to call my own evidence afterwards. But you are now suggesting a new imperfection in the bridge which has never been breathed by anybody on this side of the table.

(The Commissioner.) Excuse me, it has been suggested. He said he assumed that the columns were firmly rooted down to their bases.

(Mr. Bidder.) It has never been assumed that the conical bolt holes of the bridge were not as right as you have assumed? — No, we took nothing of that sort into account at all; we merely calculated on the bridge as designed.

(Mr. Webster.) May I remark that it affects Messrs. Hopkins, Gilkes, and Co. most materially. Mr. Law has never suggested that the bottom columns could slide under the action of the wind.

(Mr. Trueman.) Mr. Law did say that the holes were too large, and that it was possible for the columns to shift.

18,779. (The Commissioner.) My feeling is that undoubtedly that has been a point from the very beginning, and it struck me the instant Dr. Pole had answered that question to Mr. Bidder — "I observed the columns to be firmly rooted to their bases;"
and this be argued with respect to the bonding of the columns. (To the witness.) Now, will you answer this question of mine: would not the greatest wind pressure be where you have put your finger?—Yes, the wind pressure would act here (pointing to the model?).

18,760. If there was a wind pressure upon the bolts there, provided that the bolt holes were not accurately square, they would be likely to give until the bolts found a bearing on the sides of the cones, would they not?—Yes, but I cannot conceive that any wind pressure would overcome the immense friction on the flanges of those bolts, and not only a friction due to the weight, but a friction due to the screwing up, and I cannot suppose that those 30 tons of wind pressure would cause a sliding of those six columns upon their bases when they were firmly fastened down. It would be possible, no doubt, if there was force enough, but I cannot conceive it.

18,781. It is only in reference to the answer that you gave that the greatest wind pressure would be brought to bear upon the leeward 18-inch column?

—Yes, it would be a downward pressure.

18,782. The greatest amount of wind pressure would be upon the leeward 18-inch column?—Yes; that would be a downward pressure. There would be an equal sliding pressure upon all, but there would be, of course, a very special downward pressure upon the leeward columns.

18,783. And in the event of the bolts not fitting accurately into the holes, the holes being conical, no doubt the base might give slightly?—It might slide, but I do not think the force would have any chance of sliding it in opposition.

—(Mr. Webster.) May I suggest, sir, that it is the downward pressure that is the greatest, and not the lateral pressure.

18,794. (The Commissioner.) The lateral pressure is undoubtedly pressing against the bolts?—It is pressing against them equally. It tending force tending to shear it off the pier, but that we know is 27 tons, and that with 20 lbs. of wind I cannot suppose that that divided over six columns will have any tendency to overcome the enormous friction of these columns upon their bases. My argument would remain the same, that those being firmly rooted, provided that they were screwed firmly down these columns would bend a little, which gives me the effect I want for my calculations.

18,795. Then the bolts in the lugs would also possibly give?—Yes, in the lugs belonging to the tie. They have given in Mr. Kirkaldy's experiments to a slight extent under the very much smaller pressure produced by the wind, but I think not to any great extent.

18,796. You are aware, are you not, from seeing the photographs, that almost all the pier have gone just at that very point to which your attention is now called, namely, just above the bases?—Yes, and that I expected, because, when these ties were gone, each column must turn on its own base separately, and there is nothing to prevent those columns toppling over and either breaking those bolts or roosting up the stones; or doing something of that kind; and every appearance that I saw at the base of the column is exactly that to me, perfectly in accordance with the fact which Mr. Law has himself stated most clearly, that after these ties were gone the columns turned over each upon its separate base, sometimes breaking the bolts and sometimes tearing up the base plate with pieces of the stone attached; and there is undeniable evidence that the columns shed many of their separate bases and that the pier did not go over bodily as an entire structure. I think Mr. Law agrees with that thoroughly. I gather that from his evidence, and it seems to me to put the matter so clearly that there can be no doubt about it: Many people who have not studied this subject have supposed that because in some cases those stones have been torn up, therefore the pier has gone over bodily from a want of sufficient holding down power here (pointing to the model). That is entirely my view. There is no evidence for a moment that the pier turned over bodily in that way. This appearance is easily explained by the fact that when these ties were gone there was nothing to prevent the columns turning over as a single column, which would, of course, tear up the stones, and do all that is shown there.

(Mr. Tayler.) Would you pardon my referring you to Mr. Law's answer to question 14,719. In cross-examination by Mr. Webster, amongst other things, he was asked, "We are not upon that point for a moment, although you are very careful to put it in of course; but I will ask you again whether you attribute the accident to the shifting of these columns?—Yes, and many other columns, in a similar manner, the combined influence of the whole." Then the Commissioner asked a question, and Mr. Webster said, "Could you tell me of any other pier where there was any shifting, or column in any place?—Every column almost has shifted and broken its bolts and bent them. Every one, I think, may have moved.

(Mr. Webster.) That is not in the least upon the point that is referred to, the lateral sliding of the column upon the other. I venture again to suggest on behalf of the contractors that the suggestion that the conical boring of these holes on the bottom flanges of these base pieces enabled the column to slide bodily over, has never been made until this moment.

(Mr. Barlow.) I cannot help thinking you are wrong. If not the conical hole, the large size of the whole has been mentioned, as constituting a possible cause of slipping, and I think it is only necessary to refer to Mr. Law's evidence to see that. It seems to me that Dr. Polo has very well disposed of the question, and stated exactly how it is, and how far it goes.

18,787. (The Commissioner to the witness.) You were asked a good number of questions about wind pressure; have you yourself turned your attention specially to the subject?—No, except on the occasion of the Forth Bridge.

18,788. On what ground is it then that you say that engineers generally pay no attention to Mr. Rankin's statement of the wind pressure being 56 lbs. occasionally?—From acquaintance with what engineers generally do, I think that there is no more reason for paying attention to what I may say than for paying attention to anything else. I think the knowledge of the habits of engineers, and the modes in which they work, through constant communication with them, if it had been the practice and the rule to take any account of wind pressure in designing bridges, I should certainly have known of it. I can give no further answer than that.

18,789. You say that that is the general practice of the profession?—There may have been isolated cases where engineers may have considered wind, and I think very probably there have been cases that have not come to my knowledge. I merely speak of what I conceive to be the general practice of the profession.

18,790. And it is on that ground that you think they have disregarded Mr. Rankin's statement of the 56 lbs.?—Yes; I dare say a man in designing a chimney, according to Mr. Rankin's rule, may have taken 56 lbs. as his limit of safety; but in designing bridges in the general practice of engineering, certainly no such figure has been taken.

18,791. Do you know, or not, whether there is any such practice as that in France, of allowing 56 lbs.?—No.

18,792. Did you ever inquire?—No.

18,793. Do you know whether there is any such practice as that in the United States?—I do not know.

18,794. Have you never inquired?—No, I have not.

18,795. You said or assumed that the pressure of 50 lbs. was the assumed pressure upon a pole, and that that you thought to be the evidence of Sir George Airy, did you not?—Not exactly in that form.

18,796. And that of Sir George Airy concerned in that?—Hardly. I think you got it in that shape. I read the word "pole" so Mr. Tayler, Mr. Tayler,
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I dare say, did not take it literally. I merely meant that Mr. Rankin’s rule was intended to provide for a case where there was a narrow high object standing up in the air. I called it metaphorically a pole; I did not mean a scaffold pole, but that was what I meant, and it was under the impression and am under the impression that the girders which Professor Airy mentioned might apply to a case of a narrow building of that kind.

18,797. But I think you that you have not had any practical experience yourself, and all that you are stating is what you believe Sir George Airy stated in his evidence?—Sir George Airy took great pains to explain to Mr. Barlow and myself what he meant.

18,798. I am talking of the evidence that he gave here?—I am not speaking of the evidence he gave here; I did not know that that entered into your question.

18,799. The evidence that he gave here was this, speaking of the Forth Bridge,—that upon a bridge of that sort, though there might be through a space of 100 or 200 feet, provided it were 40 or 50 lbs. upon the square foot, it would do no hurt to it whatever, but that it would run this bridge. He, therefore, assumed that there might be a pressure of from 40 to 50 lbs. over a space of from 100 to 200 feet?—I can say very positively that Sir George Airy never gave Mr. Barlow and me, so far as I understood it, any idea that there was any thing like such a square foot as that at which he speaks of to us about the Forth Bridge. This was given many years afterwards. He might have forgotten that he had ever mentioned the subject of wind at all.

18,800. Then I asked him a question at page 668, "When you said a gust, did you mean a point?—I did not mean a point. Q. You meant a limited area?—Yes, I meant a limited area. In the case which I suppose of a great condensed storm coming down the valley which, I believe, was the state of things on the night in question, I think that it would be felt as a condensed storm in every part of the bridge?—I am quite prepared to admit that the opinions expressed by Sir George Airy here were not in accordance with the opinions which he gave us in 1873.

18,801. You have therefore heard evidence different from that which you had heard before?—Yes, and if you recollect, I volunteered a remark which will be found upon the note here. When I was asked if I knew and was so worried that my thinking still that 20 lbs. was right, I expressly excepted any weight that might attach to the meteorological evidence given here. I said that it would require study, and might lead to a change of opinion. It will be recollected that I expressly stated, and I say so still, that if engineers are to reconsider the subject they must take into account what we have heard, and give it its due weight.

18,802. Then you think the evidence that we have heard in this case may have a tendency to modify the views which you have expressed in your paper?—I think it is possible. I gave no views in my paper, I merely stated facts.

18,803. With respect to wind pressure. You say, in your paper, that 10 and 20 lbs. —?—That paper was entirely retrospective as to what may be supposed to have taken place in the mind of the engineer when he designed the bridge.

18,804. Therefore it is quite independent of what you state in this paper?—That is so.

18,805. Now I must ask you one question with respect to the foundations of this bridge; you gave your attention to that, did you not?—No, I did not. I really hardly know how the foundations were made. My work began here (pointing to the model).

18,806. With respect to these two 1 girders at the top would it have considerably strengthened it if the girders had been raised right across?—It would have contributed to the stiffness of the pier, but the pier was already very largely stiffened by this bracing. It would have increased the stiffness on the same principle as it would if the pier had been made twice as wide, and the columns twice as thick.

18,807. Would there be any difficulty at all in carrying the girder right across?—That I do not know. It was suggested that this space had something to do with some lifting apparatus.

18,808. I think it was simply that the girders were carried up between the 18-inch and the two 18-inch columns, but how would that prevent you from carrying the girders across?—As a matter of construction there would be no difficulty in putting the pier over the bridge, but I do not suppose the engineer thought it necessary. That would have added to the strength of the pier, just as it would have added to the strength of the pier to make it wider and to make the columns twice as thick, but I do not see that it was a necessary addition to the structure.

18,809. Mr. Barlow asked Sir Thomas Bouch, with respect to the Beath Viaduct, with which you are well acquainted, I believe?—I never saw it or heard of it until I heard of it here. I do not know where it is. I suppose that if we could have put two columns on the outside there as rakers, that would have added a very considerable to the strength of the bridge, would it not?—It has not been proved that there has been any weakness from the narrowness of the pier. Nothing has shown that the pier is too narrow, that is to say, I do not see any way in which the narrowness of the pier has contributed to the catastrophe. If the pier had turned over entirely from the line of force, as it happened, then the pier would have been too narrow; but there is no evidence that the line of resolution of force has ever been outside the pier, and if that is so then another column outside would have done good no good at all. I cannot suggest in what way it would have strengthened it. There is plenty of breadth, because the pier is stable as a whole with all the forces that act upon it. There is plenty of metal, because the strain upon the metal is vastly below the power of the iron, and I fail to see in what respect two columns here (pointing to the model) could have made the bridge stronger than one.

18,810. If the lower portion of the 18-inch column had gone, would not the bridge have come down?—Yes; it has not gone.

18,811. It has gone?—It has not gone undoubted as a cause of the catastrophe. Some of the columns have broken by their twisting over after the bridge gave way, in other respects; but there is no evidence that they went as a first effect of the wind. I have never seen the slightest evidence to that effect. If there is any it is new to me now, and if that is so I do not see in what respect two columns would have been better than one. If it had been proved that this column had failed from want of strength, then of course if you had doubled it you would have doubled the strength, but I do not see than that that would make it twice as wide.

18,812. Except that you see it has all fallen over toeward, and has fallen over in that direction?—Yes, but that was the consequence of this breaking.

18,813. But I am still asking you; supposing for instance the lower part of this 18-inch column had broken, would not the bridge have come down?—Yes, I think it would.

18,814. Then if you had had two columns on the outside, I suppose that would have been an additional security?—Yes, no doubt.

18,815. (Col. Yolland.) I see that in page 20 of your report, under section 13, you say: "Under this condition the pier will be stable without bolts till the wind pressure reaches about 20 lbs. beyond which it must be tied down." On page 14, under section 6, the corrected pressure at which a second-class carriage would be thrown over, I think you mentioned to-day would be 33 lbs.?—That is what I made it.

18,816. Col. Yolland. The evidence indicates that there is a very close agreement between the wind pressure that would bring down the pier themselves and the pressure that would blow over the second-class carriage?—Yes, that is assuming that the windward side of the pier is not tied down; but it is tied down, and consequently that
pressure may be extended, as we have shown in the able below, to 40 lbs., and even above with perfect safety, otherwise the windward bolts would have no use.

18,818. I am not speaking of the holding down poles, but simply of the columns themselves, and the manner in which they are attached to the base plates. If I understand rightly 343 lbs. would dispose of them without holding down bolts?—Without holding down bolts of any kind.

18,819. I am speaking of the base plates?—I am speaking of this column being entirely loose without any bolt at all; 34 lbs. would then tip it over.

18,820. There is only a difference of 1 lb. between the two quantities?—Yes.

18,821. I think you pointed to the base of the pier?—Being the weakest part of the pier?—The part on which the greatest strain comes.

18,822. Where the greatest strain would be brought, and where the action of the wind would have most effect?—Yes.

18,823. I think you mentioned that it was assumed that the lateral strain of cast iron was about seven?—It varies considerably. The mean of Mr. Hodgkinson's experiments gives 7 1/4; other experiments give 10.

18,824. And that the area of the lugs was 9 inches?—Yes.

18,825. And hence that there would be 63 tons required to fracture them?—Yes.

18,826. You have seen, I have no doubt, Mr. Kirkaldy's experiments?—Yes, I have seen that they broke with very much less.

18,827. And as the result of these experiments, some of those lugs appear to have broken under one-third of the pressure that you mentioned as being the tensile strain of cast iron?—Yes, that is so.

18,828. And hence, if the wind be only taken at 10 tons on the square foot with a light passenger train over one pier, the strength of the cast iron that has been tested, since this bridge has been blown down does not amount to as much as the 3-39 which is given in that column?—I think you are under a mistake there.

18,829. "The maximum stresses on the diagonal tines in tons per square inch of section are as follows: "Wind 10 lbs. No train on the bridge 2-6 tons. "With a light passenger train over one pier 3-39?"—That is on the 1/4 inch.

18,830. But I am pointing out that these tine bars involve the use of cast iron at the lugs which breaks under less than 1/3 of the?—Yes, but the area is so large. The area is 9 inches as compared with 1/4 inch.

18,831. (Mr. Buder.) That 3-39 is calculated upon the minimum section of the tie 1/69 inches, so that it is equivalent to a total strain of 5-67 tons. If you take it over the 1/4 inch of the lug it gives you a strength of about half a ton.

18,832. (Colonel Yolland.) But what I am dealing with in Dr. Pole's statement, that the strain of the lugs which are involved in the tie-rod from the bottom of one pier to the top of the next is seven tons?—It is 63 tons. Seven tons per square inch, and you are proved to break at one-third of that.

18,833. (Mr. Webster.) Your argument was that the lugs would never bear but 10 lbs. of wind. You admit that if you take the sectional area of the lug, and take it according to Mr. Kirkaldy's strain, it will bear 40 lbs. of weight at least?—Yes, I think that is so. My statement simply amounted to this: that an engineer designing those lugs might on the ordinary rules expect them to bear 63 tons, with an average quality of iron. I know perfectly well that they have broken at Mr. Kirkaldy's with less. I do not pretend here to explain why. Whether they have been damaged or not, I do not know, and I have no means of knowing. But the inference from that, as Mr. Webster puts it, is, that the tie would break with a wind pressure of about 40 lbs. With 20 lbs. of wind, the strain on the tie is 11/2 tons, with 40 lbs. on it would be 22 1/2 tons. That is just about what the lugs broke with. Therefore the lugs, as tested by Mr. Kirkaldy, are shown to be in a position to break with 40 lbs. of wind in my calculation and not 10 lbs.

18,834. (Mr. Webster.) The mistake arose in not taking the difference in area between the cast-iron lug and the wrought-iron tie.

18,835. (Colonel Yolland.) This is founded upon the wrought-iron tie, entirely, and my questions are based entirely upon what forms a portion of the wrought-iron tie in the shape of the lugs at the lower end of it.

18,836. (Mr. Webster.) But with a very much larger cross section.

18,837. (The Commissioner.) What I understand Colonel Yolland to say is this, that the pressure on the lugs will be the same as the pressure on the diagonal ties.

18,838. (Mr. Webster.) The pressure per square inch, of course.

18,839. (Colonel Yolland.) And it is calculated here on the supposition that the wrought iron breaks at 20 or 21 tons of pressure?—They did not include that. They merely state what the strain upon this is with a certain wind. They have all that to be done afterwards.

18,840. To be compiled?—To be compiled. I have merely stated what strain a certain given wind will produce upon that lag. Of course it produces a certain strain per square inch upon the wrought iron, and a certain quite different strain upon the cast iron. So those two may be, and should be, estimated from the data which an engineer may be expected to have.

18,841. (Mr. Buder.) May I point out that a misconception would have been avoided, and that it would have been more convenient if Dr. Pole and Mr. Stewart, instead of giving the strain per square inch upon the lag, had given the total strain?—You have only to multiply all those figures by 169, and that will give the total strain.

18,842. (Mr. Barlow.) Is it 1-69 or 1-625?—1-69, we have it here.

18,843. (Mr. Law.) It would not do to apply my figures to Dr. Pole's.

18,844. (Mr. Buder.) If we take 169, it will be a more convenient figure.

18,845. (Mr. Webster.) I am satisfied, that I know really where the mistake is, that if you take the section of cast iron, and if you assume that it had only in the bridge the breaking strain at which it broke at Mr. Kirkaldy's, that is to say, taking everything most unfavourably to the contractor, and most unfavourable to the lag, you will find that it will then still stand a strain upon the tie of 40 lbs. of wind; and that error of 10 lbs. arose from not remembering the sectional area of the lug?—That is so.

18,846. (Mr. Barlow.) If you put both of them into pressure upon the tie, Dr. Pole will do it for you.

18,847. (Mr. Buder.) There is another way of putting it. So far as the lag is concerned, if the lag had been up to its full theoretical breaking strain it would have stood 120 lbs. of wind?—That is so, certainly.
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18,838. (The Commissioner.) You have said that it would bear 63 tons?—Yes. It would have borne 100 lbs. of wind. The strain on the tie with 20 lbs. of wind I make 11 1/2 tons. If those lugs had been sound, there is no doubt they might have been expected to stand, 68 tons, we should have had above 100 lbs. of wind necessary to break them down.

18,839. (The Commissioner.) But apart from the wind may we take it in this way: that those lugs theoretically would bear a strain of 63 tons?—Seven tons multiplied by 9 inches. Yes.

18,840. Then as a matter of fact they did only bear a strain of about 20 tons?—Yes, that is so—that is to say: the whole thing of which the lugs formed a part, only bore 21 tons. It is not quite right to say that it was the lugs only did this; the fault may be in something else than the lugs, and I believe it is.

18,841. (Col. Forster.) Was it the lugs that broke?—Yes. It was the lugs that broke.

(The Commissioner.) In almost every case.

(Mr. Webster.) Not always.

(The Witness.) Generally; but there is every probability that their breaking so much under their calculated weight was due to something unconnected with themselves.

18,842. (The Commissioner.) But then, as I understand, there were a quantity here that were sent up indiscriminately, some of them that were sound, and some of them that were unsound. A good number of them were sound. They broke at a pressure of one third; what have you said they ought to have borne?—Yes. Let me say what my assumption means. My assumption is founded on two things: first on the area, about which there can be no mistake (I do not think that anybody denies that the area is 9 inches), and, secondly, on the strength which is known to everybody in the world in the case of ordinary mild iron, which is a mean of 7 tons per square inch. Multiplying 7 by 9 gives 63. The reason why they broke with less than that I do not pretend to say; it may have been bad iron, it may have been that they were damaged; or it may have been something in the conformation of what was used in connection with them. It would require a very large inquiry to enable that to be determined. All I say is that the fact of their breaking with less could not have been anticipated by the engeneer who designed the bridge.

18,843. I am not saying that, only as a matter of fact they did break?—Certainly. I have never denied that they did break.

18,844. (Mr. Bulder.) Being what they were, and not what they ought to have been, and breaking as they did with Mr. Kirkaldy, they are still equal to 40 lbs of wind?—Yes, that is so, that I do assert quite positively.

(Mr. Frayner.) That is subject to you going over the calculations, because I am informed that it is not correct.

(Mr. Bulder.) If Dr. Pole's calculations of the strains upon the ties are right, these lugs, breaking as they did, were equal to about 40 lbs.

(Mr. Frayner.) That is what you say, and what I assume is not quite accurate.

18,845-6. (Mr. Barlow, to the witness.) I feel very dubious in asking you any questions because I know your general accuracy, but there are certain points which I should like to have explained, particularly taking what is at page 21, article 13, of your report. There you are dealing with the action of the wind upon the leeward and windward columns. You take the first condition with no train on the bridge as if there was a compression on all the columns of 1 1/4 tons per inch?—Yes.

18,847. Next you take a wind pressure of 10 lbs., which has the effect of increasing the compression on the leeward column up to 2 1/2 tons, being a difference of 0 2/5 tons, and it decreases the pressure on the windward column accordingly?—Yes.

18,848. You do the same with regard to a 20 lbs. pressure, but when you come to a 30 lbs. pressure you depart entirely from that range; you seem to have no difference in the tension on the windward column, whether you have got 20 lbs. of pressure or 30 lbs. of pressure?—Blows have been supposed to be made; there would be no tension at all. We assume that the bolts are removed. It is in order to show that the bolts are not necessary. We supposed the bolts to be entirely removed in order to bring the strains upon other parts of the pier. If the bolts are put in they will increase the security; but this is on the worst possible assumption; that there is no bolt, and the less of resolution passes within the pier, the pier is stable without any holding down; and therefore, as the simplest way, we have omitted the bolts from consideration altogether. I did make a calculation putting the bolts in, and the result was, that by putting a little tension on the (pointing to the model), we relieved the compression on the other side; but we have assumed in this calculation as we say that the bolts are unscrewed.

18,849. Then I may take it that after the wind pressure exceeds 20 lbs. there will be a tension upon those bolts, although you may not put it in?—If they are screwed down I think there will be a tension.

Mr. Stewart and I discussed that question a great deal. If the bolts are in, we believe there will be a tension upon those bolts, and that will relieve some of the compression on the other side; but we have assumed in this calculation as we say that the bolts are unscrewed.

18,850. But when you come to a pressure of 40 lbs., the bolts appear again?—Yes, because there must have them, as the pier is unstable without them.

18,851. And with a passenger train on the bridge with a 40 lbs. pressure of wind you have a strain of three tons upon the bolts?—Yes, we must have the bolts then.

18,852. Is that a strain on each bolt, or is it a strain per square inch?—It is per square inch of metal in the bolts. It applies to the bolts alone.

18,853. In calculating the effect of wind pressure upon the ties, I understand you to say that you have taken into account two elements of resistance, one being the stiffness of the columns as bolted down, and the other the ties themselves?—That is so.

18,854. Can you without trouble tell me what proportion the one bears to the other?—Yes. For the 20 lbs. of wind with a train on the bridge each of the two principal ties bears 11 1/4 tons, not per square inch, but the whole of it. Each of the four 16-inch columns bears 7 7/8 tons. Each of the 18-inch columns gives at its top a resistance from bending of 2 3/4 tons, and each of the four 16-inch columns gives a resistance of 1 406 lbs. If you are going to add those up, allow me to remark that the strain upon the principal tie does not express the strain here, because it has to be resolved in the horizontal direction.

18,855. If you can furnish that to-morrow it may save time now, so that one may learn how much is due to the supposed stiffness of the columns, and how much is due to the ties themselves?—Between one-fourth and one-fifth of the whole resistance is due to the stiffness of the figure columns.

18,856. Can you tell me the total weight of the iron, in the ties of one pier?—No, I cannot.

18,857. Will it be about two tons? (Mr. Webster.) Do you mean to include the channel irons?

18,858. (Mr. Barlow.) No, the ties only. (To the witness.) The experiments made by Mr. Kirkaldy on the test have shown that the strength of the iron itself as iron is very fair and good, ranging about 20 tons?—Yes.

18,859. But the strength of the ties tested as a tie seems to come out, only 15 tons, or something like that, to the square inch, measured at the minimum section of the tie?—I did not know it was so low as that.

(Mr. Webster.) I should like to give it you correctly now. I do not think there is anything so low as 16 tons.

(The Commissioner.) Yes, there is one...
(Mr. Webster.) Not the one which was sent to be taken as a specimen.

(Mr. Bidder.) 6,000 lbs. I think. There is one in this house which is a little lower, 4,000 lbs.

(Mr. Barlow.) If you take the 66,000 lbs., which is about the mean, that is about 1-foot inches, what would that bring out?

(Mr. Bidder.) That would be about 16 tons.

(Mr. Love.) The tie-bars, without the channel iron in one completion, taking the second ones as well, would be about 16 tons. There are eight panels altogether, the six outer panels and the two cross ones.

(Mr. Webster.) I have before me a summary of the results of the second experiment upon the test. The first part broke with a pressure of 19,566 tons per square inch; the second one broke with a pressure of 21 tons per square inch; and the end one broke with a pressure of 19 tons per square inch.

(Mr. Barlow.) In the paper dated the 22nd of April 1880, you will find three results varying from 56,000 lbs. to 59,000 lbs. on the old tie, that is, somewhere about 15 or 16 tons to the inch, measured on the minimum section, is it not?

(Mr. Bidder.) I think it is about 16 tons.

18,880. (Mr. Barlow, to the witness.) Can you account for that difference, the metal being good metal, and yet in the particular form in which it is put into this tie, it only yields three-fourths of its strength?—It must be something in the form of the bar near the hole. We are in the habit of considering the bars which have holes punched out of them, even though their full strength; but in this case the bar appears not to have been given its full strength. It must have been something in the formation of the bar, provided that the metal has not been damaged there. We must recollect that all these ties and bars have been brought from the fallen bridge, and they may have been damaged in some way, and not able to say whether they were or were not, but they may have been. I do not mean to say that it was the simple strain, because, as I have already stated, the simple strain does not make iron weaker, but they may have been damaged by a full or in some other way, and I can only account for the want of strength either by the supposition of their being damaged or by something in the form of the bar at that place. We are not accustomed in suspension bridges, if they are properly proportioned, to consider the part where the hole is, as showing less strength than that due to its area, and certainly we are not accustomed to do so in the case of riveted structures.

18,881. In the case of riveted structures, it is the usual practice to put the rivets as great as the sectional area of the bar?—I am not quite sure of that. I do not think it would be quite possible to do that always. That is a case that I mentioned before where the iron cannot get away, and where a want of bearing surface would do no harm. I do not think that rule is adopted. The shearing surface is, but I say with submission to you, evidently: that I think in many cases, such as suspension bridge pins, and pins for girders and rivets, it is not unusual to get much more on the bearing surface than four tons, and it is difficult to see how any harm can arise, because the iron cannot get away.

18,882. In your own practice do you put more upon the bearing surface of your rivets than you do upon the minimum section of your girders?—I do not think I am in the habit of calculating the bearing surface; one calculates the sheering stress upon it, and the thing generally comes right. I do not think the bearing surface of the rivet is usually calculated. I will not say that I should not put it, and I do not say that I would not, if I designed a new bridge, but I think it often is put larger. "Do you not think, if you will-allow me to put it in the form of a question, that in the case of pins in girders and suspension bridges the bearing surface of the pins is often smaller than the sectional area of the girders?—18,883. So far as I understand it is carefully considered and made equal. Have you calculated what the bearing surface of this particular pin is in this particular tie?—No, it is small, I know; it is an inch and a quarter by half an inch, if you take the diameter, that is five-sixths of a square inch.

18,884. What proportion does that bear to the minimum section of the tie-bar?—It is a little more than one-third.

18,885. Do you find in that a reason why these bars do not come up to their calculated strength?—No, I do not, because it has not failed there I think it has failed at the sides. The corner, which is smaller, has not failed at any rate.

18,886. That is not the point. I am speaking now of the immediate vicinity of the pin?—Yes, but it has not failed by the crushing up, it has failed by pure pulling seeder. It has not failed by the crushing up, through part of the area.

18,887. At any rate it has failed, by tearing round that hole?—Yes, it has failed by tearing round that hole, and I certainly think that something in the formation of the hole has caused the diminution of strength.

18,888. Supposing that, instead of being held by that one pin, there had been a second pin of the same size, say six inches off it, do you think it would have had that result?—No, I think it would have stood its full strength.

18,889. Again, with regard to the lug, the metal there by the ordinary mode of computing would give a strength three times as great as that found in the experiment, would it not?—Yes.

18,870. Have you any idea in your own mind as to what is the reason of the difference there?—No, I should not like to say without making trials. It has puzzled me very much.

18,871. We have heard something about the holes being comical?—Yes, I think that would contribute to it.

18,872. It would bring a pressure upon one side of the iron of the lug before it came upon the other?—Yes, but then the pin tends to take its bearing over a larger surface.

18,873. Nevertheless, whatever force is required to bend that pin, is acting upon one side of the iron of the lug and not upon the other?—Yes.

18,874. We see in that some reason then for the diminution of strength which is apparent in these ties?—Yes.

18,875. We have just heard that the total weight in the whole of the ties in these piers would be about five tons. Supposing that there had been double that quantity of metal put in, and that it had been made 10 tons, would it have had the same strength the strength to double?—Yes, I suppose it would.

18,876. Supposing that instead of being made as they are here, flat bars, they had been made as originally specified angle-iron bars, would that have contributed still more to the strength?—I think not with the same area, because the strutting action was not wanted; it was a steel bar which was not intended to resist the wind, and whether this was in the form of an angle iron or a straight iron, did not matter at all.

18,877. You do not mean to suggest, do you, that if there had been a strut in the other direction it would have been a better if the pier had been made twice as?—Well,
I have steadily hesitated to consider any alternatives to the design, because if I had begun to do that I do not know where I should have stopped.

18,890. Perhaps that is right; now, speaking of the columns, you have stated that the fracture of any one of these outer 18-inch columns has led to the destruction of this bridge, seeing the way that they are fastened at the top?—Yes, I should think it would.

18,891. If there had been two outer columns instead of one, would that have been so?—If one had broken, the other might have saved it.

18,892. And also if there had been the original design of two columns instead of one, these wind ties would have acted at a better angle as regards the place in which they were placed?—They would.

18,893. You have expressed a tolerably strong opinion as to the wind ties giving way before any column gave way?—I have a very strong opinion upon that point.

18,894. May I ask upon what particular evidence you base that opinion?—Upon the appearance of the ruins. They show an entire fracture of every one of the wind ties that is accessible, and I hardly think that would have taken place if any other part had gone first, and besides you want evidence of some other part having gone first. If I had had evidence of any other part having gone first I should have considered it, but I never have had such evidence.

18,895. You have heard evidence, for example, of columns having split?—That would not bring it down.

18,896. But if they had split obliquely?—Yes, one can conjecture that happening, but I have not heard a particle of evidence that it did happen, and I have the evidence of my senses that the ties are gone, and every appearance of the ruins, so far as I have had time to examine them, is consistent with the hypothesis that they went first, and that everything else followed as a matter of course.

18,897. Now, there is one opinion with regard to the columns; you have mentioned in your report that the strain upon these columns under certain conditions is 24 tons per square inch, and you take the crushing weight of iron at 40 tons per square inch?—Yes.

18,898. But you do not propose, do you, to compare the crushing weight of iron with the strength of the column?—No; I intended to do so, but I have not been able to calculate the strength of this as a column. In fact, I had looked out Hodgkinson's rule treating this not as a mass of iron to crush, but as what he called a short column or a medium column, I forget which; I intended to calculate that, but I had not time. Mr. Stewart, who has calculated it, tells me that it makes a small reduction in the strength, but not a sight ideal, and I think the margin would be ample even on that supposition. Of course we must only assume columns of this length and not longer, because if there were less there is little enough, which I think you would consider length and not longer, because the crushing reduces the length of the column to 12.77 feet.

18,899. But when you take it on the longer length, the bulk of the weight comes upon the top of that?—Yes.

18,900. And it is seven columns one upon the top of the other, only held in their places by wind ties of not apparently very great strength?—I think, with all deference, they have plenty of strength for that.

18,901. You think they have strength enough to develop 40 tons to the inch in that mass?—I do not quite see it in that light. The tendency of that column to bend under a heavy weight, if it had no ties, would be no doubt such as to break it, but I think I explained at an early part of my evidence that the object of these ties is to hold those in their places (pointing to the model).

18,902. I quite understand that, but you were speaking of what a column of 11 feet would do as compared with what a short specimen of two or three inches would do in crushing if you took these things, which are altogether 77 feet in height, and attempted to put your weight upon them, even approaching 40 tons to an inch, would not the whole thing go down?—They would not stand, they must be braced. The columns without bracing would not stand at all, they would bend and go directly.

18,903. (The Commissioner.) That was the question that was put to you before, and I understood you to say that they would stand?—I beg your pardon, I never said anything of the kind. If I had said that without bracing they would stand the weight of the girders, I should have been mad.

18,904. You said that there would be very slight pressure indeed upon the ties, that they are chiefly intended for the purpose of resisting wind pressure?—There would be very slight pressure upon them, but that slight pressure would be enough to keep the column in place and enable it to do very difficult to calculate the pressure upon them, but still if they were not there the columns, by some accidental irregularity without exerting much force would bend, and then when once it began to bend it would break. I never denied that, but these are keyed up to a certain tightness in order to keep the columns straight, and if they do their work they reduce the effective length of the column. That the column would stand, as a whole, without bracing, I never asserted for a moment. The bracing there is perfectly efficient for that purpose.

18,905. (Mr. Barlow.) For holding these together for very large pressure?—I should think so. Mr. Law supposed that they were keyed up with a force of two tons. I should think that would be amply to keep the column straight. It is difficult to prove it.

18,906. I think a good deal of error has arisen about the effect of the wind when it is upon the stability of the bridge; I understand you to say that the wind through the bridge, in your opinion was not at all contributed here to the downfall of the bridge; that is to say, that upon a pier of that base, with proper holding-down and proper ties you could have perfectly well made a bridge to carry the trains?—I think there is no evidence that the pier has gone from want of breadth.

18,907. You said that it would be easier to make a pier twice the breadth, or some words to that effect?—No; the Commissioner asked me if this bridge would not have been stronger if it had had two roadways braced together; and I said it would, on the same principle that it could have been stronger if the base had been twice the width and the columns twice the diameter.

18,908. Supposing the base had been twice the width, would you not have required exactly the same strength in the wind-ties?—Yes; except that they might have been put at a slatter angle.

18,909. The effect of the strain upon these wind- ties, as a matter of fact, seems to have been to elate some of them to such an extent as to admit of a packing piece of wood of an inch?—Yes.

18,910. How much would that cause the upper part of the column to move?; it would be about half as much again, would it not?—Something more. It would be, I think, is the proportion of the square root of 2.

18,911. And this being three-eighths of an inch, that would bring it to about three-quarters of an inch, would it not?

18,912. (Mr. Bolder.) Five-eighths.

18,913. (Mr. Barlow.) If the bar has been elongated to such an extent as that, I presume it must have been pushed over further than that, because there is a certain amount of elasticity left in the bar which would return; the permanent set has been three-eighths, and therefore the extension of the bar must have been greater than three-eighths?—I do not quite follow you.

18,914. (Mr. Webster.) Would that spring back arise if it was in consequence of the bending of the bolt?

18,915. (Mr. Barlow.) I think so.

18,916. (Mr. Trayner.) Supposing that Dr. Pole gives his opinion upon the theory put by the Court.
18,908. (Mr. Barlow.) I suppose that the strain is
so great that after the bar endured it it comes back to
a certain extent by its own elastic action, and that it
would leave in it a stretching of three-eighths of an
inch. The pulling out of place must have been some-
thing exceeding that three-eighths of an inch which we
have been talking about in order to come back, and
leave three-eighths of an inch in it; it might have
gone to half an inch, and the result would have been
a movement at the top of the column of three quarters
of an inch?—Yes.

18,904. Would not the movement of the top of the
column of three quarters of an inch have created such
an unequal action in the bed as to throw a great
pressure upon the flange of the columns?—Yes.

18,905. And it would produce also a tension upon
the flange-bolts upon the outer side of the windward
column?—It would have strained them; I do not
know whether it would have broken them.

18,906. Then the effect of that would have been to
have strained the bolts on one side and to have
compressed heavily the flange on the other side?—Yes.

18,907. We have been told that there were about
100 bars which were tightened up to the extent of
three-eighths of an inch (I think by other computa-
tions it varies somewhere between 100 and 150 bars),
and there are a very great number of these tie-bars in
the bridge; what do you suppose could have happened
to the tie-bars when these 100 were being stretched?
would they all be stretched too, and not tightened
afterwards?—I cannot tell at all; I do not
know whether they were of what sort of force would
have come upon them.

18,908. There are about 1,500 ties in the bridge,
are there not?—So I am told; but I cannot answer
the question at all.

18,909. (Col. Yolland.) If one of the tie-bars is
elongated; that is to say, pulled out by the straw and
then elongated; that is to say, pulled out by the straw
and elongated, it would have the distance that
comes with it. the other one—the one at
right angles to it—will be made loose?—Yes.

18,910. And if these packing pieces were put into
the wrong place, they would keep the distortion that
had been occasioned?—This has always a tendency
to go back again.

18,911. I am assuming that one of the columns has
got an act by the elongation of one of the tie-bars, and
the other one would be made too long, and hence the
chattering?—I do not quite see how the column could
have got elongation from one of the tie-bars, because
you might elongate them without moving the column.
18,912. From here to there, for instance (pointing
to the model), if you lengthen that this may go out
somewhat, and this will be made too long?—Yes, it
will be loose.

18,913. Then if you come to put the packing piece
into the wrong column that will tend to keep it in the
improper shape that it will have assumed by bringing
in strain upon it. Imagine the packing pieces to be
put in the wrong places—They cannot be put into
the wrong tie-bars if they are put in those that are
loose, because the object of them is to tighten
them up.

18,914. But only imagine them pulled out by the
elongating of the holes and so on, whilst the column
is thrown out of position, these are as tight as they
possibly can be?—If you find one loose you are doing
right in putting a wedge in it, if you do not find one
loose, you cannot get the wedge in it.

18,915. One of the tie-bars is elongated?—But how
does it come to elongate?

18,916. Partly because the holes through the lugs,
and possibly through the crotchet in the tie-bars allow
it to be stretched?—It elongates and gets loose.

18,917. No, it is the efficient one that gets loose,
the one that crosses it at right angles?—But why
should it not get loose if it elongates?

18,918. It is elongated by the strain that is brought
upon it?—But when that strain is gone the column
goes back again.

18,919. Then you assume that it is an elastic thing
that will always go back to the position that it started
from?—I do.

18,920. I do not think that is an assumption which
would always be borne out?—The column is elastic,
I think, and I think a good deal that has been said
about the bending of the column may be explained
away by the fact that the column has a tendency to
right itself as soon as the strain which removed it
from its normal position is gone.

18,921. (The Commissioner.) That is to say, if the
column went in that way it would come back; but
supposing that the bolts which held it at bottom
would not at all, then it might get a permanent set?—
Yes, but they are elastic and would come back again;
but if it is permanently thrust out of its position I
can understand it.

18,922. If the bolts at the flange give way at all
then the column will get a permanent set out of the
vertical?—Yes.

18,923. And then in the other way the other ones
become shortened, and then you put packing pieces
into it, and you stereotype it, so to speak?—You fix it
in its distorted position.

18,924. And then in that way your force do not
act in the right direction, in fact?—No; but I cannot
think that any great amount of evil would result from
that.

18,925. I quite agree with that: I beg your pardon
for being so obtuse as not to understand that before.

(Mr. Biddulph.) I think you said previously that the
force required to bend a column was much less than
the force required to pull it up at the bottom?—Yes,
a column will bend considerably before the bolts give
way.

18,926. (The Commissioner.) No doubt, but the
question that I wish to put, and which was put by
Colonel Yolland, was "If the bolts of the flange
were given way at all so that the base of the column itself
was moved, the column itself might become distorted
altogether, and might remain in a distorted posi-
tion?"—Yes: and, as a general answer, I say that
if the thing gets into a distorted position from which
its elasticity will not bring it back, and then you tighten
up a loose tie you will fix it in that distorted position.

18,927. And, therefore, the greater the importance
of having the bolts as tight to the bolt holes as
possible?—Yes, I think so.

(Mr. Webster.) With reference to what the witness
said as to the number of tie-bars, there are 1,536 tie-
bars under the high girder. There are upwards of
2,500 tie-bars in the rest of the bridge.

The witness withdrew.

Adjourned till tomorrow at half-past 10 o'clock.

Dr. William Pole.

3 May 1860.
TWENTY-THIRD DAY.

Thursday, May 6th, 1890.

(The Commissioner.) Before we proceed I think it is right to call attention to a portion of Dr. Pole's evidence which he gave yesterday (question 18,753).

Sir, to Dr. Pole: "You said in answer to Mr. Bidder that the marks on the girders were sufficiently clear to bear any opinion in respect to the marks on these iron bars, and I do not recollect saying anything in that regard. It is necessary that you should have no opinion about the evidence in respect to these carriages." In point of fact Dr. Pole strongly repudiated having said what I put to him and also, as I understand, Mr. Bidder distinctly stated that Dr. Pole had said nothing of the kind. If you will refer to question 18,622, you will find this question put to him: "And if these bindings and distortions of portions of that girder, that were referred to yesterday, and the markings upon it, are indications of the effects of a collision between those carriages, then, in your judgment, in that circumstance there is sufficient to support a claim that would bring the bridge down, I think so," said Dr. Pole. I am not saying that Dr. Pole has contradicted himself. I only mention it to show that the Court might very well have been misled by Dr. Pole's answer to that first question. Then there is another point also to which I think it is necessary that I should call attention. Dr. Pole was asked at question 18,777: "Do you mean a bending of the column itself or a displacement of it? - A displacing of it at the top, which means a bending. I suppose that the lower part of the column is firmly tied down with bolts?" he asked. Now, there is no such thing as a column. The column is supposed to be firmly bolted down so as to have the power of bending when the force of the wind is brought to bear upon it. You are assuming that it is permanently fixed at the bottom, and his answer is "Yes." (Mr. Bidder.) "In this calculation you assume the column to be firmly rooted to its base? - Yes, I do." Then in my examination of Dr. Pole, I thought that it was quite necessary to test the value of that statement of Dr. Pole's, whether the column was or was not rigidly connected, or firmly connected, with the base, and I confess that I was surprised to hear it stated that there was any suggestion throughout the whole of the case that there had been any slackness or looseness either in the bolts or bolt holes, or any tendency of one face of the flange to slide over the other, and I referred to Mr. Law's evidence, and, as I understand it, it was stated that Mr. Law had never made any such observation. Now, under those circumstances, it being a most important question, I think it would be very desirable that we should ask Mr. Law, whether or not there was any looseness in those bolts of the flanges so far as he saw, or whether the looseness or the bending of the bolt referred entirely to the lugs and not to the flanges. I think it is quite necessary that that point should be settled.

(Mr. Bidder.) If you will pardon me, sir, for a moment, I ventured to draw your attention to this, when certain questions were asked of Dr. Pole as to whether the bolts of the base were conical, and whether the conical form of the holes might interfere in the manner that you indicated with the flange of the columns. I ventured to point out to you, sir, I believed, then, and as I think now, although everybody is subject to error, that as far as I knew it had never been assumed, and my words are reported by the shorthand writer, that the conical holes of the holding down bolts formed an imperfection in the bridge.

(Mr. Bidder.) If what is wanted is what Mr. Law meant by certain answers to certain questions in his evidence, of course I should not for a moment think of suggesting that it was an unreasonable thing to do to ask Mr. Law, referring to any particular answer in his evidence, where it appears to be in any sense ambiguous. What do you mean by that answer? - I should like also to say this: I know the kind of feeling with which the Court regards Sir Thomas Bouch in this matter, but I should like to say, once for all, that Sir Thomas Bouch is not here to seek indulgence; he is here simply to have his relation to this matter carefully and fairly investigated. He does not ask for indulgence at the hands of the Court, but implies for proper investigation.
Mr. Henry Law called again.

MR. H. LAW.

18,928. (The Commissioner.) You examined the bolt holes of the 18-inch columns which were cast ?

—I did.

18,929. I think you said, as Mr. Brunless said, or Mr. Light, that I do not remember whether it is, practically almost impossible to cast bolt holes square?—Yes, and explain how in their exact positions.

(Mr. Bidder.) I thought it was agreed that we were going to ask Mr. Law as to an ambiguity in some answer that had been given. If that is so, surely the ordinary course is to refer to the answer and ask him what he meant by it.

(Mr. Commissioner.) The question is a question of vital importance to the interests of the public. Here a great number of people have been lost, and an enormous deal of valuable property has also been lost, and it is of the utmost importance that we should know what were the causes, apart from whether or not the question that was put on the former occasion was properly answered.

(Mr. Bidder.) I am quite as conscious as you are of the vital importance of the question, but may I point out to the Court that a question being of vital importance does not make it a correct thing to do otherwise would be wrong.

(The Commissioner.) If I thought that Mr. Law was in any way a partisan in the case it might be another matter, but I do not look upon him in that way at all. I do not look upon Mr. Law as a partisan in any way whatever, and we require to know from Mr. Law what information he can give us with respect to the bolt holes of these columns.

(Mr. Bidder.) Perhaps Mr. Law can refer to the very evidence which he gave.

(The Commissioner.) I think I can do so.

(Mr. Bidder.) I suggest that there can be no objection to this. With regard to any evidence that Mr. Law gives, if you, or Mr. Law thinks, that there is any ambiguity about it, let it be referred to, and let Mr. Law say what he means by it. I could not raise any objection to that. That seems a perfectly fair and proper thing to do if the Court wishes any doubt to be cleared up.

(The Commissioner.) If it is at all doubtful I shall feel myself at full liberty to put any further questions that may lead us to Mr. Law.

(Mr. Bidder.) But, sir, you must remember this. You made an observation, just now about the vital importance of the inquiry, and the number of lives which have been lost. I, as representing Sir Thomas White, and the learned friends who represent Sir Thomas White, have followed with the greatest care the case that has been presented on the part of the Board of Trade, and the evidence that has been presented by the Board of Trade; and we have directed our attention to answering those matters which we suggest are the evidences which appear to cast doubt upon the complaint of the Board of Trade; and we have held, it is of vital importance to the public as well as of vital importance to the public; and therefore we have with the greatest care scrutinised the evidence to learn what is the charge, and how the phrase is advisedly, although it has been said here that no charges are made; but what are the consequences of the neglect or the breach, which you described; and we have prepared our evidence, and I have called my evidence to meet that charge. If now anything new is introduced as a matter of charge, I say charges in the sense in which I use the word, it is not fair and it is not right to my client (because I have no power to answer a certain case), after a great part of my evidence has been called, to suggest anything new, and I venture to say it is not fair or just to do so when Mr. Webster and Mr. Macnery represent that is why I press it upon you. I say the right and just course in the matter would be, if you want anything cleared up, in order to the particular questions and to the answers of Mr. Lewis and others, there is an ambiguity to ask him to explain that ambiguity in those questions and answers.

18,930. (The Commissioner, to the witness.) Will you first let us hear what you have to say?—I would have no purpose to read one or two of my answers to questions beginning with 14,710, at page 562, in Mr. Webster's cross-examination. "Looking to the position of the bottom base plate and its distance from the place where a lateral wind pressure would be applied, would any experienced constructor of ironwork, in your judgment, rely upon a spigot of that character, as affording an additional strength to his structure?"—Yes, you misapprehend their use, Q. Do you consider that an answer to your questions?—It is a very fair answer to your question; you asked what use they could be. Q. I asked nothing of the kind; I asked whether a constructor of experience would rely upon them?—He would rely upon them for the purpose of preventing the column sliding one on the other.

18,931. (Mr. Barlow.) That is the spigot and faucet?—Yes. "We see where they have moved upon the other, and that is one of faults of the structure, and they have moved the bolts apart." (Mr. Barlow.) Is that on the 18-inch columns or on the 15-inch columns?—On all. Q. Are there no spigots on the 15-inch columns at the base?—I will not say positively, but I believe they are all without.

(Mr. Bidder.) I must interpose once more. This is worse than all. You are now giving Mr. Law carte blanche to read at random any answer he likes from his evidence, and, so to speak, to make a commentary upon the evidence he has given.

(The Commissioner.) Not at all.

(Mr. Bidder.) You are not even asking him a question. You are requesting Mr. Law to read any answer he thinks fit. And now, observe, the thing that he selects does not bear upon the question upon which you were examining Dr. Pole yesterday when I interposed, it is another point of the case, which no doubt was adverted to by him, and upon which his evidence was given, namely, not what you were asking about yesterday, the conical holes in the base plates, but the efficiency or inefficiency of the spigots and faucets, which are entirely different things altogether. And you see, sir, I could not have a better illustration of the unfairness of this mode of proceeding than this, which is the very first spigot of it, that Mr. Law takes this opportunity to branch off quite a different question altogether because the matter that you were asking about yesterday, when I interposed, was that of the conical holes cast in the base plates, and the matter which Mr. Law now, having carte blanche to read what he likes, goes into, is the question of the efficiency or inefficiency of the spigots and faucets.

18,932. (The Commissioner.) I do not know what you mean by carte blanche. I wish Mr. Law not to read any particular answers to questions, but to give an answer to the question that I put to him. You seemed to object to that, and you thought it was better that he should read the answers he had given to particular questions. But, my feeling is this: that Mr. Law had better answer the questions I put to him; and, therefore, to avoid all further difficulty, I will repeat my question. (To the Witness.) You say that the bolt holes in the 18-inch columns were cast?

—Yes.

18,933. You know also, and you have so stated (and it is in accordance with the opinion given by Mr. Brunless), that it is almost impracticable to cast them square and regular?—It is impossible — not almost — it is impossible.

18,934. They require to be either rimed or drilled?

—Yes, and, even if they were rimed they would not be exactly in their position. You cannot determine the exact position of the cast hole.

18,935. When you spoke of the bending of the bolts, did you, or did you not, apply your remarks to
the bolts to which I have called your attention, in the flanges of the 18-inch columns—I did. The bearing of the spigot and fasten was this—

18,948. You must not refer to any particular answer that you gave. Never mind about the spigot and fasten—take the bolts?—The bolts being the only means of preventing the columns from shifting upon the other, and those holes being in all cases larger than the bolts in the cast holes, there was nothing to prevent one column shifting upon the other at the splice pinning together of the bolts.

18,947. And it was not firmly rooted down to the base?—Certainly not. The strut, as I explained before, bearing against the base-plate, and the tie pulling upon the column, the direct action of any lateral strain was to cause the flanges to slide one upon the other. The bolts not fitting the holes, and there being no spillage being nothing to resist that action, and in every case it took place.

(Mr. Bidder.) I propose to ask Mr. Law some questions upon that.

(The Commissioner.) I have not the least objection to your asking Mr. Law any questions you please.

Mr. Law (witness of the Court).

18,948. (Mr. Bidder to the witness.) Will you point out wherein your evidence you made that statement that the columns were not firmly rooted down to the base?—I have not used the expression; I have not said that the columns were not firmly rooted.

The last answer of the witness in answer to the Commissioner was read.

18,939. Why did you say you had not said that the column was not firmly rooted down to the base?—Because I did not say so. I answered the president's question in the affirmative, but not adopting his exact words. I gave my own words to explain precisely what I meant.

18,940. You hope we are not bandying words. I asked whether you said that the column was not firmly rooted down to the base. You said “No.” The shorthand note shows that the question was put to you: “It was not firmly rooted down to the base?” and your answer was, “Certainly not.”—Yes, I answered the question, in the affirmative, and explained the precise meaning afterwards.

18,941. Did you say that it was not firmly rooted down to the base?—Yes, applying the word “rooted” to a sliding motion.

18,942. Then why did you say “no” when I asked you whether you had not said so?—Because I did not use those words.

18,943. I take it, the words were used in the question, and you said, “Yes”?—Yes, certainly. If you take the thing logically in that manner, but it is splitting straws.

18,944. You draw a distinction between saying “yes” and answering to a question, and using the words yourself in your answer?—Yes, when I have explained exactly what my meaning was.

18,945. Did you ever in your examination-in-chief, or until this moment, say that the columns were not firmly rooted down to the base?—I never used that expression.

18,946. Is the equivalent of it?—Yes.

18,947. What?—At question No. 14,712. A column which is firmly rooted down to its base cannot move upon the other. Then, again at question No. 14,722. Every column cannot have shifted and broken its bolts and bent them; every one. I think I may fairly assert, in most cases the bolts are equivalent to their not being firmly rooted to their base.

18,947. Do you seriously suggest that that is equivalent to their not being firmly rooted down to their base?—I will not argue it, but leave it to the common sense of everybody who hears me.

18,948. Was not your calculation of the stability of the bridge, assuming it to be properly constructed, based upon the assumption that at a certain point the bolts would be uprooted and the column would be turned over?—Yes.
Mr. Allan D. Stewart sworn.

18,966. You are a civil engineer?—Yes.

18,967. You took your degree in Cambridge a long time ago?—Yes, I believe, in 1858?—Yes.

18,968. At that time you devoted yourself to civil engineering?—Yes, I did.

18,969. And for many years, you were in the office of Messrs. Blyth of Edinburgh, the well-known civil engineers?—Yes.

18,970. And subsequently you were employed as resident engineer upon various works of theirs?—Yes.

18,971. Messrs. Blyth are at present engineers for the Caledonian Railway, and they have about the largest business in Scotland.

18,972. I thought they were both dead?—No; Edward Blyth is still alive.

18,973. Benjamin Blyth is dead?—Yes.

18,974. For some years past you have been in business independently?—Yes, I have.

18,975. And I believe you have been very extensively employed in assisting Sir Thomas Bouch in some of his works?—Yes.

18,976. And the responsibility of the calculations of many of his more important works has been yours?—Yes; Sir Thomas Bouch consulted me in regard to the points, and I assisted him to the utmost of my power.

18,977. I believe you were the designer of the Rochester Bridge—that is to say, you worked out the details and calculations and assisted Sir Thomas Bouch in the design and execution of that bridge?—Yes; that is rather a complicated bridge, near Newcastle, a combination of a suspension bridge with a continuous girders.

18,978. You did a great part of the work for the design of the Rochester Bridge, as, so far as the scientific department was concerned, the calculations of all the struts and so on?

18,979. You assisted Mr. Barlow and Dr. Pole in the calculations necessary for their Report?—Yes, I made the calculations in Edinburgh previously to going up, and Dr. Pole and I went over them, and he agreed generally. In fact, in every respect, he agreed with my figures.

18,980. In the year 1869 were you employed by Sir Thomas Bouch in assisting him in preparing the design and making the calculations for the girder for the Tay Bridge?—Yes, I prepared the whole of the design for the girder of the bridge under his instructions. I consulted him with regard to many matters of detail with reference to the bridge before the Bill went to Parliament.

18,981. (The Commissioner.) The whole of the designs for the Tay Bridge?—For the girders for the Tay Bridge?

18,982. Only the girders?—Yes.

18,983. (Mr. Bidder.) At that time it was brick piers?—Yes.

18,984. I believe you were also frequently consulted by Sir Thomas Bouch on questions which arose during the progress of the work?—I was.

18,985. Were you consulted by him, amongst other things, on the occasion of the alteration of the piers to iron piers in the form we see them now?—I was. I frequently attended meetings, at his request of himself and the contractors and others, and we discussed all questions about the foundations and other parts of the piers generally.

18,986. With regard to the designs for the superstructure also were you consulted?—For the superstructure there were not many plans. The spans were altered, and I prepared the detail drawings under Sir Thomas Bouch's instructions.

18,987. Do you remember the question of whether the design should be one for six columns or one for eight columns being discussed?—I do generally. I remember seeing the drawings of both the 6-column and the 8-column bridges, and approving of the six columns—that is to say, the general features of the design.

18,988. The relative advantages of the one and the other were discussed on more than one occasion, were they not, of the eight columns and the six columns?—It is so long ago that I cannot remember the details very distinctly; but I saw both the drawings, and I can only say now that I quite approved of the 6-column pier.

18,989. You approved of the determination, this was ultimately come to adopt six instead of eight?—Yes, I approved of it then, and I still approve of it.

18,990. There is one other matter of past history that I have promised to ask you a question with reference to, and that is with reference to that matter in which there was a controversy in Mr. Guthrie's evidence. You kept a diary, did you not, in which you jot down your business proceedings in connexion with this work?—Yes. In the year 1876 I attended a very large number of meetings, both at Sir Thomas Bouch's office and at the bridge, but chiefly at the bridge, and I accompanied him upwards of 20 times during that year in visits to the bridge.
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18,980. (Mr. Commissioner.) You were not resident there?—No, I merely accompanied Sir Thomas Bouch to the bridge, as I wished to ask any questions that might arise that I could speak about.

18,981. (Mr. Biddre.) Will you fix from your diary the date on which the thickness of the columns was decided upon?—I have it in my diary 8th April, 1875.

18,982. On the 8th April what was done?—On that day Sir Thomas Bouch decided, I believe, ultimately as far as I could with advice upon any questions that might arise that I could speak about.

18,983. Have you note of that fact in your diary?—I have no note of that fact in the order was given. Just read so much of the extract under the date of the 6th April as bears upon the question?—Perhaps I should explain that this diary was jotted down after I returned to Edinburgh, either the same evening or the next morning.

18,984. Will you just read the extract?—April 6th. The Bridge with Mr. Bouch. Decided to make great pier column 14 inch thick, and inner column 1 inch thick.

18,985. That, we know, is subsequent to the letter of the 1st of April. That is all I want about that. You were also present at the final examination by General Hutchinson—I was.

18,986. I will just ask you as an engineer—you saw the bridge then?—I did.

18,987. And you saw it at various times during the progress of the work?—Yes; I did not of course inspect it minutely, but I saw it.

18,989. To the best of your judgment was it a work well and satisfactorily executed and put together, so far as you had an opportunity of judging?—It was; I did not examine the minute details of the work, but I was not in any way inspector of the works, but so far as the general features and appearances want I can speak to them.

18,990. (The Commissioner.) You speak to the design, and not to the workmanship?—My connexion was chiefly with reference to the design. As far as the general features are concerned, I can speak to them.

18,991. (Mr. Biddre.) Was the work, so far as you were able to judge, without examining to detect concealed defects, well and satisfactorily put together?—Certainly.

18,992. Do you agree with Sir Thomas Bouch that the examination and the tests applied by General Hutchinson on that occasion were of a very careful and exceptionally strict character?—I do; they were remarkably carefully done; nearly every girders and nearly every pier was tested; in fact, I have heard that in evidence and it has been perfectly correctly stated.

18,993. Does your recollection agree with this of General and Sir Thomas Bouch, that under those circumstances the bridge showed itself so be remarkably stiff and rigid, and that it bore its tests remarkably well?—I think remarkably well; the deflections of the girders were far less than I had anticipated, and the piers were very rigid and free from oscillation or vibration rather.

18,994. Do you believe that if the bridge had been slovenly, slipshod sort of structure that has not supposed, it could have borne those tests so satisfactorily as it did?—No. I do not suppose it could; but it is a hard question to answer. I think it was a very well designed structure and very well put together.

18,995. As regards the bridge itself I may ask you this. From that time till after the wreck you never visited it again, and therefore you can add nothing to the history?—No.

18,996. Have you visited the rules, have you not?—Yes.

18,997. Does anything you have seen there lead you to believe that the bridge failed through the inferiority of the workmanship, or the putting together of it?—Nothing.

18,998. It has been suggested this morning by Mr. Law that the columns were not firmly rooted, and that they shifted. Did you see any evidence that the bridge failed through any of the columns being down of any of the columns?—I did not examine the bridge for that purpose, but I can answer that question in other ways.

18,999. I will withdraw the question, because it is not fair to ask you to express your opinion?—Not from appearance, but I know perfectly well that it could neither slide laterally nor could it slip up. I fear I go into that if desired. Those are two different things altogether.

19,000. You have, jointly with Mr. Pole, made the investigations and calculations upon which the evidence he gave yesterday was based?—I have.

19,001. To save repeating a great deal of his evidence I will ask you, do you concur in the correctness and soundness of the methods adopted and in the results he arrived at and gave to the Court yesterday?—I do.

19,002. Both as regards the measure of stability of the bridge and as regards the force of wind that would affect the carriages?—Perfectly.

19,003. And generally do you agree with his evidence and his opinion that it required something more than any statical wind pressure that you could have expected to come upon the bridge to have caused what happened on the night of the 28th of December?—Yes, I do.

19,004. Do you also agree with him that the shock of two of the carriages going at the rate of 25 miles an hour, if they came into collision with the girders, superimposed upon all the normal strains upon the bridge, would be sufficient to cause a failure?—Certainly.

19,005. I believe you have not had an opportunity of examining the portions of wreck of the carriages and the marks, and so on, upon which evidence was given to the other day. I mean the fragments that have been recently raised?—No.

19,006. Therefore you are not in a position to express an opinion upon that evidence?—No.

19,007. Therefore I will not ask you any questions upon it. Are you satisfied as a mathematician and an engineer, with your knowledge of the bridge, that it required a higher wind pressure to overturn that bridge, or to cause it to fail in any sense than it required to overturn the second-class carriage of that train?—That I believe from the result of Mr. Kirkaldy's experiments.

19,008. (The Commissioner.) You believe it required a higher wind pressure to do what?—To cause the bridge to fail than to overturn the second-class carriage.

19,008A. (Mr. Biddre.) I want to take you to one particular matter which I know you have very carefully studied, and which you are particularly competent to speak to. It has been suggested to-day that seeing that you and Dr. Pole have made your calculations, proceeding upon the assumptions which you have given words I used yesterday that the columns were firmly rooted, you are basing your estimates upon an assumption that is not justified by the facts: inasmuch as there was a possibility of lateral shearing or shifting of the columns. Probably you heard the evidence of Mr. Law the other day and this morning?—Yes.

19,009. Now I ask you to give your views upon that, but first I will ask you this. Of all the frames which you have carefully studied, is it not?—Yes.

19,010. Will you now give your views upon it?—I think lateral shearing is a totally different thing from uprooting. In the first place; and I think that they should be kept quite apart. Lateral shearing is the tendency of two columns to slide over the other. I know exactly what the amount of force required by
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Mr. A. D. Stewart.

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30 oz. or 40 lbs. of wind per square foot is in producing that action. The resistance to that action in the structure is various, the first and principal one is friction. Now, at the time that a train is on the line there is a downward force of 517 tons acting on the bottom of the column. That may be taken in two surfaces of that kind as a fourth of the pressure. Therefore, there is a resistance to the power of the column sliding together of a fourth of 517 tons, or 129 tons. Taking the extreme of 40 lbs. of wind it only produces 76 tons of shearing action; about half.

19.011. The same friction, supposing there were no bolts at all under these circumstances, is nearly double the shearing force. Dubble the sheering force with 20 lbs. of wind, and four times the shearing force with 5 lbs. of wind, which is what we have taken in our calculations.

19.012. It does not stand simply upon the friction, because you have, in addition the bolts and a great many other things. You have the blocks of concrete. There are the blocks of concrete, and you have to shear every one of those before you bring the bolts into play.

19.013. The concrete, of course, has been poured in a liquid state, under the pressure of the height of the form, and has a tendency to fill the inner part. — Yes, Mr. Law. The concrete would adhere to the iron very closely except in the case of the joints where some of the contractors' men put sand instead of concrete.

19.014. There were two cases in which there was sand put instead of concrete? — Yes.

19.015. But in every other case you have the adhesion of the concrete to the iron? — Yes.

19.016. That apparently appears to have been entirely overlooked by Mr. Law? — Yes.

19.017. Can you give us any estimate of what the work to be done by that would represent? — There are a great many square feet, say 6 square feet of concrete, and the question is what the shearing stress would be; 50 or 60 tons, I think. I think 10 tons to the square foot would be a very low estimate. It is not strong concrete, but I daresay it is about that; it would certainly present a very considerable resistance to the shearing action. Then the bolts are certainly capable of resisting a very great sheering force even though bending the fact that there passes through the two columns a slight space between them. Mr. Law states that he has found a movement of that kind, but it is impossible to tell what things may be found in a bridge after it has fallen, or what the causes may have been. The shock may have done it; the fall of the column falling may have done it.

19.018. Is it by any means possible for any man, from the fact of finding the columns shifted or bolts bent after a run such as this, to infer that these happened-in the way he suggests, through the shearing action of the column before the failure? — I think not. I think it is quite impossible to tell what happened in the accident; or what caused the accident, but that is quite apart from the question of uprooting.

19.019. It would be absolutely impossible that the shearing or lateral shifting of the columns under the circumstances and with the pressure of the wind, and wind on top of them, could cause the fracture of the structure and the falling down of the bridge. Now, what we are addressing ourselves to in the case is how to come to certain results; as to the structure upon the tie. The suggestion in the questions put by the Court yesterday upon Mr. Law's evidence practically would come to this, that you have no right to rely upon the help of the column because Dr. Pole said yesterday that assumes the column to be practically firmly rooted, and we do not think that modified as he did modify them with reference to the case of Mr. Kirkland's as regards the resistance of the bolts, you have checked, and substantially you agree with them? — Yes, that is so.

19.020. And that being so, do those calculations show that the resistance of the bolts at the hinges of each column to uprooting is far in excess of the forces which you have assumed on account of the flexures of the columns? I mean that the force required to overturn by uprooting is greater than the force you have assumed in your calculations? — The columns turning over by one, yes, exactly.

19.023. Dr. Pole explained yesterday the method of your calculation, a certain lateral bending of the column is assumed, a geometrical corresponding extension of the tie calculated, the stress that would produce upon the tie calculated, and the resistance of the column itself to that amount of flexure calculated? — Yes.

19.024. Those elements being resolved according to the directions in which they act, so as to obtain the total resisting lateral force. One of those elements was the resistance of the column to the amount of flexure assumed to take place? — Yes.

19.025. Am I right in saying that that amount of resistance is very much below the force that would be adequate to shift the bolts by uprooting? (Mr. Barlow.) Are you talking of shifting or uprooting?

(Mr. Bidder.) Uprooting.

(Mr. Barlow.) I agree with Mr. Stewart that they are quite separate considerations.

(The Witness.) I cannot say that I understand your questions fully. These questions are very complicated. Do you mean that the combined force mentioned in the last page of our Report would destroy the pier sooner than the pier would uproot as a whole?

(Mr. Bidder.) I do not mean that. What I mean is this: you have made your calculation on this assumption, as Dr. Pole said yesterday, that the particular column you are discussing is practically firmly rooted.

(Mr. Barlow.) Calculation of what — calculation of what is required to overturn the bridge?

(Mr. Bidder.) If you will follow me for a minute I think I will make it plain what I mean.

(The Commissioner.) I think I understand what Mr. Bidder means. He means that taking into consideration the holding-down bolts and all the flanges and assuming them to be perfectly sound and good, then any force that could be brought to bear upon the bridge would be insufficient to overturn it.

(Mr. Bidder.) No, that is not what I mean. If you look at the last page of the Report of Dr. Pole and Mr. Stewart, you will see that they have described their method of proceeding, and they say: "We assume a certain small lateral motion of the top plate, of the lowest tier of columns." (Mr. Barlow.) That is only for the purposes of calculating the stress upon the ties — that has nothing to do with the overturning or any man.

(Mr. Bidder.) If you will follow me I think you will see what is in my mind. Dr. Pole and Mr. Stewart say in their Report, "We assume a certain small lateral motion of the top plate of the lowest tier of columns produced by a horizontal force applied thereon. Secondly. We calculate geometrically what extension this will give in such ties, and we make the stress corresponding to such extension. Thirdly, we resolve those various stresses into the direction of the force causing the motion of the top plate. Fourthly. We find what resistance the six columns will offer to an amount of bending corresponding to the lateral motion assumed." Now, what you are addressing yourselves to in the case is how to come to certain results; as to the structure upon the tie. The suggestion in the questions put by the Court yesterday upon Mr. Law's evidence practically would come to this, that you have no right to rely upon the help of the column because Dr. Pole said yesterday that assumes the column to be practically firmly rooted, and we do not think that modified as he did modify them with reference to the case of Mr. Kirkland as regards the resistance of the bolts, you have checked, and substantially you agree with them? — Yes, that is so.

19.026. (Mr. Bidder.) That is the point I am putting to Mr. Stewart. Knowing what the resistance of
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The bolts are to an overturning of the column, and knowing what forces he has taken credit for at the top of the column, he can tell me whether the column was in fact firmly rooted as far as overturning is concerned ad hoc. (To the witness): Do you follow me now?

Yes.

19,027. Was it not so?—It was. That is to say when the tie gave way, in accordance with our calculations, there was a very moderate strain upon those bolts.

19,028. A long way within the strain which you and Mr. Law agree to be necessary to allow the column to uproot?—Yes; and there was an action upon the column in addition—a downward action—not a sliding one.

19,029. I want to get this very clear and beyond the possibility of dispute afterwards. There is no doubt whatever that the columns were effective to resist force to the extent which you calculated they would sustain in calculation?—I have not the slightest doubt about the fact you put.

(The Assessor.) What fact are you referring to?

(Mr. Bidder.) To the fact that the columns were perfectly firm to resist force to the extent that Dr. Pole and Mr. Stewart have credited them with in their calculation.

(The Assessor.) That is to the extent of 2-3 tons upon each of the 18-inch columns, and 1-06 upon each of the 15-inch columns.

(Mr. Bidder.) Exactly so.

(The Witness.) That is about 20-foot tons at the bottom of the column, and according to Mr. Law's calculation they would resist 100 odd tons.

19,030. It is not more than a fifth of the overturning force that would uproot the bolts?—Exactly. At that point the tie goes.

19,031. Are there any corrections in the letter which the Court have that you wish to point out?—Dr. Pole made one or two alterations; may take it that these are the only alterations that you wish to make?—There is just the word "square" which should read "diameter" in regard to the holding-down bolts. I do not think it is of any importance. The size of the holding-down bolts built into the masonry were stated to be " 34 inches square," and it should be " 34 inches in diameter." That is under heading No. 14. With regard to the second-class carriage, I have not received an answer from your Excellency that there was a mistaken belief on our part, namely, that there were no passengers in it, but Dr. Pole, I think, yesterday corrected that, and allowing for the passengers he estimated that weights of wind would upset the carriage under shelter.

(Mr. Tear.) As you are upon that subject, I would observe that there is still a very large discrepancy between the calculation of Mr. Law and the calculation of Dr. Pole and Mr. Stewart. That is of pure arithmetic, and I would suggest a comparison outside the room so as to get the error out of it.

(Mr. Bidder.) I was going to ask Mr. Stewart if he had any idea where the discrepancy now arose between him and Dr. Pole and Mr. Law, because there is a very large discrepancy no doubt.

(The Witness.) I cannot account for it. I can account for it to this extent: without shelter we make it 25,000 lbs in shelter 227; that is only a difference of 100 lbs. 1-06 to 1-08, I do not know how.

(Mr. Tear.) Suppose Mr. Stewart was put in a detailed statement of how he brings out his result, Mr. Law would do the same thing, and then the Court would have them both before them.

(Mr. Bidder.) I see no objection to that.

(Mr. Barlow.) I think that would be a good arrangement.

19,032. (Mr. Bidder, to the witness.) Mr. Law makes a very much larger addition to the shelter of the girder than you do?—Yes.

19,033. You rather agree with the Astronomer Royal, that the girder did not shelter it much?—I simply calculated the area, placing the carriage in the most favourable position for being blown over which it took in a certain point in its course, and measured the surface of the girder that intercepted, and took the moment of that and deducted it from the moment of the overturning of the carriage.

19,034. You projected the girder in the position the least favourable for sheltering?—Yes.

19,035. You projected the thrust upon the side of the carriage, and took the area of the moment of that surface, and assumed that that portion of the carriage was fully sheltered?—Yes.

19,036. Have you in a convenient form your calculations, so that you can hand them in, in order that Mr. Tear may examine them?

(Mr. Tear.) I think it would be more convenient if Mr. Stewart would make out his new and hand it in to the Court, and Mr. Law might do the same.

(Mr. Bidder.) I thought it would be better to have it now.

(Mr. Tear.) No.

(Mr. Bidder.) Very well, shall be done afterwards.

(Mr. Tear.) Mr. Stewart or Dr. Pole will hand in to the Court the details which bring out that result, and then they can be added to the Appendix.

19,037. (Mr. Bidder, to the Witness.) I want to ask you this question upon another matter: a good deal has been suggested to this effect that there was, as we know there was, a certain amount of loosening of some of the tie-bars, and that a chattering was observed after the bridge had been opened some time by Mr. Noble, and Mr. Noble says that those loose tie-bars were convulsed up in a certain number of instances with the aid of packing pieces, and that he left the bridge full tight. It is suggested that it may be that you tightened up all that was loose, but in so doing you tightened up the bridge in a distorted form. Do you agree with that?—I do not. In order to do so you would require not to tighten up the tie that has extended, but the tie which has got slack through the extension of the other ties. Now that could only be done during the storm. A man could have used a tie in a storm or tempest blowing with a pressure of 10-12 lbs. and could cut up the bridge. Suppose he waited until the calm weather came, I am quite satisfied from my observation of the pier that it would return to its original position. The tie, which was broken during the storm, would return to its original tension—the state of tension in which it was previously to the gale—assuming 2 tons of tension to the tie, the thing began, the tie that would chatter would be the one that was extended by the action of the wind, and he would, of course, cut it up. The reason for my saying that the pier would return to its original position is that, as I before explained, the bolts of the columns are not strained nearly up to their limit, some to take an ultimate set, so that to restore the bridge there is first of all the natural equilibrium of the columns—the whole thing could not go beyond two or three inches. The columns would naturally come right, the same as anything going out of the centre of gravity, and coming back again.

19,038. The displacement of the column, not being an uprooting, but being a flexion of that column, the very force you have been relying on during the wind would be the force which, when the contrary lateral pressure was removed, would complete the column to straighten itself?—Yes.

19,039. As any other spring, when you take the constraint off it?—Yes; there is, first of all, the elasticity of the cast-iron in the column. I forget the flexure of the column at the moment, but if it is deflected, it would certainly return. The strain upon the cast-iron are very much more moderate than they are upon the bolts, so that the elasticity of the cast-iron would bring it back to its original position. The natural equilibrium of the columns each separately would tend to bring them back, in addition to the pulling back of the bolts which were extended.

19,040. You said as far as the extension of the tie bar by the strain, was concerned you consider that the tie-bar would recover itself after the storm was over, that is to say, you have not stretched it nearly to the
19.041. I want you to take that assumption in a little more definite form, because it has assumed a definite form. What happens is this: That owing to there being, we will say a bolt in a hole which should have been cylindrical in a lug, but which was conical, the strain during a storm would bend that bolt. Yes. Well, you are assuming that the bolt is not in the centre of the hole; there is a slackness which is taken up that would not be recovered again after the storm was passed; and the tie-bar would consequently bend. Yes.

19.043. That being so, the bolt being bent, we say a quarter of an inch, or whatever it may be, the tie-bar in consequence being, after the storm is past, slack. ——On account of the return of the column, it becomes slack.

19.044. And would what is called chaster? —Yes.

19.045. If you then put in a packing piece and cut out the tie-bar up, do you not thereby shorten it to its original length? —You do certainly, and it is restored to the utmost extent of tightness that it was originally in —one exactly in the same position in which it was before.

19.046. By putting in the packing piece and cutting it up, you shorten the tie-rod, if you go to the same tightness that there was before, by precisely the same amount of permanent elongation that has been given by the bending of the bolt or the giving of any other slack piece? —Certainly, I assume, which I think is absolutely certain that the column itself would return to its original position.

19.047. (The Commissioner.) The assumption is that as soon as the force was taken off, the column would return to its original position, and then there would be a chastering? —Yes, I think that assumption is correct.

19.048. (Mr. Bidder.) I gather from your evidence that that assumption is correct and represents what must happen in the case of a structure like that bridge? —Quite so.

19.049. Now, I want to ask you one further question. Assume the other alternative, which you say is an incorrect one—but assume that the columns have been to some extent displaced and have not to the full extent returned to their original position, and that you have then cut off and tightened all the ties, so that to a certain extent—I am not talking about an extravagant amount to a certain extent—the structure might be said to be distorted; that is to say, that some of the rectangles, or distortions, have become oblique. We will say a fraction of an inch in the head of one column and a fraction of an inch in the head of another—but all tightened up—would that materially alter the condition of the stability of the structure, assuming that the distortion was within small limits, and assuming that all the tie-bars were tightened up as before? —If the motion was very small I cannot see that it would do any harm. It is one of those things that you would require to consider very carefully before answering. I have not considered that question before. I did not think it would arise. You must take into account the fact that, in the case of these high columns, if a material bend takes place at any of the joints under a heavy load the bend is more apt to increase.

19.050. That is why I said within small limits? —If the limits are very small it becomes a simple question of resolution of forces, and it must be a very small factor in the conclusion.

19.051. Looking at the structure, as I understand you, you see no reason why the columns should do anything but return to its original position after the stress is over? —Quite so. I see not the slightest reason for the column being distorted at all.

19.052. When the storm is over all the forces operating are forces tending to bring the columns back to its original position, and as far as you can say there is nothing resisting it? —Nothing.

19.053. You concur with the evidence of Dr. Pole both with regard to the safety of the structure and about lateral pressure? —Yes.

19.054. There is one matter that you wish to explain, I understand, with reference to the position of the L girders? —There are two or three points which I wish to explain about the construction of the pier. With respect to the L girders, I have been anxiously considering any reason for breaking them together, and I utterly fail to see any other thing that has been said, and I cannot see why it should be done. The L girders are broad; they will not turn over on their bases, they will not slide laterally, and there are absolutely no forces that I can see tending either to bring them together or to separate them. The top braces may look very light to the eye, but as a matter of fact it has only left the work to do that all the other horizontal bracings do the work down the pier. That is upon the assumption that the forces are equal upon the top to what they are below.

19.055. On the assumption that the forces are acting equally, that top strand does half the work of the other lower strands? —The top strand does half the work of the lower horizontal struts.

19.056. On the assumption which you say is impossible, that the whole of the force is to the windward side, then it does the same work? —Yes.

19.057. But that is an assumption which you say is impossible? —Yes.

19.058. On the other assumption, which is also impossible, that all the force is on the leeward side, then it does no work at all? —Exactly so.

19.059. On the assumption that the lateral force acts equally over both trials, it does half the work of any of the lower horizontal struts? —Yes.

19.060. On the impossible assumption adversely to the pier that the whole of the lateral pressure bears upon the windward trial, it would then do the same work as the lower horizontal struts? —Yes.

19.061. On the hypothesis, which I may say is impossible, that the whole of the lateral pressure is out the leeward trial, then it would do no work at all; is not that right? —That is quite right. So that I think the top horizontal bracing is certainly as sufficient as any of the other horizontal bracings, and I certainly think the other horizontal bracings have not been objected to. They are beyond suspicion. They are very heavy for the work they had to do.

19.062. As you have taken us to the top of the pier, whilst we are there I will ask you another question in connection with that, because a question was put to the Astronomer Royal as regards the effect upon the stability of the structure (I think it was put by Mr. Tait, I believe) pointing to the fact that the girders in the cases of most of these piers simply rest upon the top of the pier, and is free to slip off laterally. I think Dr. Pole has already explained that as regards all the piers without exception, even if none of them were fixed, it would take a force of 70 or 80 lbs. of wind acting over the whole structure to cause the girders to slide laterally off.

19.063. That is to say, without relying at all upon the fringes of the rollers upon which the girders rests? —Yes, or the fixity to the pier.

19.064. Taking the stiffness of the girders itself, it would require from 70 to 80 lbs. of wind simply to overcome the natural friction due to the natural weight of the girders resting upon the top of the pier? —Quite so.

19.065. Therefore you may say that no force of wind that can be conceived to come upon the bridges could possibly shift that girders laterally upon the top of the pier? —That is so. There is another point that I want to allude to. With respect to the vertical load, these horizontal ties do absolutely nothing, and I think it is as well that that should be explained. The only thing they do apparently is I may say which they certainly do, is to press the columns from bending.
From buckling— From buckling, but what they do is to prevent the commencement of buckling.

Perhaps I may put it in this way, that if you had a 60 foot ladder standing upright, and could not keep it upright, if it was not quite upright half a dozen men could not keep it upright when it began to fall over?—Yes, exactly; if the motion has not commenced there is no force.

If it was at all out of the vertical then it would act at one corner—Yes, but that is another thing.

It was mathematically correct, no doubt, the pressure would be all down the column, but if it was at all out of the vertical in any way the tie would begin to act?—I am not quite sure that it is correct.

If they are out of the straight?—Yes, quite so. If there is a bend at any point in the column, then an action in proportion to the bend is brought into play, but until the bend takes place in the column, there certainly is no action.

That in an undestroyed structure is, impossible from the way in which the columns are fitted—It is impossible in any practical series. There may be 36 of inch bend without really inappreciable.

That is from the way in which the thing is fitted. The faces of the flanges are turned, are they not?—Yes, for all practical purposes it is absolutely straight. In all constructions there is a certain amount of distortion, but it is so small that it is not to be thought of. In girder work there is a great deal of infinitesimal distortion. Therefore the work done by the ties in connection with the vertical load is infinitesimal?—It is quite infinitesimal.

Inappreciable?—Yes.

Is there any other point upon which you wish to make any remark?—There is only one other point, and that is, whether or not your, the masonry, is inappreciable, that I would like to say a word about it. I highly approved of a 6-column bridge in preference to a 4-column, for this reason, in one word, because the two consecutive columns are in the same plane. I mean that the planes vary all the way round. The effect of the keying up of the ties is, that instead of bringing the bolts into full action in the strut, and also to bring the six columns towards the centre. The effect of the bolts of the strut (and it is only that they act and properly) is to resist this so that every column is, as it were, held in its position by forces in four directions. Then the screwing up of the bolts of the head stock hold it in that position, and no lateral force can bring those struts into tension or tend to draw away the bolts which are pressing them in. Any lateral force tends rather to press them closer in, and therefore think that when these planes change, a much more rigid structure is got than when you have three or four of the columns in one plane.

That is to say, if you have 4-in. column and 4-in another anything like so strong as this, you require very much more bracing. You require, in fact, to divide it into triangles to brace each column in every possible direction.

Then, as we know also, given the diameter of the caisson adopted, or indeed any diameter of caisson, you get a wider base with the 6 than with the 4?—Yes, certainly.

Will you just explain that?—Of course, the diameter of a circle is its largest dimension across. If you take a chord to the north or south of the diagram, you have a shorter line, and if you think of another north-south line, then the distance across the caisson, and the brickwork necessary, you must bring in the column to that extent. I do not think it does to put the column anything like at the very outside edge of the masonry; it is certainly never done with girders or any work resting on masonry.

But, of course, whether you act upon that which appears to have been Sir Thomas Bouch’s view, and is yours, that you must not go outside of your masonry, or whether you do not, equally the limit of your substructure is a circle, whatever rule you impose upon yourself about going to the margin, or keeping 18 inches within it, that would bind you in both cases, and you would come to the result equally that you can get a wider base with a hexagon than you can with an octagon?—Yes, certainly that is quite clear. Then I should like to say a word about the width of the base. There is no difficulty.

I am putting this rather as an abstract question; there is no difficulty upon a base half that size (pointing to the model) to make a three pier strong enough?—I have no doubt. I could design a pier in wrought iron half the extent of this pier properly sunk in masonry, that would carry not only the superstructure, but any wind force—in fact, I could make it strong enough to tear up the base of the whole structure.

You mean that you would carry the pier directly under the girder?—Yes, I could do it in that way; there is no practical difficulty about it.

What you mean is this; you cannot say that it is impossible either to affirm or deny that a particular base is or is not sufficiently wide?— Quite so.

The problem is, given a certain base, it requires a certain strength of superstructure to make that base sufficient?—Quite so, that is what I mean.

If the base be in a wider base, these you are relieved in many respects in your superstructure?—Yes, you are relieved of material; perhaps you may not make it so strong.

But if the base be a narrower base, then you require greater strength in proportion?—Yes, I cannot understand an objection being taken to the base of this structure. It really comes to a question of material. With a stronger superstructure it is strong enough. That is a question depending upon different considerations in regard to the strength of the superstructure as designed, but to say that you cannot make a strong enough pier with the base one fourth of the height appears to me quite wrong. There are many cases where the base and the superstructure are made of those propelling the bolts, and I might as well say that you must not make girder of the height of an eighth of the span, that they should all be higher. Most people tell me that they should be lower.

Have you had an opportunity of seeing a design prepared by Mr. Law which he thought was an eligible one to substitute for these iron columns?—Yes.

Is that a design which commands itself, to your mind as a satisfactory design?—No, I think not.

What would happen if a bridge were built according to that design?—I think it would turn over. A five-arched bridge in a strong wind would most assuredly turn it over. It proceeds upon an engineering mistake, I think, that brickwork of the same weight or lighter than iron can be used. The advantage of brickwork is the advantage of weight only. With iron you have a power of trying it down to an indefinite extent, but with brickwork that is a very difficult thing to do and is never done. You depend there upon solidity and weight for your stability.

In point of fact if Mr. Law’s design were one that could practically be carried out satisfactorily, it would amount to this, that instead of resorting to ironwork when you wanted to lighten your foundations, you would resort to brickwork?—Yes.

Exactly on the same principle upon which Sir Thomas Bouch thought necessary to adopt when he found his foundations were weak?—Yes. There are other objections which I have, but which I need not go into in detail. I do not think it was well considered.
19,060. You seem to claim some credit for the design of this girder; do you say it was your design? — I explained to you as nearly as I could that it was Sir Thomas's design. It is a very general thing in engineering to distinguish between his credit in the matter and my own.

19,071. The credit is divided between you, what every it may be? — Yes.

19,084. When you went to this bridge before it was opened, and when General Hutchinson was there, you agree with Sir Thomas Bouch that it was a careful examination, as one would not doubt it would have been, from its being made by General Hutchinson? — It was a very careful inspection.

19,109. Upon that occasion I suppose you did not pay any attention to see how the work had been executed, as you have said, in detail, but did you pay any attention whatever to the proper execution of the work? — I, of course, in going over the bridge, saw the riveting of the joints as an engineer would in passing over a structure. To that extent I did.

19,105. But you did not test a single rivet with a hammer, and did not look at a single tie-bar to see how it was broached up, keyed up, or tightened up. I mean on the piers — you did nothing of that kind? — No.

19,111. Was General Hutchinson's examination of the work and material more minute than your own? — I think it was. I had nothing whatever to do with the construction of the work.

19,112. You were there with General Hutchinson for the purpose of being present at the Government inspection and with regard to any duty that you yourself had to perform? — I went there at Sir Thomas Bouch's request, prepared to answer anything with regard to the strains upon the girders that might arise.

19,113. But not to make, either for Sir Thomas Bouch or for anybody else, an inspection of the bridges? — No.

19,114. Taking the piers — was it you who suggested that the original design of eight columns should be departed from and six columns substituted? — Of course my memory rather fails me in regard to what took place in 1874, but, so far as I remember, I did not suggest the alteration.

19,115. Do you know from who the suggestion originally came? — No, I cannot tell.

19,116. Sir Thomas Bouch could not tell us, and you cannot? — I cannot.

19,117. [Mr. Barlow.] You drew out a design for the eight columns, did you not? — No, I made no design for the piers.

19,118. [Mr. Pryer.] These tie-bars, you have told us, are not of importance in the piers for supporting vertical pressure? — No.

19,119. But at the same time they are essential parts of the pier? — Yes, most undoubtedly.

19,120. Because if they were not there, looking to the height of the columns, the columns would bend or go under vertical pressure?

19,121. Their essential function is to keep the columns rigidly in place? — That is not their principal duty; that is a duty.

19,122. What is their principal duty? — Their principal duty is to resist lateral stress.

19,123. [The Commissioner.] You are speaking of the ties? — The ties.

19,124. [Mr. Pryer.] You mean to enable the columns to resist lateral stress? — No.

19,126. To keep the columns in their place? — Yes, they perform the same duty as the bracing of the girders — to keep the top and bottom members apart.

19,127. They are not calculated to support vertical pressure? — No.

19,128. They are not calculated themselves to resist lateral pressure, but in both cases they enable the columns sufficiently to resist both? — I do not accept that statement; they are for the purpose of resisting...
the lateral force of the wind; all the lateral force of the wind is transferred through those ties to the struts, and downwards to the bottom of the piers.

19,128. Those bars, as I understand you, apart from the columns, are not material in the matter of lateral pressure any more than vertical pressure. — They are as material as the columns, and equally in the path of the forces—certain forces act upon the ties, and certain forces act upon the columns.

19,129. If they were not there the columns would not be kept in place when a pressure came from above or laterally. — If they were not there the columns would do almost no work. They do a little work by their own weight, but they are a framework structure. The columns may be taken as lines revolving round the joints; and, so far as that action goes, the columns would have no strength without the ties. This differs from a framework structure, inasmuch as the columns are not geometrical lines, but have a certain amount of strength in themselves.

19,130. These columns from base to top do not maintain, if I rightly understood Sir Thomas Bouch, an exact perpendicular? — No, none of them do.

19,131. That again necessitated ties, did it not? — No; that does not again necessitate ties. The fact of them having a better does not make it more necessary for the ties that they were vertical.

19,132. I should have thought that if those columns were absolutely perpendicular, and subjected only to vertical pressure, the ties would not have been necessary? — Oh, yes.

19,133. But if they are raked, or have a batter, as they are, they would need the ties to keep them in place, I think. I have already explained that the ties, so far as preventing the breaking of the columns by bending, is concerned, only act to prevent bending. If the columns are straight from top to bottom it does not matter whether they have a batter or whether they are vertical.

19,134. I suppose we are agreed about this—they were essential parts of the structure? — Yes.

19,135. I suppose it was also essential to the fulfilling their proper duty that they should be kept braced up, tight and in place? — They would do their duty better as regards the downward pressure if they were tight than if they were loose. If they were loose they would allow a slight motion and then they would act.

19,136. You distinguish between the performance of their duty as regards vertical load and as regards lateral pressure. Is it not also essential to the fulfillment of their duty to resist or aid in resisting lateral pressure, that they should be kept tight? — No, it was leaving the columns.

19,137. Would you have considered them in a position, to do their duty, no matter how much they had got loose? — I mean with regard to lateral pressure? — If they got loose so far that the columns were brought into more than full play—that is, if they got so loose that the columns by bending in one bay would break at the hole sooner than the ties—then they would be too loose.

19,138. Can you put in figures the extent to which the yielding in the tie would have resulted in that inequality, which you have just mentioned? — I made the calculations one evening. I do not know whether I can add it now.

19,139. Without troubling you for that, let me put to you this question: supposing these ties loosened to the extent of a quarter of an inch, would that have materially affected in your opinion, the stability of the structure? — Not in the least. I may say it is a very remarkable thing that the loosening of the ties somewhat beyond what Dr. Pole and I calculated would add to the strength of the structure by bringing into play, first of all, the resistance of the columns to bending to a greater extent. It also brings the diagonal ties somewhat more into play.

19,140. Do you mean to say that the loosening of these ties to the extent of a quarter of an inch would have made the structure more stable then it was when it was newly tightly braced up? — According to the calculations, so as a matter of fact it would.

19,141. Then it was a mistake to tighten them up? — You may draw that inference, if you like.

19,142. Is not it the necessary inference from what you have said? — No, because I think it is not a thing to be depended on. If one extends a quarter of an inch, others may extend half an inch.

19,143. Take the hypothesis that is put to you, that these ties were giving to the extent of a quarter of an inch, do you say that would add to the stability of the structure, or that it would detract from the stability of the structure? — Of course I mean this and the one opposite (pointing to the model)? It would add to the stability of the structure.

(Mr. Bidder.) Do you mean giving by extension, or giving by a bolt bending?

(Mr. Trager.) I mean giving by extension.

(The Witness.) I still hold to the view I have expressed. If Sir Thomas Bouch could have put in some kind of spring that would have allowed a yielding of a quarter of an inch, it would have added to the strength of the structure. It would have been very difficult to do.

19,144. It would have been something like building a castle in the air? — Perhaps.

19,145. Take this other case, that after these had been braced up rigidly, as they were, either by the yielding of a bolt or anything else, these braces got loose to the extent of a quarter of an inch. Do you say that that would have added to the stability of the structure? — That does not seem to me to differ from your last question.

19,146. Only in this: One case is the extension of the bar proper, and the other is the bar coming out of its original place because it was not sufficiently tightened up through the bolt not holding sufficiently, or the hole being too large, or some cause of that kind? — My answer is the same to both.

19,147. That being so, I am curious to know whether you can suggest any reason why the structure was made less stable by the tightening up of these bars and making the structure as rigid as it was when General Hutchinson saw it? — No, I do not suppose I can.

19,148. It was a waste of energy, was not it; to tighten them up when the result was to lessen the stability of the bridge? You cannot suggest any reason for that? — No, it is very hard to answer these philosophical questions.

19,149. In a general sense, does not the stability of a bridge depend on the rigidity of the columns on the large extent at least? — Certainly.

19,150. Did you anticipate when you looked at the bridge that these braces might possibly be loosened or extended from the vibration of the structure occasioned by the passing of trains or by the wind pressure on either or both sides of it? — At the first place I may say no, but with respect to the first part of your question, the vibration of passing trains has no effect whatever in producing tension.

19,151. I quite understand that the passing of trains would not strain the metal itself, but you understand the suggestion. I am putting to you, that assuming these bars to have been originally badly adjusted, and not tightened up, if somehow the crotches are more or less loose, the vibration of a passing train might have the effect of making that which was loose still looser? — I do not know.

19,152. Do you think it is likely or unlikely? — I do not think it likely.

19,153. Nor do you think that result likely to have been produced by pressure on the bridge of a lateral description by the wind blowing either from the east or the west? — That is another question. I did not think at the time that such a result would be produced, but knowing now what I did not know then, namely, the nature of the holes in the bars, I think that a
heavy lateral pressure might produce looseness in the ties after the wind pressure was removed.

18,154. Will you go a step farther and tell me whether looseness was the ground of the belief that the stability of the bridge was thereby endangered or whether the stability of the bridge was thereby increased?—If that looseness did not exceed a quarter of an inch, the stability of the bridge was not in the slightest degree endangered or injured.

18,155. Was the stability increased?—The resistance thereby increased undoubtedly.

18,156. When these bars chattered in the way we have heard described, it was again a piece of unnecessary work?—Mr. Noble's part to fill them up with packing pieces?—You have already asked me that question. I do not know that it is always wise to increase the stability of a bridge by looseness, I think it would have been wiser to pack it up. It is difficult to answer that question.

18,157. Unless I have terribly misunderstood you that the looseness added to the stability of the bridge if it did not exceed a quarter of an inch in the one tie, surely it follows from that that Mr. Noble was setting up most unnecessary work if he went and filled up these places with packing pieces, thereby in your own view, reducing the stability which the looseness had given?—No; I think he was right in putting in those packing pieces.

18,158. Why?—Suppose it went another quarter of an inch. I mean after the packing pieces were put in. It is very hard to answer that question at all. I had better make it more clear. If these are loose to the extent of a quarter of an inch all the way up, the pier is in that position to resist a heavier wind pressure than it was before; there is no doubt about that, because to cause a bending of an inch at the top of the pier, you bring into action greater forces in the column, whether that is a good or a bad thing to do, it is very hard to say.

18,159. (Mr. Barlow.) Would you like to do it in the case of this girder on the top; would you like to make the tension bars of that loose?—No, because the case does not apply there—it is different. If the tension bars of the girder were loose, you would bring into play the excessive play. I do not need to say that it would endanger the bridge, but with a maximum strain on those struts of three toots to the square inch, placed in the most disadvantageous way, with one of the ties loose, it would come up to six tons to the square inch, which would be more than it would be right to put on it as a working load. How that ties were put in, I do not quite see.

18,160. (Mr. Trayner.) You would not, by appointing an inspector or otherwise, have provided against the possibility of a loosening of these tie-bars?—I would certainly have preferred having the whole bridge thoroughly tight, and I do not think my two answers were good enough with each other. I would rather not bring this question of the resistance of the columns into play. I would rather depend more upon the tie for resistance to side motion than I would on bringing the columns into more severe bending action.

18,161. As to this L girder, you have said after careful consideration, you cannot see any good reason why it has been continuous?—Why they should have been connected.

18,162. Would not it have added to the stability and rigidity of the columns if they had been so connected?—I do not see how. If you will point out any way in which it would, I would be very glad to see it.

18,163. If they had been continuous would not the pier have been one of six columns instead of being, as it is now, in fact two piers, each of three columns?—I have heard that suggestion made, but I can attach no meaning to it whatever. You are assuming the pier to be thoroughly braced and sound. The facts of an L girder being placed on the top of these three, and another put upon it, and the load put upon it, cannot affect the structure.

18,164. If the L girder had been continuous would have afforded any safety against the possibility of a weakness arising on one of the columns of the triad?—I cannot see it.

18,165. A column is no stronger than its weakest point. Suppose this to be a weak point in one of these triads sufficient to endanger its stability, would that risk have been lost to any extent, in your opinion, by the existence of a continuous L girder connecting both triads?—I think, perhaps, another way to put it would be to put it in this way. If this outer 18-inch column was taken away, and this was placed across, and the L girder put up, it would be a continuous structure, it might be an improvement, I think.

18,166. Go a step further—an improvement, in what way, or to what effect?—To the effect that you could do without the top of that outer 18-inch column.

18,167. And therefore would have provided against a contingency which otherwise would have made the defective pier utterly unstable?—I cannot conceive that.

18,168. Suppose you took out that top column, would that triad stand? suppose you took out the top column altogether of the 18-inch column would the pier have stood?—No.

18,169. You say if the L girder had been continuous it would have stood, though you had taken away that 18-inch column?—It might have stood; it would be a very rickety affair.

18,170. It would have stood better with a continuous L girder than without it?—Yes, on the assumption that this column is away (pointing to the model).

18,171. Not assuming anything so radical as the splitting out of a column, but some other weakness which did affect, or might possibly be anticipated to affect the stability of the column, that would have been provided against by the continuity of the L girder?—The column, recollect, is bearing about 1/3 of the weight which would crash it—even less I believe at the top—I do not understand what kind of imperfection could exist in that column which would make it necessary to make this L girder continuous.

18,172. Is not every structure of this kind, according to your own view, liable to the risk of such imperfections as to make it desirable for an engineer to guard against them?—Engineers always guard against imperfections by giving sufficient strength of material; and if an engineer gives a strength of material 18 times more than the working stress, I think he sufficiently provides for all contingencies.

18,173. There are other contingencies besides crushing stresses which have to be provided for. Take the case of the splitting of a column in an oblique direction, which would have brought it down?—No, I do not admit that it would have brought it down.

18,174. Suppose the top of that 18-inch column had been split in an oblique direction, would there have been no risk of the column coming down?—I do not think it. Of course you may take a very extreme view, you may suppose it to split from top to bottom.

18,175. Suppose it to split across?—You do not mean square across?

18,176. No—I if it were square across there would be no risk. You mean the chance of one piece sliding over the other, I suppose?

18,177. Yes—I think the column would probably give way.

18,178. That is a risk against which you, as a prudent engineer, putting up a structure of this kind, on which not only property but life would depend, would have provided against?—The only provision I would have made would have been careful watching, and if I had discovered any cracks of that sort in a column while the work was being constructed I would have taken away the columns and put another.

18,179. After the bridge had been put up and in full operation, how often would you think it desirable to go over these columns to see whether there was any imperfection in them?—I cannot tell you that.

18,180. How often do you think, if you were the engineer having the responsibility of a bridge of this...
kind you would deem it your duty to inspect the bridge so as to guard against the possibility of these dangers arising without your knowing of them, and therefore being able to provide against them?—That is a question I cannot answer, I have not considered it. With regard to what you put to me just now about the splitting of the column, I say those dangers are very rare; but I may say that no column has been known, or at least it has not only been in excessively rare cases, to split diagonally across in the way you describe. There may be cases without my knowing them.

19,181. Take another view, suppose a column to split vertically from top to bottom, would that endanger its stability at all under any pressure vertical or lateral?—Not under any pressure that could be produced with the wind or the train. That is my opinion.

19,182. Supposing it was to split vertically from top to bottom, being constantly subjected to vertical pressure, such as these columns would be from the constant passage of trains?—Two tons to the square inch.

19,183. Would not the tendency be for a split column to open out?—Yes, when you used the word "tendency" theoretically, there is such a tendency; practically, it would not be sensible, it would not be visible.

19,184. Do you think a vertical split in one of these columns subjected to constant pressures, such as I have been referring to, would not open out the split in course of time?—Most decidedly, think not; I think it should be guarded against, but that is a very different thing.

19,185. Guarded against, why?—I think strips should be put around it.

19,186. Yes, why.—If a split is not going to open out, what is the use of a strap?—We often guard against things that never do arise, and that we do not think will arise.

19,187. I am suggesting the possibility of the loosening of the braces and other things which rendered the stability of one of these triads very questionable, and I am also suggesting to you that the continuity of the L girder would have provided against such contingencies; have you not conceded that?—I have not conceded the first part of your question, that the loosening of the braces would render the triad entirely unsafe.

19,188. Have you conceded this, that the continuity of the L girder would have given stability to that pier more than it has just now where it consists of two sets of columns instead of one, as it would virtually be, if connected by a continuous horizontal girder, not a vertical girder?—Yes. I have heard your evidence, you can take it as it is.

19,189. (The Commissioner.) I also understood you to say that if the L girder had been continuous and the outer 18-inch column had been removed, in your opinion it is quite possible that it might not have come down, but not being continuous it would most certainly have come down.—I have not said that.

19,190. (Mr. Trendle.) It comes to this, that the continuity of the L girder would afford such strength as to keep the pier up, where its want of continuity would have permitted, in certain circumstances, one of the triads coming down?—In circumstances that could have happened.

19,191. I am getting to you—your own illustration of the removal of a column. You say it never could arise. Let us assume that that or something equivalent to it in effect could have happened, the continuity of the girder would have prevented a fatal result, and the want of the continuity of the girder would not have been so fatal?—Yes, I must say that if engineers do not provide for the removal of vital parts of a structure, suppose the girder was not continuous, and I removed a bay of boom, the girder would not stand. If you remove any vital part of the structure it necessarily will fall.

19,192. Do you think it was not part of the engineer's duty, or that it would not have been your duty if you had been engineer for the bridge, to provide against all the contingencies which might have arisen threatening the stability of the bridge?—Yes.

19,193. Can you conceive no possibility of the destruction of some of these triads from any cause whatever, after they had been put up, even in your view, perfectly rigid, and with absolute safety?—I cannot. I say those dangers are very rare.

19,194. Not being able to conceive any possible contingency of danger you cannot conceive of any measure by which that possible danger could have been avoided?—No.

19,195. You suggested the giving way of one of these columns?—The removal of one of these columns.

19,196. Suppose I suggest to you the giving way of one of the lugs of that thing which was a contingency, to be provided against?—No, not to be provided against.

19,197. In short, the pier being there, as you see it standing in the model, or as it was in the bridge, you would not have regarded it as necessary, to go back to that pier again, because it was in your view perfectly stable?—No, I think all the structure should be occasionally inspected.

19,198. Can you tell me what you mean by "occasionally"?—No, I cannot; I cannot tell what amount of inspection should be given to a bridge. I do not know what amount of inspection is given to the railway bridges over the Thames here.

19,199. Would it affect the stability of one of these triads if one or two of the lugs in the triads gave way?—Very little; the lugs in the triads do about half the work that the lugs in the north and south faces of the columns do.

19,200. If the lugs gave way the bracing would give way?—The bracing would not act.

19,201. It would give way?—You may call it so; it is just a question of language—if the lugs gave way the bracings would not act.

19,202. It would be the same as if they were not there at all?—Yes.

19,203. How many of those lugs do you think could be dispensed with with safety to the stability of the bridge in one of these sets of columns, one of these triads?—I cannot answer that question better than by telling you that the north standing pier of this bridge has the white internal bracing of the north and south faces clean swept away, and it stood out the gale after the girders fell over, and the storm was as bad as if after the bridge went over as before, it stood out the gale entirely by the action of the triad without any bracing upon it at all.

19,204. Then I may translate that by saying that in your opinion these lugs and bracings were of very little importance?—Certainly not.

19,205. If the triad has stood with every one of the lugs gone and the bracings down, do you not think they were of comparatively little use?—No, the thing is quite simple, it is a simple matter of calculation. If I took out the two end braces I could tell you the exact strength of resistance to sheering that the columns would have possessed. It would be perfectly easy to work that out.

19,206. In your opinion were these lugs essential to the stability of the bridge?—Certainly.

19,207. And the want of them, or the giving way of these lugs would to that extent have imperilled its safety?—To that extent certainly.

19,208. Then that part would have been as much as these as the number of lugs that were destroyed increased?—You are speaking of one tier, because if you break a lug in this tier, and if you break a lug in another tier it does not increase the peril; if you take away all the bracing in one tier of course you have a very weak bridge.

19,209. If it were prevented in one tier gave way it would seriously imperil the safety of the bridge?—It would diminish its power of resistance to lateral force.

19,210. Will you accept, or will you decline to accept, the view I put?—If you took away all the lugs in one tier, that would not materially affect the stability of the bridge?—I cannot answer that in this way: if you removed all these lugs it would stand a little
force, but of course the question of the amount of lateral force which it ought to stand is involved in answering the question, yes or no. It would not stand so great a lateral force if all these lugs were removed, undoubtedly.

19,210. You have said to Mr. Bidder that you concur generally in the evidence which was given yesterday by Dr. Pole.—Yes.

19,212. And that is quite a fair way to take it so as to preserve the necessity of repeating all these questions. You were present, and heard Dr. Pole examined and cross-examined; I believe?—I did.

19,213. May I take it from you that, except in so far as anything that you have said to-day may modify it, if it does so, you concur generally in Dr. Pole's cross-examination also?—I think so. I do not know anything of this subject from that time that I differ from it.

19,214. There is one point that I want to ask you about specially. Do you agree with Sir Thomas Bouchon that the breaking-out of any two consecutive ties or struts from the side of the girder would bring the bridge down?—Yes. I think that, if you broke out one or two consecutive ties or two consecutive struts it would probably break the bridge down. It is a difficult question to answer, you cannot tell what will bring the bridge down; it certainly has no theoretical strength to speak of.

19,215. By the by, can you tell me what, in your opinion, brought the bridge down?—The train leaving the station, and the wind acting upon the train. That is my notion.

19,216. Did you see any signs at all of the columns having shifted at their bases?—I did not make an inspection that I could speak much to. I did not see any sign of that at the end of the columns.

19,217. We have seen these things and we have seen the photographs, but have you seen any of the bolts that came out of the flanges where the bridge went over?—Yes.

19,218. Have you seen the condition that they were in?—Yes; Mr. Law showed me some of them.

19,219. How do you account for that twist or bond in the bolts?—I account for it in a very simple way—certainly not by the sliding of the columns, but simply by the turning over of the columns. That occurred to me at the time. I do not profess to be sure of that. You may see some of the bolts were left on the lee side of the column, but if turning over, all those were twisted round with great violence, and even those that were drawn up were drawn round in a circle, with a tension to stress them. I do not say positively that that is the reason, but it strikes me that that is the reason.

19,220. You are not in a position from your own inspection to give any positive opinion upon the subject, that is the theory that you would rather accept than any other?—That is what I am inclined to think.

19,221. Will you, kindly keep it in mind to make out your detailed calculations?—I will.

Re-examined by Mr. Bidder.

19,222. Just to take that question up first, if any columns of this bridge, either by the uprooting of the ties or by the blow of some portion of the structure falling upon it, is uprooted and turned over, would it not in the natural course of things follow that the bolts that are on the fulcrum edge round which it uproots must be bent or broken?—Certainly, and when I saw those bent bolts I was compelled to notice, that, this was very possibly that.

19,223. Taking a column, with a flange or a base piece bolted down with four bolts, taking an example as shown by Mr. Law in his diagram. No. 2 in his Report, where he takes a single line, A, A, through the centre of this bolt, and supposes this column to be rolled over, not only the flange, but that the column itself.

19,224. And if, after the thing has happened, anybody goes amongst the ruins and looks at what bolts is that the slightest indication of that which is suggested by Mr. Trayer, viz., that they were bent by the sheering of the columns?—No, I think not.

19,225. It is equally likely, is it not, that they were bent in the way that I have suggested to you?—Yes.

19,226. Now, upon those points which my learned friend, Mr. Trayer, has put to you—and I confess that I had a difficulty in following what was in his mind—he asks whether if in that 18-inch column the top piece were absent, the continuity of the girder would not have possibly kept the bridge up whilst otherwise it would have fallen, and whether or not it would not be a prudent thing to provide against it. Let me put this illustration to you. If you were driving in a mail coach at a rapid speed down hill, if the hind wheel came off, would it not be a very serious accident?—Yes.

19,227. Would it be the duty of a prudent and able coach-builder to put a fifth wheel there?—I do not think we provide for these things by that.

19,228. Or, to come nearer home, if a certain length of the top member of one of these girders was destroyed by, we will say, an accident, or any other catastrophe that might happen, would not that be fatal to the girders?—I think if it was discontinuous. It would be fatal to most girders. Continuity is a great advantage in strength to the girder, but in the majority of cases it would be fatal.

19,229. Is it not true of every member of a composite structure of this kind which is properly designed that if that member is absent the stability of the structure is greatly affected?—Undoubtedly.

19,230. And the argument would be that every portion of the structure is of the slightest importance or essential to it will require to be duplicated?—I think that seems to be the argument.

(Mr. Trayer.) That may be your argument, but it is not evidence.

19,231. (Mr. Bidder.) Is there the slightest reason whatever (to put a question which is perhaps more relevant to this inquiry) to suppose that the failure of the 18-inch column, or anything equivalent to its being removed or absent as a sustaining portion of the structure did occur in any pier, or in any way contributed to the accident?—No. I think not.

19,232. Have you heard any evidence whatever from the beginning to the end of this inquiry which suggests to your mind the possibility of anything of that kind was a contributing cause?—I think not. I myself examined the pier, and I agree with Dr. Pole that the prime effect of the accident, the first thing that happened, was the breaking of those ties at the base, and I do not believe that it was due to any fault in the column. The breaking of the ties of course left the columns almost helpless, and they turned over, but I cannot conceive of any weakness in the columns from all the calculations that I have made, and from what I know of the thing, causing the failure of the bridge.

19,233. You said that the weight put upon the leeward column, which is of course the one that carries more under the circumstances, is so far within the margin of safety that there is no reason to suppose that there could have been any failure at all quite so. Engineers are not in the habit of putting, so far as I know, exceeding, of making double securities against accident. All do they is make very part of their structures of sufficient strength with the proper factor of safety.

19,234. When my learned friend was asking you about the split columns you wanted to make some explanation about the fact which he referred to, the column which you make; perhaps you will be kind enough to make it now?—All that I meant to say was that in order that any piece of iron from should act as a strut it must be of a certain form; a· straight line will not act as a strut; but three-fourths of a circle is a very good and satisfactory thing effectual, and most suitable for the whole.
19.234. (The Commissioner.) What are you talking about now? I am confounding the difference between any construction and one of the top booms of the girders.

19.235. (Mr. Bicker.) Upon another matter: my learned friend, Mr. Traynor, tried to land you in an absolute difficulty; think I succeeded; but I ask you one or two questions upon it. He says (or rather you said in answer to him, if I understood you rightly) that if you had a greater extension of the tie, that is to say, if, with the same strain to begin with, the tie extended more, that would in a certain sense increase the power of resistance of the bridge to a height ?—Yes.

19.236. And that is absolutely and mathematically true, is it not?—Yes, perfectly.

19.237. Because, as I understand you, the strain on the tie remaining the same, and the extension of the tie being increased there is simultaneously a greater bending of the column, and consequently more work done by the resistance of the column to fracture ?—Yes, that is what I meant.

19.238. That is true also, I suppose, even if the extension of the tie is produced, not by the normal extension of the iron, but by, we will say, the bending of a bolt?—Quite so.

19.239. When you do it in the least, therefore, follow, as my learned friend suggested, that because in that way it increases the lateral forces there are not other considerations that make it important that the structure should be braced together so as to be rigid ?—Certainly, it does not seem to be a desirable thing to have loose ties, though, as a matter of absolute fact, it increases the stability.

19.240. If, I understand aright, it increases the stability in the sense of increasing the forces which resist lateral pressure ?—That is quite so.

19.241. And, however my learned friend may cavil at that, that is a geometrical truth which there is no defence for for breaking the shape of concrete and angular angles, but, nevertheless, it may not be an expedient thing to do for the sake of the structure as a whole?—Perhaps so. Probably the distortion of the vertical load would be increased.

19.242. And for that reason the more the column bends over, the more you have that vertical load nearer the foundation. —Yes.

19.243. If you throw this an inch or two nearer the edge of the base you diminish the amount of stability due to load by an infinitesimal quantity.

19.244. Therefore although your former proposition is perfectly true it does not follow that it is a good thing to lessen the ties loose?—No, I think not, I should much rather have them tight, but it is a thing of very little consequence, or of very moderate consequence.

19.245. My learned friend asked you whether you had designed and constructed bridges you have been responsible, as I understand, for the calculations and the details of the calculations of this bridge, and for those of other bridges which were carried out under Sir Thomas Bouch’s supervision and responsibility in chief?—Yes.

19.246. And amongst others of the Forth Bridge, though of course that is not yet carried out?—Yes.

19.247. I suppose it has not been your fortune to go to Ferness?—No, I do not remember any more that I have done that widening of the bridge over the Tay at Perth. I threw out a bridge from that bridge, and widened it. It is not a very large thing, but it was rather a difficult thing to do.

After a short adjournment,

19.250. (The Commissioner.) I think you said that you had been consulted by Sir Thomas Bouch throughout the building of the Tay bridge, did you not?—Yes, I have been consulted by him.

19.251. In regard, I suppose, to all the details of it?—Yes.

19.252. How long before you had been in communication with Sir Thomas Bouch?—I think, I first knew Sir Thomas Bouch about 1864 or 1865—about 15 or 16 years ago.

19.253. And since that time you have assisted him in most of these things, have you?—I have very often.

19.254. In most of his works?—In most of his girders.

19.255. But your attention in this case was not confined to the girders, but it applied to all did it not?—It applied to all.

19.256. I did not quite understand you when you said that you got a wider base with a hexagon than you do with a parallelogram. No doubt you can get a wider base with a hexagon if you carry the horns of the hexagon quite to the extreme point; but in this case I think the total length of the base from centre to centre was 21 feet 10 inches, or say 22 feet?—Yes, I know that.

19.257. The breadth of it from centre to centre was 12 feet?—Yes, it is 12 feet.

19.258. Supposing, for instance, that instead of the one column which you see there, two columns had been placed in the same plane as the two side columns (if you will just make the calculation), assuming the caisson originally to have been in the proper line, the bases of those columns would have been inside the brickwork?—They would certainly be inside, but not so far inside, as the 18-inch columns now are.

19.259. That may be so, but have you the same objection as Sir Thomas Bouch had to placing them partly upon the masonry and partly upon the concrete?—Undoubtedly.

19.260. Then could you not have removed some of the sources of brickwork?—That is a question for a practical engineer, but I know very well the practice of engineers in that matter, and they are very particularly in getting a uniform foundation for large structures. Even if you remove a few courses of the brickwork, you have harder or at any rate different material below you in the shape of brickwork than you have in the shape of the walls or the base of this bridge, and you do not have a few feet, but it is most desirable to have a perfectly uniform foundation.

19.261. Quite to the bottom?—All the way.

19.262. Then what was the object of having brickwork at all?—That was necessary because a 31-feet caisson cannot be built of any stiffeness; it requires a protection as a stiffener to the caisson.

19.263. One course of brick in the face have been quite sufficient to stiffen it, would it not?—That was not our opinion; we thought it necessary to put 18 inches of brickwork, and I think so still. Of course we might have done it by putting a double casing of iron.

19.264. Which might have been removed afterwards?—The inner casing could never have been removed.

19.265. However, is it the facts that we put iron bracings?—Yes, that is quite possible.

19.266. But at any rate, taking that plan which you have before you, there really would have been no reason why you should not have put, as you originally intended, two columns externally?—There would.
attempted to explain that. When you build up your brick block, as we call it, you require to have the centre of your column a certain number of feet within that.

19,267. Let us get something definite, if you please. How many feet—do not think it could be nearer than 2 feet 6 inches, that the column is, with any reality—that is about 2 feet 6 inches.

19,268. 22 from 31 will give you 9 feet; that would be 4 feet 6 inches from the outside?—I beg your pardon, you are mistaking what I mean. I do not mean the outside of the 31 feet caisson, but the outside of the brick block, which is only 27 feet wide. Then you have got 22 feet, and 22 feet from 27 feet leaves 5 feet 2 inches. But it appears to be 2 feet 6 inches. I think that is a very fair distance to put a heavy pressure on.

19,269. And that is your opinion still?—It is my opinion still. I think it is very undesirable to put a heavy pressure, less than 2 foot 6 inches, within the brickwork.

19,270. Then you can tell me why, at column No. 27, the base of the raking column there is actually at the present time overhanging the pier, quite on the edge?—The centre of the raking column is certainly not overhanging the pier.

19,271. I do not say the centre of the column, but that it is, and therefore the centre must have been at any rate within a very few inches of the outside of it.

19,272. (Mr. Bidder.) Is not that a raking column?

19,273. (The Commissioner.) It is a raking column; I have said so, corresponding to one of these outer columns. (To the Witness.) If there is a danger in putting the outside columns within less than 2 feet 6 inches of the edge, how is it that in pier No. 27 we find that the outside column is just on the edge of the pier itself?—I should like very much to know the fact accurately. I did not say it was dangerous, but "undesirable," I think, was the word I used. I would rather not put a heavy column involving a pressure of hundreds of tons less than 2 feet 6 inches from the edge of the brickwork. At the same time, I do not suppose it would be absolutely dangerous to put it 1 foot 6 inches or 2 feet off. If it is a column of this character (I think it is one of the high columns), I should doubt it 1 foot 6 inches, because, if it projects only 6 inches, it will leave 2 feet of bearing—it would be still 2 feet 6 inches within the brickwork.

19,274. The columns, I think, are all 12-inch columns.

19,275. (Mr. Bidder.) That No. 27 is one of the low spans.

19,276. (The Commissioner.) Yes, that is so. Mr. Bidder has quite rightly stated that the pier of which I am speaking now is one of the piers which carried the low girders, as we call them; it is just south of the high girders—Quite so.

19,277. And the base of the raking columns, as Mr. Bidder has said, on the eastern side projects over the end of the pier; consequently, the outer one must be resting within a very short distance of the edge of the pier?—I think you will find the column still a good way within.

19,278. We have been practically on the spot, and I know it, and that is the reason why I mentioned it?—From the drawing.

19,279. That will not help you?—Of course there is this difference—that there is far less pressure upon the small piers in the first place. In the second place, although it is a very undesirable thing, I do not infer that it is a question of danger. It might possibly be set at the very edge, but I would not like to do it.

19,280. (Mr. Bidder.) Is there not some evidence that these columns were added afterwards? I have some impression of that kind?—Besides, I think it is a baseplace that projects; it is not the column.

19,281. (Mr. Barlow.) I think what Mr. Bidder means is that some cylinders were added afterwards in one of the piers.

19,282. (Mr. Bidder.) I am very busy about it, but I have a sort of recollection that there were some raking columns added afterwards.

19,283. (The Commissioner.) I think Mr. Bidder is quite right.

19,284. (The Witness.) I think that column has a base-place which projects; it is not the column itself which projects, so that I think you will find the centre of the column to be pretty well within the brickwork.

19,285. It will be within the brickwork, but not to the extent that this one would require to be?—No.

19,286. You have told us that it was not you who suggested the alteration from the eight columns to the six, and that you do not know who did it?—No.

19,287. And consequently, as you are not responsible, except in having assented to it?—Quite so.

19,288. But my object in asking the question is simply to ascertain from you whether they could not have been placed there?—I do not think I can add more to what I formerly said, viz., that with the answers on the brickwork they could not have been placed 6 inches further out, that is a difficult question. I do not think there is any objection to six columns in comparison with eight.

19,289. (Mr. Bidder.) I believe it is the fact, sir, that these columns were added afterwards.

19,290. (The Commissioner.) Yes, I think they were added afterwards, and there is a fair case for them. Then, in the upper joint bending in that way (describing the same). (To the Witness.) You say that you have assisted Sir Thomas Bouch for a considerable time in building these bridges; you know his work the Tay Bridge I dare say?—That was built before my day, but I know it generally.

19,291. I think each pier is composed of six hollow placed columns in the form of a tapering trapezium and firmly braced together with cross girders at distances of 16 feet perpendicular and by horizontal and diagonal wrought iron tie-bars; that is say, is it not?—That is so.

19,292. (Mr. Bidder.) As represented upon that plate, I think (handing a diagram to the Witness)?—I have no doubt this plate is correct, but I do not know it.

19,293. With reference to that, Mr. Barlow asked Sir Thomas Bouch several questions which I will read to you to see whether you asssent to his answers or not. "Do you remember what description of horizontal ties were used in your design of the Tay Bridge?" Sir Thomas Bouch says:—"What did the horizontal "tiers consist of?—From the drawing, I have seen, "they appear to consist of girders placed quite across "between the columns?" "That is," says Sir Thomas "Bouch, "from column to column; and the ties go "into them." Then he is asked, "In this structure you "deposited from that construction?" and Sir Thomas "Bouch says, "Yes." Then he is asked, "Why did you "deposited from that construction?" and the answer "he gives is, "I can only tell you that, that I had a "different idea of the force of wind at that time before "I got the Report on the Forth Bridge." I then "asked Sir Thomas Bouch, "Is that the only reason? why you did away with these ties?" Sir Thomas "Bouch is, "They were so much more expensive. This "was a saving of money;?>—I beg your pardon, there were no ties done away with. I did not follow that question.

19,294. He has himself called these horizontal struts horizontal ties?—They are struts; but I understand now what you mean.

19,295. They are horizontal girders, but he calls them horizontal ties. Therefore I repeat: the question: "Is that the reason why you did away with "these ties?—They were so much more expensive. "This was a saving of money." Then we may "ask that this construction was adopted, partly because Sir "Thomas Bouch thought that the wind pressure "require so much strength to resist the lateral "load of wind, and partly because it made it less "expensive. Is that your opinion too?—Sir Thomas "Bouch thought that the wind pressure was less when he designed.
the Day Bridge than when he designed the Bealih Bridge.

19,297. Then that would have brought it well within the concrete?—Yes.

19,298. (Mr. Barlow.) Are you sure that was so?
—Yes, I think so. I remember the drawing very well. This is 21 feet 10 inches, and the other was 19 feet 10 inches.

19,299. (The Commissioner.) That is a foot on each side?—Yes, I do not know where the drawing is.

19,300. Then if you had had this you would have brought it well within the concrete?—Certainly.

19,301. There would have been no difficulty in that?—No; there would have been no difficulty in that.

19,302. Then any weakness at all in one of them might perhaps not have endangered the stability of this bridge. One of them might have been weak and yet the stability of the bridge might not have been affected?—Yes, I should like to make this statement: That all the engineers do in designing a structure is not to put a double column to make up the necessary strength, but to make each column of a sufficient strength and to leave a large margin of safety; beyond that they do not think it necessary to go.

19,303. But in the Bealih Viaduct they did put two columns outside, you know?—Yes, they did; but I do not think it is of the least consequence.

19,304. In what way is it not of any consequence?—Because I do not see any way that it is of consequence. That is my difficulty.

19,305. You mean that if one had become defective the bridge would not have come down?—Perhaps not.

19,306. But if this one became defective and failed, the bridge must come down?—I admit that; but I say that if that were the case, the whole thing could be supposed for a moment to give way when it is twenty times its proper strength, I fail to see any argument in favour of the precaution of putting a double column.

19,307. You explained very clearly that at the meeting of the 5th of April it was decided that the outer column should have an inch and a quarter, the inner ones having one inch; that was done, was it, because the outer column in that arrangement would bear as much strain as the two inner ones?—Certainly. I always held the view that on account of this not being a rigid structure, but an elastic structure, in which the column would only carry a uniform pressure per square inch on each of the columns under a directly vertical load was the same.

19,308. You still hold that opinion?—I still hold that opinion.

19,309. And you think therefore that there was the same amount of pressure upon the outer column, that there was upon the other of the two?—Yes, under a direct vertical load.

19,310. Then why did you increase it to an inch and a quarter?—It was not my doing, and I really cannot answer that question. It was Sir Thomas Beech who increased it.

19,311. Then you think that it was unnecessary?—I preferred an inch and a quarter, because in certain circumstances with 20 lbs. of wind there is very considerable greater pressure upon the outer column on the leeward side than upon any other.

19,312. That is a turning over pressure, is it not?—Yes. Of course if you put a lateral wind—pressure upon the top of a pier you bring a greater pressure upon the leeward side than upon the windward side.

19,313. Then if you have two outer ones, you get the pressure upon two instead of upon one?—Yes; but if you put them upon a smaller base you get that pressure very much increased. There is no difficulty in providing sufficient strength in one; there is nothing in the principle of the thing which is not any consequence.

19,314. I understood you to say that there was no difficulty with a base of that size in having a structure sufficiently strong to bear the whole weight and the whole of the wind pressure; but it depends entirely upon whether that pier was constructed

19,315. Do you think that was a worse form?
—No. I have already stated in my evidence, I prefer the hexagonal form to the rectangular form.

19,316. And do you think that the hexagonal form was as strong as the Bealih Viaduct with its horizontal girders?—I have never tried the strength of the Bealih Viaduct at all, and I cannot tell. As far as the shape, the arrangement of the pillars, is concerned, I prefer the hexagonal form.

19,317. The look of it?—No, the shape for resisting lateral pressure.

19,318. Do these ties on the inclined faces act so directly upon the pillars north and south as if there were two pillars at the outside?—No, they do not. The amount of stress upon the inclined ties on the inclined faces is considerably less than the stress upon the north and south faces of the bridge, therefore we might have made them lighter had we thought proper without weakening the bridge, still I do not think that is an objection.

19,319. But if you had had two pillars at each end instead of only one, you would then have had your ties acting just in the same direction?—But I consider it no objection to a bridge that certain parts of the bridge should not act with just as much strength as others. I cannot see that that can be taken as an objection. The arguments in favour of the hexagonal form were of a different character; I need not go over them, I can see no objection to the fact that a certain member of a structure acts with less effective power than another member. You may if you like make it a little lighter section, or you may make it unnecessarily strong.

19,320. As a matter of fact I suppose two, as we have two columns outside there would have been something more power to resist overturning than if there had been only one, would they not?—I think that one as strong as the two combined is as effective as two.

19,321. Then how do you make out that that one is as effective as the two combined?—I am speaking generally.

19,322. You were present when I put the question, were you, namely, that the sum of the metal in the two inner ones was equal to about 91 inches?—That is right.

19,323. And the metal in the outer one was about 65 inches?—About fifty-five inches is what we took it at.

19,324. Now suppose it was as much as that?—Sixty-three inches is what Mr. Law made it.

19,325. But you must not take it to the external part upon which you take it to the centre of the metal?—I did so. I may tell you that if it is 1 inch thick, there are 654 inches of metal. However I agree with you that the section of the outer columns is not equal to the section of the two inner ones, but the outer column has the advantage of being placed a foot further out than the two were put in the drawing that was furnished to the Court with eight columns.

19,326. The other two columns would have been put a foot further in, would they?—Yes, a foot in each side further in.
scientifically wrong; I say that this pier was built of sufficient strength to resist any wind pressure that could come upon it; but any imaginary wind pressure would be provided for by this base. Mr. Law's pressure of 800 lbs. or any other pressure, might be well resisted by a pier constructed upon that base.

19,385. (Colonel Yolland.) I think I understood you to say that the passage of trains along the bridge would not produce any tension whatever upon the pillars or ties?—Certainly not; it would produce no tension.

19,386. Can you, at all, explain what, Mr. Noble's reference to Mr. Thomas Bouch was that he found the columns at the north and south end very much strained by the action of the trains when they got to where brakes were usually applied?

(Mr. Bidder.) That was on the curve, if you recollect.

(Colonel Yolland.) Still it was the passage of the train.

(The Witness.) There are two points there. First of all, at the curve there is a centrifugal force coming into play; and secondly, I did not speak of the putting on of brakes, I merely meant the passage of the train in the curve.

19,387. (Colonel Yolland.) The conditions apply except where the railway was on a curve. It is both the curve and the putting on of the brakes that modify my answer. I do not say how far it is modified, but I merely thought of a train rapidly passing along the great space of the bridge.

19,388. But you recollect that Mr. Noble did refer to Sir Thomas Bouch that a great strain had been brought upon some of the columns towards the northern end?—Yes.

19,389. And that there was some question about means being devised for strengthening that part of the bridge?

19,390. Then your answer would be modified by the fact of the curve in the line?—Certainly, the curve in the line by centrifugal force would throw an outward pressure, which would act very much as wind does in a very moderate way.

19,391. Then is it correct in supposing that you wish to understand that the tension of the tie bars in a structure shortly after the line was opened for traffic, so as to possibly produce chattering amongst the tie-rod, would increase the stability of the bridge.

19,392. I think I understood you to say so?—What I said was this: that theoretically (and I am quite correct in this) that the tension of the tie bars by a quarter of an inch increases the resistance of the bridge to lateral pressure by bringing into play the resilience or bending action of the columns. I should like to explain why it is an objectionable thing. Under a heavy vertical load on the columns, when designed and when erected, were perfectly straight line. If on account of the space, the tie bars and before a strain comes on, they are a little bent, another action is brought on, due to the pressure, which is undesirable; for if you increase the resistance of the bridge to lateral pressure by bringing into play the resilience or bending action of the columns, I should like to explain why it is objectionable thing. Under a heavy vertical load on the columns, when designed and when erected, were perfectly straight line. 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19,388. I drew the inference from your statement of the fact that the structure would be more stable by the elongation of the ties— I do not draw that inference. I should like to ask the Engineer to be sighted, because through the life powerful to resist the pressure it better comes downward pressure. 

19,389. (Colonel Yolland.) Then I think another statement that you made was this: "that if those columns were perfectly vertical, the ties would not be brought into operation at all."—Quite so.

19,390. I suppose there can be no question that that would be the case, but there is not any one of these columns that is actually vertical?—When I said it vertical, I explained that the word was wrongly used. I do not know why I used the word "vertical."
19,346. Have you any statement to show how much?—Yes, I can give you that. I think it cannot give it you with a live load, but I can give it you with a dead load. On the expansion pier for the 4-span girder, with a uniform load, it is 112 tons due to the dead load at the first pier; after that it is 326 tons, leaving out declivities; then at the next it is 269 tons; then 326 tons; and then 112 tons.

19,347. Then, in the pier upon which you have made your calculations is that which has the 326 tons?—Yes. Of course, if you add to that the weight of the pier, plus the weight of the train, you get 517 tons.

19,348. You said something about the lateral pressure being different upon the expansion joint pier?—The lateral pressure upon a 4-span continuous girder is always proportional to these figures, diminishing it, of course, in the ratio of wind pressure to load. Of course, 112 tons represents the weight only on one of the 4-span girders. I think there was a suggestion made by Mr. Groth that pier No. 33 was the first to go of all the piers on the bridge that is the least liked by me; but I think the first expansion joint, because, although the downward pressure is there very light, the lateral pressure is proportionally light, and the sight of the pier taken into account reduces it. Thus, the pier gave way, not from a moment of forgetting from a shearing action. I have no doubt of that. The shearing action at pier No. 33 is absolutely less than the shearing action where we take it in our paper, in fact.

19,349. You seem very positive that it was a shearing action, will you tell us why you think it gave way from a shearing action?—I think it gave way from a shearing action from examination of the bridge. I saw it, and, as Dr. Pole very distinctly explained, I believe the ties were the first thing to give way.

19,350. The lower ties?—I cannot tell which of them.

19,351. The lower ties would be more strained in proportion to their strength, would they not?—They would be somewhat more strained.

19,352. I understand you to say that if anything did break one of these outer columns, and broke it with what I might call a dangerous fracture, an oblique fracture, it would lead to the downfall of the bridge?—I said that with regard to the upper columns; I did not say with regard to the lower ones.

19,353. Will you take the second one, if you please. I can see that it becomes less as you come to the bottom; but this bridge stands in a navigable river, does it not?—Yes.

19,354. And you have considerable shipping in that river?—Yes.

19,355. I know one of the first thoughts that occurred to my mind (and I believe it did to some of my colleagues), was that the cause of the falling of the bridge was the fouling of a ship upon the pier. Would it not be possible to break one of these columns by a ship?—A ship could not touch the columns, I think.

19,356. (The Commissioner.) Why not?—As a matter of fact, a ship did strike the pier and went to the bottom.

19,357. Where did it strike it?—It struck the masonry.

19,358. But where did it strike the ship?—I cannot give you more information about it. Sir Thomas Beecham was my informant. This is 5 feet above high water (pointing to the model).

19,359. Not spring tides, is it?—Yes, high water, spring tides, and the spring tides are 18 feet, so that it must be high water spring tides before the ship could reach the column.

19,360. What is the height of the bowwater of a ship?—Proportions to that subject. I have no doubt that that was Sir Thomas Beecham’s reason for keeping the masonry so high out of the water; but the shipping there is not large.

19,361. (Mr. Barlow.) You said that if these piers were forced out of their vertical by a pressure of wind sufficient to extend the ties in the masonry in which they have been extended, when that pressure of wind ceased the pier would go back again?—I did.

19,362. Upon what forces do you rely to bring it back?—I rely upon the forces of the equilibrium of the pier. What I mean is that the motion is small, and it cannot be very large. Then 3 or 4 inches, each of these columns is 2 feet at the base, and when the wind has entirely ceased, if you tilt it up a thing so as not to throw it over the centre of gravity, it will return naturally. But that is only to a certain extent true.

19,363. That is not the great force?—It is not the great force at that height, but still it exists. But I rely chiefly upon the bolts connecting one column with the other.

19,364. And the general elasticity of cast iron?—I beg your pardon, I was confused. I rely chiefly upon the nature of cast iron. Most of that bending is due to the bending of each column, and not to the extension of the bolt, and the resilience of the column brings it back.

19,365. The force that has produced this extension must have been a very large one, of course; you cannot suppose that a light force would make a permanent extension of 4% ft. of an inch in these tie-bars?—No.

19,366. Do you think that the thing would restore itself with an elastic spring?—I do, and it will tell you why. In the first place, this, at any rate, of that force is expended upon the ties, and not upon the columns. The columns themselves are not stretched to more than a ton, or a ton and a half, by the tension to a square inch. I do not think that there is any point at which cast iron at tension does not return a full amount, so that I think the breaking weight of cast iron is 7 tons, and I think you cannot pass the limit of elasticity in cast iron.

19,367. It is upon that elastic property in cast iron and upon the elastic property in the bolts that you rely for the force to bring it back to its place?—I do.

19,368. (The Commissioner.) As I understand you, you say you believe that this casualty was due to a sheering action caused by the great pressure of the wind?—Yes.

19,369. And acting ultimately upon the ties and breaking the ties, and then leaving the columns unsupported, as it were?—Breaking the ties, and then the columns would be very weak and would go over.

19,370. As it has been described as a pair of rulers?—Yes.

19,371. Assuming that to be the case, I think you said that you would require from 70 to 80 lbs. of wind to overcome the friction of the girder lying upon the pier?—Yes.

19,372. But as soon as, by the sheering action of which you have spoken, the pier was thrown over and came out of the vertical, then, of course, that friction would very soon be destroyed?—Yes.

19,373. And the end of the girder at the expansion joint would slip off, would it not?—Yes, it would slip off in time.

19,374. Much more quickly than it would where it was originally connected with the top of the column?—I think so.

19,375. (Mr. Bidder.) You mean when it was coming down?—Yes.

19,376. (The Commissioner.) And it is owing to that, therefore, that you think that on every occasion the ends of the girders near the expansion joints are nearest the pier?—Yes.

19,377. They lie at the top of the pier?—Yes.

19,378. And, therefore, the pier comes bodily over, as it were, the girder slipped from the top of the pier, and would go down vertically into the river. The next one would be held partly, and would be carried a little farther out; and where it is rigidly connected, where it is fixed, it would be carried farther out still?
It is very difficult to tell what would happen; but I think that that is most probable.

19,379. And that leads you to suppose therefore, that most probably the pillar came over by what you have described, as the shearing action, breaking away the ties. — No, that does not lead me to think that.

That is a very natural consequence, but that is not what led me to that view.

19,380. But it is quite in accordance with it. — It is in accordance with it.

19,381. (Mr. Harlow.) You mentioned that in regard to the wind-pressure that would come upon the expansion joint pier, it would be modified in its influence, somewhat similar conditions to those which would modify the shearing action in the continuous girder; but in order to bring about that complicated girder action, you have, you have not, in the construction of this bridge to elevate the ends of the girders, and then bring it down to its place after the fastenings have been provided? — Yes, I calculated that, and it was done.

19,382. Of course you could not do such a thing as that in a horizontal direction? — No, I think you are wrong. I will explain that to you. The object of this is to elevate the end of the girder to build the girder as it was built, upon a continuous platform, and then remove that every putting up is on account of the weather. Horizontally there is no weight; the thing is in a straight line when built.

19,383. Would your point of contrary flexure come in the same place, whether horizontally or vertically? — Exactly.

19,384. (Mr. Bidder.) You asked Mr. Stewart, air, whether he knew the fall of the bridge to shearing action; was that shearing due to the pressure of the wind? — (The Commissioner.) Or something else.

19,385. (Mr. Bidder.) Of course you will understand that it is taken in connection with what he said before, that that was not enough.

The witness withdrew.

MR. BENJAMIN BAKER: SIR.

19,388. Are you a member of the Institute of Civil Engineers? — Yes.

19,389. And I believe you have had very large experience in the construction of iron bridges, both in this country and abroad? — Yes, I am responsible for some dozens miles of iron bridges, and viaducts, I should say.

19,390. And amongst them I think some of considerable size? — Yes, viaducts of great height.

19,391. Give me an instance? — With my friend, Mr. Dixon (whom I see here), I designed and constructed a viaduct in the United States, one of which was about 1000 feet across and 200 feet in curve.

19,392. (Mr. Baker.) Was that in England? — Yes, that was the Quay Viaduct in York. That is on a line that is not opened yet. Then I am constructing this for the Norwegian Government in respect to bridges used in viaducts, and I have been so for some years now. If the viaducts built in Norway pass through my hands for revision and approval, and also if made in this country they are made to my specification and under my inspection. That includes a good many dozens viaducts.

19,393. (Mr. Bidder.) I believe you are responsible for some Government bridges in New South Wales? — To some extent; at least they pass through my hands.

19,394. And you are at present constructing some considerable bridges and viaducts in association with Mr. Fowler? — Yes, in association with Mr. Fowler, I have viaducts and bridges for about 80 miles of line in hand, and I may say, also, that the design and estimates for the elevated railway in New York, which comprises, I suppose, about 14 miles of viaduct, also passed through my hands some years ago.
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instances in sinking the foundations they tried first the pneumatic process which is common on the continent and in America, but which did not answer and at once one of the chief staff, Mr. F, a perfectly novel process which was an entire success. The ability of the chief made a great impression upon me, and it had a practical result some years afterwards.

(Mr. Traynor.) I do not want to interfere with this sir, if you think it is desirable, and I do not object to this gentleman expressing his high appreciation of the ability of the chief, but is it desirable to go further?

(Mr. Bidder.) I think so, or else I should not have asked the question.

(Mr. Traynor.) I object, if it is to go to any length.

(Mr. Bidder.) I think you will find that it will go to much less length if you permit me to take it in my own way.

(Mr. Traynor.) I will take my chance of the objection, reserving the inquiry if it is carried much further.

(Mr. Bidder.) I do not understand being told that Mr. Traynor object to a question, on the ground that it is to be followed by other questions.

(The Commissioner.) At present I do not know that Mr. Bidder has exceeded his right. Mr. Baker comes into connection with these gentlemen, and he expresses his opinion about them.

(Mr. Traynor.) Even that, sir, is not the question upon which this gentleman is here to give his evidence. You have seen these men, and you can form your opinion as to their capacity. I have no objection to the examination of these men being continued, but I am going to say what effect it had on his mind, and what he subsequently did. I think it prolongs a long inquiry too much.

(Mr. Bidder.) (To the witness.) What were you going to say?—I was only answering the question by practical example, that it made such an impression upon me.

(The Commissioner.) The impression upon your mind, I think, is hardly evidence. However, it will serve time if you let us hear what it was.—When some very important and difficult works were being contemplated in Egypt by Mr. Fowler, I recommended Mr. Grooth as the man, so to all others, to be entrusted with the carrying of them out, he being an engineer, and being perfectly familiar with bridge work of all descriptions.

(Mr. Traynor.) You knew nothing of him except from that one day?—I saw his works.

(Mr. Bidder.) I am willing to take it that you have studied the knowledge of Mr. Grooth, but I cannot go any further.

(3rd witness.—Sir Thomas Bouch's resident genius upon the same occasion.

(Mr. Bidder.) You made it your business then to understand, as an engineer, gathering experiences from other people's works as well as your own, to make yourself generally acquainted with the design of bridges. I would carefully into it, and in fact, I wrote a descriptive article which was published the next day, or a day or two after.

19408. Did you come to any judgment then as to the sufficiency of the design?—At that stage the piers were not erected, only the foundations.

19409. And before the design of the piers was that bridge sufficiently known to you?—No. You have just heard the bridge very recently, since the accident, have you not?—Yes, I was there last week.

19410. (The Commissioner.) Then you had not seen it in the interval?—No.

19411. (Mr. Bidder.) And you examined the ruins of the piers?—Yes.

19412. And you have also heard the evidence as to the nature of the defects which are suggested in the bridge?—I have.

19413. In your judgment, as a question of design (apart from the question of workmanship), was the design of that bridge sufficient for resisting the wind strains that could be expected to come upon it?—The design of the bridge was merely, you may call it, a duplicate of previous designs by other engineers, and previous experience had shown the sufficiency of it.

(The Commissioner.) That is hardly an answer to the question.

19414. (Mr. Bidder.) May I take it that in your judgment the bridge was sufficient in design for resisting the wind strains that might be expected to come upon it?—If you ask me whether I think the bridge was blown down by the strains that came upon it, I say I think it was simply strong for the wind that it has sustained since it has been erected.

19415. Do you mean this,—that, having regard to the wind on the night of the 28th of December, the design was amply sufficient?—Yes.

19416. Whether it is possible to conceive a wind for which it would not be sufficient is another question?—Of course it would go down in a tornado, or anything of that sort.

19417. In your judgment, having regard to the strength of the wind on the 28th of December last, the design of the bridge was amply sufficient to resist it?—Yes, with a factor of safety of between two and three.

19418. Then, in your judgment, is the cause of the failure of the bridge on that night something in addition to the mere static wind pressure?—I think so.

19419. I asked you that question just now simply with regard to design, but I must now ask you your opinion with reference to certain defects of workmanship which have been suggested in the carrying out of this bridge. Is it in the first place impossible to carry out a work of this magnitude without there being some defects?—Of course good and bad work are merely relative terms. I could point out much better work than this, and, on the other hand, I could point out very much worse work. Take, for instance, the girders, look at the state they are in now. After falling about 80 feet you find that the damage that they have sustained is comparatively little, and if it is had, then you would have been much more smacked up than they are. Then the piers were made by the same contractors, and I have no doubt that they gave the same attention to the piers that they did to the superstructure.

(The Commissioner.) I think that is hardly evidence.

(Mr. Bidder.) That is no evidence, of course.

(The Witness.) They have not picked up the piers from the bottom of the river—they have the girders—so that I could not look at the workmanship of the fallen piers; that is my difficulty.

19420. You cannot speak on seeing their work when they were upon the piers, because they had not been built; but they were building the girders when you were there, were they?—No, I looked at the girders in their fallen condition.

19421. Let me ask you with reference to certain defects which have been suggested, for instance, taking the more important ones at once; a conical form of hole in the lag instead of what is conceded on all hands was the right thing, a cylindrical hole permitting the bolt to bend when a severe strain came upon it; you understand what I mean?—Yes, I think that if the bolt had been stiffer, it would had been bad for the lug; but, as the bolts bent, it allowed that the lug was strong enough to bend the bolts, and when the bolts were once bent they could not have been worse.

19422. I gather that you agree with everyone else that, undoubtedly, the conical hole is a defect?—Yes.

19423. Assuming that when any tie-bar became loose or chafed it was tightened up, to what extent, or did it to any extent imperil the safety of the structure?—I do not think that the pin or the defective bearing of the cotter had any operation at all in the failure of the bridge. My view is this; if you suppose that, in place of one of these flat bars with a cotter of a small bearing area and a bent point, you substituted a portion of a ship's cable, and then put a high strain upon that cable, you will see at once that the bearing area of the links
upon each other is practically a line much less than that of the cotter. When a high stream comes on the links, the links bend just as these pins bend, in fact as Mr. Barlow will know at a high strain a cable becomes perfectly rigid; you could stretch it from one side of the table to the other and sit on the middle of it. That is due to the bending of the links. The thing is to prevent the links from being bent. That is distinctly that neither the bending of the pin nor the small bearing area of the cotter would cause the failure under high strain.

18,423. Of course the bending of the bolts would cause a thickening of the tie-bar?—Yes.

18,424. Supposing a bolt bent and that the stress was due to the bending of the bolt when the pins were under a pressure or considerable lateral wind pressure, what is your judgment upon the question of whether or not when that pressure is removed, when the storm has passed away, the column would return to its original position?—It would obviously return to its original position unless some part had been strained beyond the limit of elasticity, and then it would return to the bent position selected.

18,426. Taking the figure which Mr. Stewart gave us as the result of his calculations that the strain per inch was a factor of a decimal; is that upon cast iron approaching the limits of elasticity?—No, it is only a normal strain.

18,427. Mr. Stewart gave us the lateral force taken up by the base of the column, and I cannot charge my memory at the moment with it. That was not per square inch, but on the whole column. It was 2-3 tons at the top of the column. I must frame my question with that altered figure. Assuming that the 15-foot beam bent with a total horizontal force of 2-3 tons to the top of the column. I have not calculated it, but I think it was not.

18,428. You have not repeated the calculations of Dr. Pole and Mr. Stewart?—I have not.

18,429. You did not have followed carefully the principle upon which they have founded their calculations and think that all engineers would be in agreement?

18,430. I agree that the principle of their calculation is accurate one?—Certainly.

18,431. In your judgment, then, the bridge, being as it was, is what it was when inspected, rigid and apparently well set up, as it was passed over from the first inspection to the second inspection, is certain from time to time developed looseness and were cotted up when they developed that looseness, thus the bridge being so kept tight up, practically in an efficient and satisfactory state?—Clearly so.

18,432. Assuming for a moment that there had been in one case a column which had gone over (I refer to the small limits, fractions of an inch), and that the structure was discovered, and that the structure had been in the form distorted to that extent that the column was a fraction of an inch out of its proper position; would that seriously impair the stability of the structure?—No, the effect would be negligible.

18,433. If you believed, I think, when you were there, what has been referred to by a good many witnesses viz., that the cast iron lugs are mostly broken?—Yes.

18,434. Does that give any indication to your mind as to the nature of the failure?—I think it indicates pretty clearly that the weak point was in the lugs. The lugs fell first, and they would be peculiarly liable to fall, because we know it was a strong bolt and the smallest shock would break a lug, of course.

18,435. Given cast and wrought iron of approximately equal tensile strength, the cast iron would be the first to fail under a shock, would it not?—Yes, of course.

18,436. I endeavored to make my meaning clear by an illustration that I gave to one witness: If you hook a wrought-iron rod from the ceiling with a cast-iron fastener at one point of it, the two kinds of iron being of equal tensile strengths statically, and if you dropped a weight on the rod down to a check at the bottom, so that it gave a heavy blow, would not the cast iron break?—Yes. I can give another illustration of that: I had great trouble once with a series of turnbuckles; the notch into which the catch dropped was of cast iron and the catch itself was of wrought iron. In turning those turnbuckles round, with only one carriage on them, the shock of the catch going into this notch in every case knocked a great piece of the cast iron from the back. I think in two days there were about 16 turnbuckles disabled, although, judging from the sectional area, it would have taken at least 20 times as much to have broken the cast-iron notch, as to have bent and destroyed the wrought-iron catch. It was merely the shock of the turnbuckle being turned and brought up suddenly with the weight of only one wagon on it.

18,437. (The Commissioner.) The wrought iron not being injured in any way?—Not at all. I was going to add that although cast-iron lugs are peculiarly liable to fail from shock, they have been used in precisely this way successfully in tens of thousands of years of viaducts; therefore, I think Mr. Bouch was only following precedent in using these turnbuckles. Mr. Barlow will know that on the Bombay and Baroda line they were used for a great many viaducts.

18,438. (Mr. Barlow.) I forget the height of that work?—There were a number of viaducts; some were 40 feet high, and some were 100 feet high. There was one type of viaduct adopted, and it was increased in height according to the height, but the same type was used.

18,439. We all know that lugs have been very much used?—But they were used in precisely this way. The struts in these viaducts were not bolted up against the columns, as it is stated here that they should be, but they were merely dependent upon a pin. They did not get electrical up against the column.

18,440. Is that the way you make your viaducts?—No, it is not. I must say that there is a model of these viaducts at the South Kensington Museum, apparently for the instruction of young engineers, and I think it ought to be promptly removed, if it is not approved of. It is there still in the Science and Art Department.

18,441. With struts depending upon friction only?—Yes, the struts depending upon one pin, not butt joint solid against the column.

18,442. (Mr. Tragner.) Is it not there as a beacon to young engineers to warn them off a bad practice?—It is a very nicely made model.

18,445. (Mr. Biddick.) Take the case of a strut: Mr. Law, I think, put it that there is a play in each case of one eight of an inch, so that you might have a quarter of an inch on the two sides. Supposing the case of a struts which was fastened by friction which was imperfect, and that the bolt being upon the wrong side of the hole, each side came in one eight of an inch, then you had a quarter of an inch in the hole, and that the sides were cut away tight, would that seriously imperil the safety of the structure?—No, but you have no right to assume that the struts would slide. The friction is ample to hold them. Experiments have been tried over and over again upon that point. And quite recently some German engineers went very carefully into the question, and they found that the friction was equivalent to a sheering strain of seven tons per square inch upon the bolts holding it together. For instance, if it were an inch and an eighth bolt the friction would be sufficient to withstand a pull of seven tons.

18,446. (Col. Peckland.) Are you speaking of a wrought-iron bolt?—We know it, a wrought-iron bolt. That is an experiment that has been tried on other occasions, but these were the most recent. They were very carefully done.

18,445. (Mr. Biddick.) With reference to the small bearing area of the cotter, I think you alluded to that?—I have compared that to a ship's cable, which usually has to do very important work in which the bearing area is important. I want to ask you your judgment upon that. In your opinion is that a satisfactory form or not?—Yes, I think so...
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It is quite optional. I have built clustered columns piers with four cast-iron columns, instead of six, that is, two raking ones on each side (pointing to the model) and omitting these inside ones altogether.

19,437. (The Commissioner) Outside the girder?—Yes, we ought then under the girder, and then raking them out. I may say that one effect of raking them from the top is very much to reduce the strain upon the bottom ties and lugs. With a certain rake you would reduce the strain one half.

19,438. (Mr. Barlow.) Was it of four columns that you were speaking?—Yes, I have used also two columns frequently for viaducts of this sort.

19,439. (The Commissioner.) One under each girder?—One under each girder raking out, and in the recent ones that we have put up in Norway these columns have been raking; they have had rockers at the top and rockers at the bottom. Instead of having expansion rollers, the girder is made fast to the top of the pier and the whole pier rocks with the expansion.

19,450. (Mr. Barlow.) You did not use cast iron in that case, did you?—No, wrought iron.

19,451. Do you fill them with anything?—No, they are just like small lattice girders set up on end.

19,452. (Mr. Bidder.) That is right, and Mr. Barlow that both speak of in Morescambe Bay; I think there were two pillars in that case?—Yes, cast-iron columns.

19,453. That rather suggests a comment upon the question that was put this morning. It was suggested that if the head of one of the outside columns was absent by fracture the bridge would come down, and—

19,454. Its absence would be felt?—Yes; I have put a weight of 400 tons on a single column. I think that is about the heaviest load there is on a cast-iron column.

19,455. You are aware of course that in this case there was a question of limit of area so to speak in the foundations, that the foundation had to be put on a cabinet?—Yes.

19,456. That you are not free to spread out at random as you would on terra firma.—No.

19,457. And you are aware therefore that it was a balance of advantages as between the relative advantages of arranging eight columns in a rectangle or getting a wider base, as it was considered that you did, by the hexagonal arrangement?—I think the hexagonal arrangement is one of the circumstances here.

19,458. May I take it that under the circumstances, you think it the better?—I think so; there is not much choice between them.

19,459. Is it that one of those questions upon which a great deal of experience must exercise his judgment to the best of his discretion, balancing his own knowledge of his own judgment which has an advantage?—Quite so.

19,460. (Mr. Bidder.) You have said that, in your judgment, the base was perfectly safe, having regard to wind pressure. You have also observed that it was to bear on the night of the 28th of December?—Yes.

19,461. You have visited the spot, and have heard all the evidence, what is your judgment as to the wind pressure that the bridge, as a whole (I do not mean any isolated point of it) had to meet?—I do not think the ruling maximum pressure of the wind on the whole bridge was 15 lbs. per square foot.

19,462. (The Commissioner.) What are you judging from?—I am judging from the strength of the structures which now exist, but which would have been destroyed had the wind pressure exceeded that amount. There are two signal boxes, one at the end of the bridge and one a few yards farther away; those signal boxes have windows. Amongst other experiments which I have made from time to time, I have tested a great deal of glass up to 14 inches in thickness. I have tested the strength of a window with the sah-bars, by placing a ledge round it and pumping water on it till the glazier?—No, we ought then under the girder, and then raking them out. I may say that one effect of raking them from the top is very much to reduce the strain upon the bottom ties and lugs. With a certain rake you would reduce the strain one half.

19,467. (Mr. Barlow.) And the opposite side of the cabin had no door or window?—There were windows all round.

19,468. Did you try the effect of opening one of them?—The reason why I asked was that I would not get the full pressure upon the glass if it was acting upon a room closed on the other side of the glass. You would not get the pressure of air in the room itself unless you open the window on the other side.

19,469. (Mr. Bidder.) Is that so?—A very small aperture would communicate wind pressure; but I should not like to say one way or the other.

19,470. (Mr. Barlow.) I am afraid that a great many of our windows would go away if we were not for that.

19,471. (The Commissioner.) There would be no increase of pressure in the room.

19,472. (The Witness.) A long time ago, previous to this inquiry, I tested a small door with four panels. It was a 3-feet by 2-feet window, and the thickness of the glass was 3 inches. That failed with a pressure of 54 lbs. per square foot. The strength per square foot, of course, will vary approximately as the square of the thickness, and inversely as the square of the width of the pane. That will give you sufficient data to estimate approximately the strength of these windows.

19,473. (The Commissioner.) Then there is one other fact also to be taken into consideration; that both these cabins are protected to a considerable extent.

19,474. (Mr. Bidder.) That is so, no doubt. They are not exposed to the same extent that the bridge on the centre of the river would be. I should say not; but, looking at the effect of the wind on the ballast now remaining on the platform of the bridge, I noticed that there was quite as much disturbance of the ballast near the signal boxes as there was near the centre of the river. It had been blown away, scudded away in both cases.

19,475. Did you notice any other structure from which you could draw any deductions with reference to the wind forces?—Yes, there is the gable end of the station.

19,476. That is of course on the north side?—On the north side, and it is near the sidings where I understood it was alleged some waggonette were blown about. This gable and fronts, as nearly as I could
ascertain, the direction of the wind in the same way as the bridge.

19,472. (Mr. Barlow.) Do you mean the end of the station or the end of the engine house? — The end of the station, the passenger station.

19,473. (Mr. Barlow.) Is that (handing a photograph to the witness)? — I would not like to speak to that, but it is the gable and at the station roof on the side next the bridge and facing the wind.

19,474. (Colonel Yolland.) Which station, the Caledonian or the North British? — The Caledonian station, the cold station. In shape it is very much like a small ellipse, I think, it is about 62 feet wide, and about 20 feet high. This gable end is made of boarding, it is closely filled in, and the only thing to prevent the whole thing being blown in is one strut at the centre, and what you may call a wooden tie-beam that runs across the bottom of the gable. I did not get a ladder, but I estimated the bar is about 6 inches by 5 inches, and the whole of the wind pressure would depend upon the transverse of that. That is a beam of that size 62 feet long, imperfectly in the centre. That works out to about the same strength as the glass.

19,475. (Mr. Barlow.) Fifteen pounds to the square foot? — Yes, about that.

19,476. (The Commissioner.) Between 9 and 18? — You cannot tell the strength of the wind. Wood varies quite as much as that, but it is a regular box structure. I think it was about 62 feet span, and about 20 feet high. I did not measure it, but I passed it. Then, further down, there is a building slip with two roots. It is 120 feet, wide altogether, and there are two spans of 60 feet in the air; there are no sides, and it is fully exposed, so that the wind could get under.

19,477. Would that be exposed to the direction in which the wind was coming? — It is on the side of the Tay; it would not be exactly in a line. Then, there was a photographer's shop, which had been stuck on the top of the roof of another house like a very large box, and extended on the ridge of the roof, and the other end was propped up on 2 or 3 inch columns that could have been pulled over by a couple of cart horses. Therefore, you can multiply instances of structures of that sort which could not possibly have stood a greater pressure than 15 pounds.

19,478. (Colonel Yolland.) But that is at a considerable distance from where the bridge fell? — It is.

19,479. (Mr. Rider.) Qualified to this extent: that the bridge itself, at a height of 80 feet across the tarry is necessarily somewhat more exposed than the buildings on the shore at the side? — Yes.

19,480. Taking all that into consideration, do I correctly understand that in your judgment there was not a sudden average pressure per square foot greater than 15 lbs.? — No, I think not. I may say that for the past 15 years I have looked very carefully for evidence of any structure capable of standing an uniform pressure of 20 lbs. per square foot, which has been blown down. I issued a challenge in a letter to "The Times" which appeared about Cleopatra's Needle, and these heavy pressures were brought forward; about 80 feet, and so on, and I said I had been a very careful observer, myself, and I should be very glad if any one could give me an instance of a chimney or a wall, or anything capable of standing a pressure of 25 lbs., which has been blown down. I think the most violent storm I have seen in my life was in Brighton, when I saw a house propped up on 4 fence wall, some of them on the side of the cliff, and some of them on the town, and it was dismembered and their stability, and there are miles of wall there which would distinctly tumble over with a pressure of 18 lbs. per square foot, and they have been there for 80 or 40 years, and that has been blown down.

19,481. (Colonel Yolland.) Did you hear of any instance of a chimney falling down of 31 tons? — It would be difficult to discuss the subject of tombstones.

19,482. (Mr. Barlow.) You heard of those waggons being blown along the rails at the station? — Yes.

19,483. Did you calculate what wind pressure was required to do that? — No, I did not, there might have been a gradient.

19,484. A wind pressure of about 8 or 9 lbs. per square foot would do it, would it not? — Considerably less than that, I should think.

19,485. They were loaded waggons? — Yes.

19,486. (Mr. Rider.) Of course I suppose you do not deny in giving in these evidences, that anemometers may record, and truthfully record, in a particular spot higher pressure upon a limited area? — Yes, upon a smaller area there may be a sort of jet of air, but not over a large area. I should be very glad if any one would give me an example. I have issued a challenge any time during the last 15 years, and I have never got a single example. In this country, of a wind blowing down a structure which would have stood a pressure of 20 lbs. a square foot.

19,487. You have found, although you have searched for 15 years, no instance of wind doing damage to any structure of reasonable area that would have involved a pressure of 20 lbs. or upwards? — No instance; I have never heard one cited.

19,488. (Colonel Yolland.) Did you ever hear of any railway carriages being blown over? — Yes.

19,489. (Mr. Rider.) I am coming to that. It has been suggested in this case that the wind upon the limited surface of the second-class carriage may have blown it over, and I do not think you have gone into the calculations which Dr. Fede, and Mr. Stewart, and Mr. Law have made to ascertain what pressure would have blown it over? — No, I have not.

19,490. It has been said that nobody ever knew of a railway carriage being blown over. Is it quite certain that railway carriages have never been blown over? — There are three very well known instances of carriages being blown over in France. There are cited over and over again, and they are the bases upon which French engineers proceed in calculating their viaducts. There were three instances; they were all in the same district of France, near the Pyrenees, in the south-east. Two occurred on the 27th of February 1860, one near Salces, and the other at Rivesaite. Then there was a third, which occurred on January the 19th, 1863, in a station at Leucate. The carriages were empty at the time they were blown over, and in the two first cases the loaded carriages in the train remained on the line, only the empty carriages being blown away. In the last case the whole train, consisting of 17 carriages, was blown over; it was standing on a siding. In the first two cases the train was running, and in the last case it was running on a siding. Those are the cases upon which the French engineers proceed, and they have calculated the wind pressure in the same way as Dr. Polo and others; that is to say, what effective pressure would turn them over, and it varied from 24 lbs. per square foot to 32 lbs. per square foot. The calculations vary between those two figures. The carriages were of different weights. On the bases of those results French engineers have since that date always assumed the wind pressure on a train on a viaduct at 34 lbs. per square foot, because they say that any greater pressure than that would upset the train, and it is not necessary to calculate the wind pressure on a train at more than that, and that you will find is universal in France.

19,491. (Mr. Barlow.) That is the calculation which is made with regard to a train upon a viaduct; but from a letter which I have received, they have a different mode of estimating for the structure without the train? — Yes, they have. That is based upon investigations made 60 years ago by an engineer who was building a lighthouse at that time, and he had instructions to make it as strong as some other lighthouses, and he took the opportunity of going generally into the strength of chimneys and lighthouses, and all that sort of thing; and as a result of that the French engineers adopted an arbitrary figure of 53 lbs. But
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(Prof. Bidder.) No, I do not have later information than you upon that point.

(The Witness.) I must add that some of the samples taken on this occasion in 1830, especially one chimney in Paris, would have blown down with a pressure of about 59 lbs. per square foot. I have no doubt Colonel Yolland will know the case of the guard's van being blown over on the Chester and Holyhead line in January 1867.

19,491. (Col. Yolland.) No, in 1868 there was more than one vehicle blown over. I have only heard of the van, and I do not know the particular point.

19,492. (The Commissioner.) Do you know whether it has happened in India? I have heard of horse boxes being blown over, and also of carriages being blown over in India, but as the wind was generally stronger, the pressure was higher than that which was necessary to blow them over; it does not afford any useful data.

19,492. (Mr. Bidder.) Except that it is another instance of the fact occurring.

19,494. You, I believe, have had the opportunity, have you not, of seeing the markings on the girders, and the other matters upon which evidence has been given, so that you are able to form an opinion as to whether they were done by the overturning of the train or not, but assuming, as a matter of fact, that the two last carriages of this train, going east, say, 25 miles an hour, did overturn and run into the Bowden girders, would the sudden arrest of their momentum, in addition to the normal strains caused by the storm upon the bridge, in your judgment be a shock sufficient to account for the failure of the bridge in a way that would have hurt the girders at all? But I can imagine that in a very high state of tension, the girds would be at that time, with their peculiar liability to fail (as I have instance by the turn tables), with comparatively slight jar, very probably fail with a very slight shock.

19,495. (The Commissioner.) You think the girders would have failed in the transmitted shock? Yes, certainly.

19,496. (Mr. Bidder.) I can easily imagine that the blow was transmitted to the bottom of the pier in the same way that a man falling on his head often fractures the base of his skull. The shock, in my opinion, would not hurt the girders.

19,496. (Mr. Bidder.) Do you mean that it would weaken the girders or it would not mark the girder? If it would mark the girder, but it would not bring it down. It is surprising how wrought iron or steel will absorb a blow. One of the "Thornycroft" torpedo boats ran at a speed of 14 knots an hour into a stone pier, and it did not disturb any thing on board, except the life-buoys and the boiler about 4 inches, but the boat, steaming at a speed of 14 knots, is, of course, of very high velocity.

19,497. In any of those cases which you have cited of carriages overturning, did it appear that the overturning carriage dragged down any other carriages with it? In two of the cases it was thought that there was a derailment; there has been something which has been set down by somebody else.

19,498. That is a mistake. He did not make these observations which you refer to; they were made by the Astronomer Royal in Scotland.

19,499. Was Mr. Peddie, Sir Thomas Bouch's assistant, with you? Yes.

19,500. Was there any proposal to show you the girders that were raised? Yes, I went down and saw them.

19,501. I thought you said in answer to Mr. Bidder that you had not seen any of them? I have seen the girders, but I have not gone into the question.

19,506. Was not your attention called to the marks supposed to have been made upon the girders? Yes, but I did not regard them at all.

19,507. Why? Because I saw no use in going into it slightly.

19,508. But you knew that there was a theory upon that subject? Yes.

19,509. And you did not think it worth while to go into it? No, I do not attach any importance to the marks upon the girders, because I believe if one of the struts or one of the ties was destroyed it would not bring down the girder at all.

19,610. (The Commissioner.) Nor even if two of the struts were destroyed? It would depend upon their position. If the two in the centre were struck away it would not affect it at all.

19,511. (Mr. Trayer.) You have told us how the French engineers have arrived at their view as to what wind pressure to provide against; do you happen to know that Professor Rankin states that the wind pressure to be provided against in Great Britain is 55 lbs.? He may, but it is of no value, because it is not based upon experiments.

19,512. I am not asking you to give a judgment upon Professor Rankin, but I am asking you whether you happen to know that that is stated in engineering literature by a man who is recognised as an authority.

19,513. I have a recollection that he does speak about it.

19,514. (The Commissioner.) I think it is right to show the Court what is put into my hands. Professor Rankin's manuscript notes, and he gives his authority.

19,515. (Mr. Bidder.) I do not know anything about Professor Rankin. If you say they are Professor Rankin's notes, of course I believe you.

19,516. (Mr. Trayer.) They are signed by him.

19,517. (Mr. Bidder.) They purport to be signed by him.

19,518. (The Witness.) I think we may accept it. I have a distinct recollection that it is so.

19,519. (Mr. Trayer.) "The maximum value of the wind pressure observed in the Neuchatel experiments, at the bourne of Glasgow is 55 lbs. per square inch," says Dr. Nicol. Do you know who Dr. Nicol is, the astronomer at Glasgow? No, the appliance for measuring wind pressure may be very crude and unsatisfactory; I do not believe in them at all. I would rather take my word and see whether it stands.

19,516. As an engineer you have had to provide for wind pressure? Yes.


19,518. And you put out of view any other man's observations as not those upon which you would rely in comparison with your own tests? Certainly not Professor Rankin's.

19,519. What is your particular objection to Professor Rankin's? Because he is not an original observer, and he is merely passing on something which has been set down by somebody else.

19,519. That is a mistake. He did not make those observations which you refer to; they were made by the Astronomer Royal at Glasgow.

19,520. Was he not qualified to make those observations? I do not think he had an apparatus to enable him to do it.

19,521. Have you a higher opinion of the Astronomer Royal for England? I have.

19,522. The Astronomer Royal stated here in a report which he gave that in Scotland the provision against wind pressure should be 100 lbs.; he says that it is evident that the pressure is greater than which may amount to 49 lbs. on the square foot, and that in Scotland it may be more than 20 lbs. on the square foot, and that the Astronomer Royal could have
You think if you could not get the dimensions; but, there are chimneys in existence with stableness ranging. It may be from 30 lbs. up to 100 lbs. They are very much.

You said that you did not take any trouble to ascertain what the stability of those chimneys was, and you cannot tell us.—I know from trying on previous occasions that there is almost always an excess of stability in chimney stacks. You find that in the case of an ordinary fence wall in any part of the country on the bridge of a cliff or on the top of a hill, the stability very readily exceeds 20 lbs. per square foot, and is more commonly 13 lbs. per square foot.

You said that at your first visit Mr. Grothes went over the plans and gave you the facility to instruct your mind upon the intended structure.—Yes.

You asked that in your opinion, it was sufficient for the piles or all wind stress.—All these iron piers were not settled at the time.

But the design that you saw?—No, I saw this season base (pointing to the model).

Had you any idea at that time what wind pressure the bridge was then designed to resist?—We did not discuss it at all.

Then you rather had information from Mr. Grothes as to what was intended to be provided against, did you calculate what should be provided against?—Oh, Dr. Bower, we did not discuss anything but the foundations; all the difficulty is in the foundations. The superstructure of the piers is ordinary.

What wind pressure do you think was brought to bear upon the bridge upon that night of the 26th of December 1879?—Taking the bridge as a whole, and on the basis of those other structures, of which I have given you the simplest information I can, the inference that I draw is, that the pressure did not exceed 16 lbs. per square foot. And I would also call attention to the condition of the ballast of the bridge. It must have been blown away if there had been any such tearing hurricane as they speak of; it would have come in.

You have not given me the pressure was 15 lbs. over the top?—I draw my attention to what would be the wind pressure at any point of the bridge?

With regard to these two signal boxes, did you notice that one of them was in use, and that the other had been deserted?—They were both deserted last summer.

Did you see, that one of them had the apparatus in it for a signal station, and that the other had not?—There was a wooden one, which had the ears, and suit that in; and there was a brick one in which I do not know whether there were levers or not.

If, in the case of the brick one, the brick window was the one that suffered, which was really the brick window that the bell fell, is it not possible that the brick window, on being blown away, was blown away immediately to the south-west of it, within 100 yards of the south-west of the line?—I should not say that it was very much protracted.

I do get a tremendous pressure of wind very local, and comparatively short distances from the brow that.

(The Commissioner.) Still there is a blow?—Yes, a long distance off.

(Mr. Trayler.) What do you call a long distance?—Do you think it is more than 100 yards?—I do not know. I have referred to the condition of the bridge.

How did you say the door of that cabin stood?—If this was the entrance, the bridge door would be there (describing the same).
Re-examined by Mr. Brodie.

19,553. You are aware, as everybody is, that Mr. Kirkaldy's tens are properly and fairly done; but if these logs had been severely strained previously in position on the bridge, it might considerably weaken them?—If they had been over straining it might weaken them.

19,554. My friend asked you if you had been down to the girders where these marks were, I think I am right in saying that you were a great part of the day upon the roo?—That is so.

19,555. And at the time that you got to the girders, I think the tide was making—I looked at the girders, and I was very much surprised that they had not been loosened about, so I have already stated.

19,556. Was it at West Ferry, that you saw the girders?—I saw them down the river on the Dundee side. Do not know whether that is West Ferry. I shall saw some fragments elsewhere.

19,557. (Mr. Pryor.) But they were out all of the water?—New-piece being lifted out of the water by the bow of the ship.

19,558. (The Commissioner.) You said very truly that Mr. Kirkaldy is an original observer; are you an original observer of the force of winds or not?—I think so. I can give you a tremendous number of examples.

19,559. From your own anemometer?—My own observation, measurements of actual structures and calculations of their stabilities. If those structures had been standing 40 years, and by the uniform laws of gravity, their maximum stability would be so much, then I draw the inference that during that 40 years the pressure of the wind on that structure has not exceeded that calculated amount.

19,560. You have referred to walls and fences. You know that: they are of course very close to the surface of the earth?—They are.

19,561. And of course therefore the force of the wind is very much broken there?—That is so.

19,562. And the force higher up would be very much greater?—Yes, that is so; but I think a fence wall on the edge of a cliff with the wind blowing in the direction to throw the wall over the cliff is placed under very disadvantageous circumstances, because the air can escape so freely from the other side of the wall that it causes a vacuum behind the wall. I may say that the reason why I instanced the gable end of a cottage was to show that its structure was not liable to the objection I put to the girders, because the gable end is right up in the air, and there was a free passage underneath.

19,563. Have you stated very truly the allowance that is made for wind pressure in France by the engineer in 1850? is any such allowance made in the United States?—It has not been settled.

19,564. (Mr. Barlow.) What is your habit?—I assume that there may be a wind pressure of 28 lbs. per square foot.

19,565. (The Commissioner.) Do you ever make that allowance in calculations?—Yes, in this viaduct the wind pressure is 14 lbs. per square foot, and I thought it inadmissible for the quantity of the flanges to be raised up by the wind pressure driving it against them.

19,566. That is for the girders, is it?—No, it is for the flanges.

19,567. (The Commissioner.) They differ in different States?—Yes, some of the railway companies take it at 50 lbs. per square foot. In America the companies do not make their own designs of bridges; they make a specification and send that round, and the railway companies, in any design they like, provided it complies with that specification. It is 50 lbs. with some railway companies, and 360 lbs. per foot run with others and there are other small variations; but they always allow a higher strain on the iron in the wind than in any other part of the girders.

19,568. (Col. Yolland.) I think we gather from your evidence that you consider that the fall of the structure was due to the giving way at the base of the pier?—Not necessarily at the base, but the giving way of some of the logs.

19,569. Without saying whereabouts. Those girders have been designed to bear the pressure of a train of 14 tons per foot run and not to have produced a greater strain upon them than a little over four tons, certainly under five tons at all events, on the square inch. Supposing, for instance, you had placed yourself at the centre of one of these two 45 feet spans, and cut the two central lattice bars in two, do you imagine that the bridge would have come down—Certainly not. Within the past 12 months I had to tighten up the central diagonal of a bridge of about this span, which were perfectly slack, although the ship was five inches in diameter, and therefore had a very large bearing area. I consider the question of tightening these ties as merely a question of time. If the cotter were twice as big you would have to tighten them, but you would not have to tighten nearly so often. It is just the same with the Crumlyn Viaduct; there, although they had pins of 8 inches in diameter, they worked loose in a certain time. However big the pin is, it will want tightening up once in twenty years perhaps.

19,571. Would you go so far as to say that if you cut the two centre lattice bars in each girder, that would not bring it down?—That would not bring it down. I will tell you what I have done. I have run over a girder bridge upon an engine with every one of the web joints unriveted. I did not put one over time.

19,572. (Mr. Barlow.) You have told us that you attribute the coming down of the viaduct to the giving way of a lug, but what made the lug give way, was undue pressure of wind, or do you attribute it to a shock or jar?—I think not undue pressure of wind, alone, because my opinion is that, taking the strength of the bridge upon the basis of the wind pressure and the moment there was a factor of safety of between 2 and 3; and therefore I think there was a pretty severe strain upon the lug, and then there was some jar.

19,573. Such as would be occasioned by what?—It might be occasioned, as has been suggested, by the train striking the girder.

19,574. (The Commissioner.) Or it might have been from defective work?—It might be from a thousand things.

19,575. (Mr. Barlow.) If the wind pressure was only 16 lbs. per square foot, it would not upset a carriage?—No, I do not think it would. The rails here were away special; the sun was good, and the rail was very tough, and there was no tendency for the flanges to mount the guard rail from the pressure of the wind driving it against it. It would be mere assumption on my part if I said what amount would be necessary. I know that railway carriages get off the rails on curves, and in a variety of ways without any wind at all.

19,576. (Col. Yolland.) You are aware that the remaining part of the structure of the Tay Bridge that is standing has the girders immediately under the permanent way; does it not naturally present a great element of danger, in the fact that carriages will get off the rails, and axles will break, and tyres will fly off, and so vehicles be thrown over?—In most of these cases the vehicles would not those vehicles be thrown into the Tay?—Yes, unless you adopted the American plan of having a couple of boulders as rail-guards outside.

(The witness withdraw.)
TWENTY-FOURTH DAY.

Friday, 7th May 1880.

(The Commissioner.) We have received a return from Mr. Ewur, which we think it is our duty to call for this afternoon. We have received a copy of his evidence, which is before you. It is a summary of the results of experiments under the heading "pulling, thrusting, and bending stresses of special types of columns cut out of broken cast-iron columns received from various makers and manufacturers, as the occasion required." I think Mr. Trotter and Mr. Webster had better see that before Mr. Gilkes’s evidence begins. (For this Return, vide Appendix.)

(Mr. Webster.) I can only say that I am very much obliged to you, sir, for calling our attention to it; but I have not heard of it. I have heard of it only within a very few minutes that Mr. Gilkes has himself cut out from columns that have fallen, at random, pieces, and had them tested, and that they have borne a test far above the test which had been prescribed by the contract, and therefore he was well aware, from his own information, that the iron would stand the test shown by Mr. Kirkaldy’s experiments.

(The Commissioner.) There is one other point upon which, as yet we have had no information at all, and that is this: the high girder portion is divided into three sections, an expansion joint at each end, and two in the middle. We know the direction of the permanent way after the strain that has been put upon it and the north end, and at the south end.

(The Commissioner.) That is after the accident.

(The Commissioner.) We should be very glad indeed to know what is the direction of the permanent way at the two intermediate joints.

(Mr. Webster.) As found?

(The Commissioner.) Yes; I say, for I need hardly say, and I think both parties ought to know this—that it might throw some light upon whether the south section or the middle section or the north section came down first.

(Mr. Webster.) Yes. As far as I understand, what you desire to know is what is the bend in the rails?

(The Commissioner.) Yes; that was the object of the looking at the photographs yesterday.

(Mr. Bidder.) I do not know that I have any further information in the Court on that matter, and perhaps it will be convenient that I should say now that I have not any further evidence to offer.

(The Commissioner.) We should be glad to have the information I have asked for before our report is made.

Mr. Edgar Gilkes sworn.

Examined by Mr. Webster.

19,577. You are, and have been for many years one of the managing directors of Messrs. Hopkins, Gilkes, and Company, Limited?—Yes.

19,578. For how many years have you been concerned with the manufacturing and making and marketing of iron?—Since 1842.

19,579. I believe you have constructed a very great many bridges?—Yes.

19,580. And you were, of course, a member of the firm at the time that they entered into the contract for the completion of the Tay Bridge, which had previously been contracted for by the late Mr. De Bury?—Yes.

19,581. I believe that bridge construction is a matter that you have yourself personally paid attention to for many years?—Yes, I have.

19,582. Have you constructed any large bridges and viaducts?—Yes, a good many extending over some years.

19,583. I will not go into any great number of them, but only some of the principal ones. Did you construct the Bealha and the Dee Dale Viaducts?—Yes, I constructed the Bealha for Sir Thomas Bouch.

19,584. That was constructed under Sir Thomas Bouch’s designs?—It was.

19,585. The Dee Dale is a different one to the Bealha?—They are both of the same construction; but the Dee Dale is on a curve, and the Bealha is straight, the Bealha is a good deal taller in some of its parts than the Dee Dale.

19,586. Those are two bridges of similar construction, one being an a-curve, and the other...
Mr. E. Golden.

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Mr. E. Golden.
I suppose you had no foundry there before you undertook the Tay bridge work?—No, on taking the contract I had to take a certain amount of plant that had belonged to the Mr. Bolt Works, that was part of the arrangement with the North British Railway Company or the Tay Bridge Company, under which I took the contract, and part of that plant was the unfinished foundry.

19,644. Have you anything further to add about that?—I completed it as soon as I could, because I thought it was a judicious outlay of money.

19,645. In order to have the means of doing the work on the spot?—Precisely. I would have preferred making the castings all at Middleborough, had it not been for this—sometimes those upper columns varied in length, because we had not been able to sink thefoundations so low as we expected, or some other alteration of that kind; it therefore, became convenient to have a foundry on the spot.

19,646. It is not necessary after what has happened, to go at all into detail, but I ought, in fairness to you, to put a question or two with regard to the bolts—it is not denied now that the bolts, taken as bolts were of sufficient strength. I want to ask you how was the course of practice at Middleborough with regard to the inspection of the bolts—where were they inspected?—Those that we made ourselves, which were a large number of those that were used in the bridge, were inspected, as all our work is inspected; those that we bought, notably those from the Cleveland Nut and Bolt Company, were inspected in our storehouse as soon as they were brought in.

19,647. Can you give me the names of the inspectors?—I can.

19,648. Will you be kind enough to give them?—Mr. Newcomb, and Mr. Mayer, one of them is a foreman and the other a workman.

19,649. (Mr. Webster.) I will just say as I intimated before, that if you have the least wish that either of those men should be called, they shall be called. You will remember that Mr. Law very frankly said that the bolts as bolts were perfectly satisfactory. (To the witness.) Just tell us what sort of inspection was given to those bolts as they came to you?—Every bolt was examined, and so many of them taken to the anvil and nicked, and bent for quality—so as to show the quality of the iron.

19,650. The Cleveland Nut and Bolt works are just on the other side of the street, I believe?—Just opposite our works.

19,651. Was it more convenient to inspect them at your place than at the Nut and Bolt Works, or why was the inspection made at your place?—It was quite as convenient and it was a little safer—that is to say that we knew they did not get mixed again.

19,652. You said that a very considerable number of the bolts were actually made at your place?—A very large number.

19,653. Do you remember the proportion at all?—Of the particular bolts in question—the 1 ½ inch bolts.

19,654. Yes?—I think we made 11,000, but I can hardly say how many.

19,655. Why did you not make more?—If I remember rightly it was because our bolt-making arrangements were so occupied that it was more convenient to get them made next door, and it was really like making them ourselves—we were in there constantly.

19,656. And you had brought to your own yard, and tested there, and then returned to the Nut and Bolt Works?—Yes.

19,657. It is not necessary probably to go now into it in detail, but you have taken out from your books the returns of bolts made to the Cleveland Nut and Bolt Company?—Yes, I have had them taken out.

19,658. Did you ever until this inquiry hear any suggestion made that those bolts were made of bad iron, or, in point of fact, were not sufficient and proper bolts?—Never.
Mr. E. Gilks.

7 May 1860.

19,659. Now, as regards the tie-bars, where were the holes at the end of the tie-bars made?—At Middlesbrough.

19,660. How were they made?—Slotted out.

19,661. With a punch or a slotting machine?—A slotting machine. The hole at the other end was drilled out.

19,662. Were any of the singlets made at Middlesbrough?—I think it is most likely they were. I do not quite remember, but I do not doubt they were. I should have said so if you had not asked the question, but when you put it as a matter of memory, I am not quite certain.

19,663. You know a very large number of them were made at Middlesbrough?—Yes.

19,664. Where were the cotter made?—At Middlesbrough.

19,665. And the gib?—The same.

19,666. (The Commissioner.) In your factory?—Yes.

19,667. (Mr. Webster.) I will put this general question to you: The drawings of these various parts from time to time were furnished by the engineer to you, and were carried out in your works?—That was so.

19,668. I think that is all I need ask you about Middlesbrough?—Perhaps I might add that from time to time Mr. Wemyss came over from Edinburgh to Middlesbrough to see the progress of the work there.

19,669. At the inspection at Middlesbrough, on behalf of the engineer, was Mr. Wemyss coming over from time to time and seeing how the work was going on?—That was so.

19,670. I should like to put a question as to your practice. Are you, I may say almost daily, or from time to time in your works testing the iron from which the tie-bars were made?—That is so.

19,671. Were the usual tests being carried on in your works with regard to the iron, out of which these materials were being manufactured?—Yes, for the cast-iron currently. We do not usually continue to test wrought iron unless we are called upon by the engineer to do so. We can test it sufficiently in the working of it.

19,672. No. I will go to Wornit for a few moments. You spoke to your having been there constantly and seeing the work yourself?—Yes.

19,673. Did you see how the casting was being done?—I did.

19,674. With your own eyes?—Yes.

19,675. I think there has been a little misapprehension about the casting; something has been said about the columns being cast in sand, that is to say, the lower half of the mould being in sand, and the top mould only being fastened down by stakes. Is that correct?—No, I think Mr. Cochran was in error there—I know he was in error, but I think it was from his giving the statement of information which he had received; it was not a matter of fact.

19,676. He said he had only been informed, but as a matter of fact can you tell us how the columns were cast, and what means were taken for keeping together the upper- and the lower flasks?—They were cast in the ordinary way, with a top and bottom flask.

19,677. (The Commissioner.) Do you mean in the case of all the columns?—Yes.

19,678. (Mr. Barlow.) Those cast at Wornit?—Yes.

19,679. (Mr. Webster.) I must at once tell you with reference to this, that I am desirous of asking Mr. Gilks this question, because the evidence that was given with regard to the bad quality of the iron on account of defective casting is absolutely untrue. (To the witness): Will you tell us what you yourself saw being done?—I myself saw they were cast with a top and bottom box or flask; to the best of my belief they were also cast, and I have confirmations of this from Mr. Frank Bostall who was manager of the foundry, and to whom I wrote asking the question;
pecuniarily or in any way by having horizontal instead of vertical castings?—I think not.

19,699. Now about the lugs themselves, I am not speaking of the holes now, I will keep that entirely separate; with regard to the lugs themselves, have you any knowledge of casting lugs on to the columns?—No, not frequently.

19,700. I believe there are a large number of bridges where casting lugs on to the columns—That is so.

19,701. Rightly or wrongly, I am not suggesting for a moment that it is wrong, but rightly or wrongly was this the method by which you had to proceed?—That was so.

19,702. You do not for a moment suggest that it was wrong on the part of the designer to have cast-iron lugs for those columns?—No, it was not my place to make such suggestion. I think the question of lugs, or another mode of attachment, is a good deal affected by the heights of the columns, and the width of the spans, and the position of the whole structure.

19,703. The Beadah Viaduct was very much higher than this?—It was; it was 195 feet to the rails from the bottom.

19,704. (Mr. Bartlow.) Were lugs used in that?—Lugs were not used in that. They were cross girders.

19,705. (Mr. Heaton.) The bridge is on the face against the column, and the columns were turned up to receive the ends, and a clip was put round.

19,706. (The Commissioner.) It was only in one part that the Beadah Viaduct was of that height?—Yes, it was across a valley with varying piers according to the side of the valley.

19,707. (Mr. Webster.) I think, as far as I know, that is all I have to ask you as to the course of business in the way of casting at Wornit. Now, I ask you this: Has come to your knowledge since the bridge has been down that in, I will not say how many instances, at the present moment, but in some instances, the metal has been sold on one of some of the columns that now remain in the bridge—Effective casting, I should say?—That is so.

19,708. Of course you have seen them yourself?—I think I was with Mr. Law when he took the samples from the columns.

19,709. Did you know of the existence of those holes, whenever their extent was, would you have allowed the columns to have gone into the bridge?—No, certainly not; nor do I think that any one of my staff would have done so either.

19,710. You yourself have seen the ruins, and I think you have examined every pier?—I have.

19,711. Whatever the defect was, did it exist to any great extent? Have you seen, or so far as you believe did it exist to any extent in the bridge?—I only saw two or three columns that were very seriously defective. I think Mr. Law gave similar evidence as to that also.

19,712. I would ask you upon this part of the case, is it your judgment, had there been eccentricity in those instances, taking the worst, anything whatever to do with the fall of the bridge?—I think not. The worst column that I saw was in advance of the place where the engine and train lay; considerably in advance.

19,713. There are one or two minor matters of detail that I should like to ask you about; the first and perhaps the most important of all, if I go from the bottom to the top of the column, so far as you are concerned, is the question of the spigot and faces. You were aware that at the bottom joint there was no spigot and faces?—Yes.

19,714. Did you have any evidence of Mr. Gröthe's evidence as to those columns that had to be fitted on to the base of the column?—Yes.

19,720. In your judgment, would it have been, I will not say a prudent or proper thing, but would it have been a thing that could have been easily fitted to have had a spigot and faces going into those bases?—I do not think it would have been of much use there; it would have been very difficult to have made so good a fit off, as to be 'of any avail; and as a matter of fact, it was not originally designed to have been so made, it was made so for a matter of the difficulty.

19,715. Had each base piece to be faced at the angle necessary to take the rectangular column coming upon it?—Yes.

19,716. So that the pitch of the base was given by the base piece?—Yes.

19,717. The whole of the column above that being intended to be in one straight line and all the flanges parallel?—Yes, parallel, and at right angles to the axis of the column.

19,718. Now will you tell us with regard to the boring of the holes or making of the holes in the flanges of the columns themselves: how were they made in the 15-inch columns?—The columns were cast without any holes in them.

19,719. You are speaking of the flange holes entirely?—Yes, the flanges were faced up, and faced upon the edges, and then put into a machine which I had constructed for the making of the Beadah and the Deep Dale originally, and had sent to Wornit in which we drilled the eight holes through the solid simultaneously.

19,720. The holes in the flanges of the 15-inch columns were drilled?—Yes, they were drilled and all drilled at the same time, the whole eight.

19,721. So that the holes must all be at the same distance apart relatively in such column; they must all correspond to one another?—Precisely.

19,722. Now the holes in the 18-inch columns?—They were cast in.

19,723. From the beginning?—From the beginning, the whole time.

19,724. They were all cast?—Yes.

19,725. Will you just explain to the Court the method of casting with regard to making the sides parallel, or as nearly parallel as may be, what is the sort of core that is used?—In the flanges of the larger columns?—Yes?—A dry sand core, which is made in a core box, and so far as reasonably can be expected is a parallel core, and should produce a parallel hole.

19,726. A dry sand core, by which you mean a core made before you cast the column for the purpose of putting into its place?—That is so.

19,727. What means were taken to secure that these dry sand cores made the holes in the proper places in the flange?—The ordinary means by which we usually secure accuracy.

19,728. What are those ordinary means?—Core prints on the pattern.

19,729. That is to say, something stuck through the holes in the pattern that leaves a hole, into which you can put your hard sand core?—Yes, more or less.

19,730. Perhaps you will be good enough to explain it yourself?—The prints leave places in the sand into which we can drop the core so that we assure that the core represents the hole that is left when we pour the metal into the casting. The pillar pattern has a stud, if I may so call it, upon it, when drawn out leaves a hole, into which you drop the hard sand core.—Yes.

19,731. Then, in fact, the wooden pattern may be called a template—it is not exactly a template, but it corresponds to a template?—It is part of the pattern that leaves the place which we fill up with the sand core.

19,732. Now, with regard to the fitting of those holes, that is to say, their being suitable for the bolts, what is your own opinion as regards the superiority of a drilled hole or a cast hole in such a position as that?—The chief advantage of a drilled hole, where you have not a turned bolt is, that if they are drilled simultaneously with the others you get more perfect accuracy the one flange with the other, but you can get accuracy quite sufficient if care is taken in casting the holes.

19,733. I forget at the moment to ask you—were those bolts 15 inch that went into the base pieces?—That is so.
Mr. Gilber:

19,731. (The Commissioner.) You say that you can get sufficient accuracy if you take pains in the casting?

—Yes.

19,732. (Mr. Webster.) You have seen, I know—

—and I have told you already once or twice—the ruins of this bridge, and you have examined every pier?

—Yes.

19,733. And you have seen the fractures and the way in which the columns have broken off, sometimes one way and sometimes another, and sometimes at one place and sometimes at another?

—Yes.

19,734. In your judgment had any shifting taken place of those columns upon their base pieces prior to the accident?

—I do not think any such shifting had taken place prior to the accident. Nothing that I saw on any of the piers lead me to that conclusion.

19,735. Whatever may now be seen with regard to the shifting, I am not speaking of the shearing of the rivets, but with regard to the shifting laterally, do you believe that any shifting that is now seen is either the result of the accident or took place simultaneously with it, and not antecedently to it?

—Certainly not antecedently to it, but it is most likely to have been caused at the time and as part of the accident.

19,736. Have you seen that any holes in the flanges of the 18-inch columns were conical?

—I was not. I do not think they were to an appreciable extent.

19,737. You have not had your attention called to or seen any conical holes in any of the flanges?

—No.

19,738. Now, I come to the lugs; how were the holes in the lugs made?

—They were made with a sand core.

19,739. But cast?

—They were cast in.

19,740. In all cases?

—Yes.

19,741. That is to say, the lugs both on the 18-inch columns and on the 18-inch columns?

—Yes, they were cast.

19,742. What sort of sand core was it?

—A dry sand core.

19,743. Was extraordinary care taken with the cores to make them substantially cylindrical?

—Yes, they ought to be.

19,744. For now, then, that after all, you have heard Mr. Law's evidence, the holes in the lugs were tapered and were not conical?

—Yes, I am aware they were.

19,745. Had you known of those holes being conical should you have allowed those lugs to go to the bridge?

—Certainly not.

19,746. Do you to the best of your judgment: the conicality of the taper of those holes had anything to do with the falling of the bridge?

—Nothing, whatever; because the bolt would soon adjust itself to the slighter taper that was in them.

19,747. Now, with regard to the ribs and gibs: I am not going to deal with the question of inspection, but I think I have heard that what has been pointed out with regard to the roughness of the sides of some of the slings: it is not suggested that it was so in the case of all the slings, but it was pointed out that in some slings that were produced there were rough edges, having been punched out with a circular punch, and not with a slot: how many of those you have seen, and also whether you seen some indication of them. I believe there were very few; they were only made under emergency. The bulk of those things were made and properly slotted at Middlebrough, but if there was one lost or dropped into the river, and one had to be made impromptu, as they had no slotting machine at Worsmiffe, they punched it out.

19,748. You say that the bulk of those were made at Middlebrough. For what, then, you believe to have been required to fill the place of others that may have been lost, were punched at Worsmiffe?

—Yes, I know that.

19,749. Assuming that in some few instances there were rough sides, as is pointed out, at the sides of the slot of the slings, would that in any way, in your judgment, affect the holding of the gibs and gibs in their places?

—Not in the slightest.

19,750. I need not trouble you about the channel iron, but there was a rib that I learned that I should like to ask you about. You have heard it said that it was found that some of the gibs could be driven further home after the bridge had been worked some time, and that packing pieces were put in?

—Yes.

19,751. Assuming the bolt to have bent, would that elongate the tie and so admit of the gibs being further tightened up? If the bolt had bent it would render the action of the cotter needless to bring the bar as tight as it was before.

19,752. If the bolt bent, it would render a cotter useless for the purpose of bringing the bar into the state of tension it had been in before?

—Yes.

19,753. It being the doing together of two slots, sliding one over another?

—That is so.

19,754. Assuming that to be done, that is assuming the bolt to have bent, and the cotter to have been tightened up, I ask you as a matter of opinion, would the bridge then be, as far as the tying or bracing was concerned, if properly done, as safe as it was before?

—Entirely so.

19,755. It is entirely possible the bolts are put in for the purpose of tightening up the bars, should there be any weakness from any cause.

19,756. Did you go upon the piers of the bridge in the course of construction?

—Yes, everyone.

19,757. And did you, as far as you could, in the course of your going upon those piers, examine the workmanship yourself with the view of seeing how the different parts were being fitted, and how the work was being carried out?

—Thoroughly.

19,758. Did you, when you were able to detect anything that you did not approve of, order it to be taken out and other work to be put in?

—I had occasion to do so from time to time in various parts of the work.

19,759. In the course of going over those piers and seeing the work as it was being executed and carried out, did you form any opinion as to whether the inspection that was being carried on by those under you or under the engineer was being sufficiently and properly done?

—I was perfectly satisfied with it.

19,760. I think I may now pass to some other matters: you remember the work being finished?

—Yes.

19,761. Roughly speaking, about the end of 1877 or the beginning of 1878?

—Yes.

19,762. Do you remember the fact of the inspection taking place by Mr. Macbeth and Mr. Reeves?

—Yes.

(Mr. Barlow.) When was that?

19,763. (Mr. Webster.) It took six months altogether. Mr. Reeves inspected from October 1877 up to the 28th of December, and Mr. Macbeth inspected three months before the inspection, and two months afterwards. (To the witnesses.) You know that the work was being I will not say scrutinised, inspected, but being specially inspected during that time.

19,764. You yourself appointed Mr. Reeves to go with the necessary staff on your behalf to do anything that might be required under the orders of Mr. Macbeth, the engineer's inspector?

—Yes, that is so. I think he had about 10 men constantly working.

19,765. You knew that they were properly selected, and the others, which you believe to have been required to fill the place of others that may have been lost, were punched at Worsmiffe?

—Yes, I know that.

19,766. I am not going into detail more than necessary, but was it or was it not a thorough and careful inspection of this bridge?

—It was very minute indeed, and very carefully done; more so than I ever saw with any bridge that I ever built.
19,767. Did you see, and were you a party to the tests to which the bridge was subjected? Yes; I was with General Hutchinson all the time.

19,768. You saw and stood upon the pier while trains went over the bridge, and went upon the trains yourself? Yes.

19,769. You saw the testing with the six 72-ton locomotives, and also the test with the four locomotives running at 40 miles an hour? Yes.

19,770. I think there is no doubt about the question of the pace, because you actually timed it yourself through the high girders? Yes.

19,771. What was the pace at which they travelled the distance of six miles, locomotives coupled together? A little more than 30 miles an hour.

19,772. (The Commissioner.) What time did it take to do it? 52 seconds.

19,773. (Mr. Webster.) You had a stop watch? Yes.

19,774. And you yourself timed it through the high girders? I looked when we entered and when we left, and General Hutchinson took the stop watch.

19,775. Was the testing that the bridge was put through a testing which in your opinion was sufficient to develop any weakness of material or defect of workmanship due to the ordinary working or running of trains? I have no information in any part of the bridge that that inspection would not have detected at that time.

19,776. Was there any vibration, or what opinion did you form as to the stiffness of the bridge or as to the workmanship and materials as the result of that inspection? It was extremely stiff, more so than I expected. There was no perceptible vibration perceptible with the theodolite in the large girders, and there was very little trumour in the piers. We tried them at every joint.

19,777. I must apologise to the court for having forgotten; on one thing regarding to the spigot and lances, and you knew that there was a spigot and lances was 60 feet long, in every joint at the upper part? That was so.

19,778. Do you believe, as far as you know, that the spigot and lances was left out in any single instance above the base? I have no belief that there was at all. I have no knowledge of such a thing in any joint.

19,779. To take up the thread again at where I left off, the inspection went on, and the bridge was opened, and personally, I think I may say, except as taking an interest in it, you had no connexion ceased when the inspection of General Hutchinson had taken place? Yes.

19,780. Your connexion ceased on the 16th of January, as far as the engineer was concerned, but you did happen to be there at the time of the inspection. From that time until the fall of the bridge, had you any intimations, or anything was wrong with the bridge or the workmanship of it? None whatever. I have no knowledge or information in the cracked columns.

19,781. Did you see the cracked columns, and you did not hear of the necessity for or the insertion of the packing pieces? I did not.

19,782. There is one other little matter which I ought to clear up, and which, perhaps, you will be glad enough to explain. There was a passage which communicated between the lower parts of the cracks, and the lower parts of the cracked columns.

19,783. Did you see the packing of the cracked columns, and did you have heard of the necessity for them? I did not.

19,784. In a matter of fact, did Messrs. Hopkins, Gilbert, and Company paint the bridge at all—after it was finished. I had not the painting done, and it is said that they had not the painting done.

19,785. That remark applies to a joint, I presume, where the spigot and lances are used? Yes. The spigot is inside the column, the column is kept continuous.

19,786. You rely upon the spigot for steadiness? Yes. The spigot is a steady pin, in point of fact. It is not strong enough to be anything more than a steady pin. It is about an inch or something like that.

19,787. (Mr. Webster.) Would not this rely upon it for resisting any lateral turning over, so to speak? No. It was a steady pin, and it was also useful in guiding us in the erection.

19,788. I do not want you to go into a matter of calculation, but if you had cast-iron under tension, as those were, or might have been, at the time of the accident, would you expect that a blow or a shock would be likely to break them? Very likely, if the tension was great.

19,789. Cast-iron under tension breaks more easily than cast-iron when it is not under tension? Certainly.

19,790. I will not ask you to go into detail at all in the matter, but I should like to ask you, having
considered: the matter generally, what in your judgment was the cause of this bridge going down. It meant what was the actual cause that made it fall, in your opinion? There is very little in the ruins to give evidence as to what was the cause, but I think the hypothesis of Sir Thomas Bouch, that the guard’s van and the carriage in front of it were first tilted, and then thrown off the way against the inward girders, has with it the greatest amount of evidence, and I think it sufficient to account for all that followed.

19,801. I should like to ask you in your opinion, as an expert with regard to iron manufacture, was that bridge broken by a shock, or by what has been called steady pressure? I do not think it could have been broken by steady pressure, but with a steady pressure and a shock I think it went down.

19,802. You think it was a shock supervening upon a steady pressure. That is so.

(The Commissioner.) You put that as Sir Thomas Bouch’s hypothesis, but that was not his hypothesis.

(Mr. Webster.) I would rather put it as Mr. Gilkes’ hypothesis.

(The Commissioner.) That was hardly Sir Thomas Bouch’s:

19,803. [Mr. Webster.] I understand you, give that as the result of your own opinion?—Yes, I do.

19,804. Leaving Sir Thomas Bouch out of consideration for a moment, your own idea, I understand, distinctly, is that whatever the cause may have been, that is to say, whatever the way in which you may have been, there must have been a shock supervening upon the strain?—I think so.

19,805. The cast-iron already subjected to a strain, receiving some additional shock?—That is my opinion.

19,806. Did you form that opinion quite early in the inquiry?—I did, the first week of the inquiry at Dundee. When I had an opportunity of seeing the whole structure as it lay, I came to the conclusion that that was so. I was partly, perhaps, helped to that conclusion by having seen the results of a similar fall of two girders and two piers during the time of the erection.

19,807. Two girders were blown over or tumbled over at the time they were being erected?—Yes.

19,808. They were not fastened in any way?—They were not fastened in any way—they were just raised up 18 inches above, on two points for some exigency of the work at the moment the blast came down.

19,809. And you say that what you saw then confirmed you in forming an opinion within a week of the accident that the collapse was caused in the way you have described?—Yes.

19,810. You have seen the ruins yourself and the various distortions, and breakages of every kind; do you think that the appearance of those ruins confirms you in the opinion you formed, that the accident must have been caused by the bridge already subjected to a steady pressure receiving a shock?—As far as they give any evidence at all, they confirm me in that view.

Examined by Mr. TRAYNER:

19,811. You are of opinion that the suggestion or theory of Sir Thomas Bouch, that the bridge was sent over by a shock when in a state of extreme tension is the most likely way to account for the accident?—That is the hypothesis that presents itself to my mind as being the most probable.

19,812. And you have come to that opinion after hearing me considering the views for that theory, and the opposite theory?—I have.

19,813. Is it your opinion upon a review of the evidence on both sides?—That is so.

19,814. You said that your opinion acquired some confirmation from what happened when two of the high girders fell in 1877?—Yes.

19,815. Was there any shock to send them over?—No.

19,816. What did they go over with?—They were blown over by the wind.

19,817. And nothing else?—And nothing else; because they were up on two points about 18 inches, raised above their beds, there being only those two points to spring on.

19,818. They were not in position?—No.

19,819. There we are quite agreed that it was the force of the wind only that produced that disaster?—Yes.

19,820. With regard to the columns, we have heard your opinion and heard other opinions. I will not cross-examine you on the ground of your opinion, but I want to bring one matter of fact before your notice—of its importance the Court will judge—you said as to the mode in which the columns were cast, that they were cast in a double box?—Yes.

19,821. In the evidence which was laid at Dundee we were certainly led to believe the contrary. I want to know from you after hearing this evidence as to whether you adhere to your own statement. At question 5506, Richard Baird was asked, “How did you avoid it in the lifting column?” The question was about shifting, and he talked of how the lifting column was cast. “How did you avoid it in the lifting column?” From the fact of having the two parts of the box to make the lifting column in we got better at that. Q. In what mode were the ordinary columns cast; were they not cast in the same kind of box?—No. Q. Was kind of mould used on the ordinary columns?—The floor of the moulding shop formed the one half of the columns, and they then had what are termed ‘flasks’ or ‘tubes’ that covered the top part. They had only one part of the box to make it in.

And Fergus Ferguson talks of the floors at question 7975. He is asked, “What sort of sand had you for the casting?” He says, “The sand we used for the floors, or for the holding of the columns, was London sand from the bed of the Thames.” Looking to those two statements made by Fergus Ferguson and Richard Baird, the men employed at the casting for 19 months or so, before the foundry closed, do you still say that all these columns were cast in a double flask?—I believe they were.

19,822. And those statements were incorrect?—Those statements are incorrect as applied to those columns; but they are correct as applied to the bases, and especially to the bases of the other columns—not those large ones, but those now on the piers of the bridge.

19,823. What columns?—Not the large piers; but in the case of the other piers we had the square framing work on which the columns stand made in two pieces to cover the whole area, and those were bedded in the floor.

19,824. This witness Baird, whatever right or wrong, is speaking to the casting of the columns, and speaking to the casting of ordinary columns as distinguished from the lifting columns?—I do not think he is correct. My own knowledge says he is not, and I am confirmed in that by a recent application to both Mr. Booves and Mr. Beatson, who both say in all cases, taking it as a premise, that there is no exception, and particularly in the case of short columns—but as a rule they were all cast with top and bottom boxes—I have no doubt that is correct.

(Mr. Barlow.) There are certain marks shown by the photographs in some of the columns which strongly indicate a shifting of the upper box. Perhaps you will refer to that.

19,825. [Mr. Trosper.] Yes, I will do so. These were shown to Mr. Beatson at Dundee, and to Mr. Campbells (showing some photographs to the witness). You see that there is a shifting?—Here is evidence that there was a top and bottom box here.

19,826. It shows that there was a shifting of the top box?—It would not have been cast if it had been shifted on sand.

19,827. In your opinion does that show a shifting of one of the flasks—the upper flask?—Certainly.

19,828. Could not that have occurred if the under
part had been bedded in the floor?—It could have occurred, but it would not show so clearly an edge as that—it would be a blunted edge.

19,839. You think that though it shows a shifting of the flasks, it tends to confirm your view that there was also an under-flask?—Yes.

19,840. There is another in pier No. 4. That is the same thing?—Yes, I think so.

19,840a. (Mr. Webster.) I would point out with reference to the last answers that Mr. Law has drawn the same conclusion. If you refer to Question 18,690, he was asked, "Have you any opinion as to the mode in which the inequality was produced?"—Mr. Law was evident in some of the columns that it was owing to the shifting of what was called the top flask. The mould consists of two halves, to enable the pattern to be taken out of the "upside," and so on.

19,851. (Mr. Traquair.) You say that what you see in the photograph confirms your view that they were all cast in two flasks?—Yes.

19,852. (The Commissioner.) The shifting might take place whether there were two flasks or whether there was a single flask only?—It might take place, but the line would not be so clearly defined in the one.

19,853. (Mr. Barlow.) In the two flasks you have steady pins?—Yes, the one flask in exact position as regards the other?—Yes.

19,854. Both those steady pins are of metal?—They are metal pins.

19,855. In casting on a floor you have no metal to hold the bottom part of the pin, and it is much more liable to shift?—Yes.

19,855a. (The Commissioner.) You observe that at Question 447, Baird was asked "What is known in the trade as scabbing in the column?—That is the shifting of the sand from the under surface of the mould during the time that the molten metal is running into it." Then the next question is, "The sand of the mould in some places was washed away by the running metal."—Yes. Q. What effect has that on the column when it happens?—The sand would be washed off the top of the metal and come to the top of the column, causing a re-composition of the sand and metal. Does that lead you to suppose that he is speaking of the lower flask being of iron or being of sand?—It has no reference to it. The fact simply is that where we find a scab we generally know that a portion of the mould has been broken away, and we look to find it in some other part of the casting, where it may do mischief or may not.

19,856. He says, "That is the rising of the sand from the under surface of the mould during the time that the molten metal is running into it." He means the core sand, does he not?—Yes.

19,857. (Mr. Webster.) You find the flasks are lined with sand above?—Yes.

19,858. (The Commissioner.) No doubt. (To the witness.) You say that you thought it would be more prudent to cast the columns horizontally than vertically. By that I suppose you mean it was more practicable to cast the lugs and projections on the columns?—Yes, I spoke of the columns in question.

19,859. But if there were no lugs and no projections, then you would have preferred to have cast them vertically?—I should say so, certainly.

19,860. If you were to cast horizontally, I suppose all you say is, that it was much more practicable to cast horizontally, but the lugs and projections upon them?—I think, by adopting the horizontal position of casting them we insured a better all round joint than otherwise.

19,861. Having those lugs upon them?—Yes.

19,862. But if they had not had those lugs upon them, what would you have done?—I would have cast them vertically.

19,863. You did not express any very confident opinion on the question of the lugs?—You said that the question of the lugs varies with the height of the pier. Do you mean by that, that if the pier are low, you think the lugs might with advantage be cast horizontally?—That is so. If the pier, lugs can be used with perfect safety, but with a very high pier, other things being equal, I should prefer some other application, some other mode of joining the ties to the columns.

19,864. Such as you did in the case of the Beelah?—Yes, the Beelah was 195 feet high, and this was 88.

19,865. Would you apply that mode to these 88 feet high piers?—That is an engineering question which I find it rather difficult to answer offhand; it would be a matter of careful consideration.

19,866. But you have had a great deal of experience?—I should prefer, I think, for a pier of this height to fasten the lugs on, rather than to cast them on, knowing how treacherous a thing cast iron is, but if an engineer gave me such a thing to make, I should make it without question, believing that he had apportioned the strength properly.

19,867. The pressure, of course, would be the greatest on the lower luggs, would not it?—It might be.

19,868. As a matter of fact is it, would it not, in proportion to the wind strain?—If there was any wind strain it would be so, certainly.

19,869. And it is there that you would expect, at any rate, that the lugs, if they showed any weakness, would show it?—That is so.

19,870. And that is the reason why you would have preferred to fasten them on to the columns?—Yes.

19,871. (Mr. Barlow.) You do not mean fasten the lugs on to the columns?—No; I mean the ties.

19,872. (The Commissioner.) You said that you had observed some defective castings in the wreck of the bridge, and that if you had known of them you would certainly not have allowed them to go into the bridge?—I would not.

19,873. Why would you not?—Because if I had seen those defects I should have considered that they would have been an imperfection in the work that I would not have allowed to go into a work of this magnitude and importance.

19,874. Would you have thought that they would have been likely to affect the stability of the work?—I do not think that I should have thought so, but I should have thought it improper to put them in, simply because they were an imperfection in the work which ought not to be there if we could prevent it.

19,875. You told that if you had yourself observed that the holes in the lugs were of a conical shape?—I have observed it since the fall of the bridge; I was not aware of it before.

19,876. You would not have allowed them to have gone if you had known of it before?—No, I should not.

19,877. You said that such ought not to have been if the workmanship had been carefully done?—I am not sure that I used those words.

19,878. I think you said, with ordinary careful work they ought to have been made cylindrical?—Yes.

19,879. What you say is this, that with ordinary careful work those holes should not have been made otherwise than cylindrical?—What I mean is this, that it would not have been difficult and not any more expensive to make those holes parallel or nearly so, instead of giving them the slope which they have now, the taper, which was given in order to make the core leave the core box easily?—Yes.

19,880. It was done in order to make the cores leave the core box easily?—Yes.

19,881. And that is the reason why they had that conical shape?—Yes. Had the effect of that been realised by those who did the work, they certainly would have been made more parallel.

19,882. Whose fault would it be?—Would it be the fault of those who were supervising the work, or the workmen's fault?—It is rather difficult to say. It would be done as a matter of course, and unless at
Mr. Webbe. - I would do so. As a matter of course, by the workmen, unless it had been carefully supervised by those whose duty it was to do so. - Yes.

Mr. Webbe. - As a matter of course? - Yes.

Mr. Webbe. - It would not be done also in the case of the hoses that were cast in the flanges? - The hoses that were cast in the flanges were much more easy to make parallel, than those in the lugs; in fact, there was no reason for making them anything but parallel in the flanges. They were made with dry sand cores, and they were made separately, they had no core, no pattern, or mould of the column, but were poured in the ordinary way, and it was easy to make them parallel as the cores were taken out.

Mr. Webbe. And that is the reason why you think they might very well have been cast in the flanges parallel, whereas in the lugs, they would be cast conical? - I mean there are core that made the holes in the lugs. In the hose core, a difficult core, it had two side cores and one middle one.

Mr. Webbe. Did you know that there was likely to be that difficulty with respect to the casting of the lugs on the column? - I do not know that it ever struck me as a difficulty; it was only one of the ordinary things in casting. Unless some stress was laid upon it, there was nothing to draw particular attention to any slight taper in those hoses. The attention that is drawn to it now gives it an importance which it was not supposed to have at the time of making the castings.

Mr. Webbe. You did not give any special instructions with respect to getting those hoses perfectly cylindrical, because you knew that they would, as a matter of course, be cast slightly conical? - I did not give any special instructions with regard to them at all. I did not think it necessary to do so. I had a very competent man at the head of the foundry, and I did not think it necessary to follow out those minor details, nor did I do so.

Mr. Webbe. Nor did he do so? - He would do so naturally, it was his business to do so; he had nothing else to do but looking round the foundry and the fitting yard.

Mr. Webbe. Yet I understand you to say, as a matter of fact, that the hose, as a general rule, would be cast with a conical taper. They would be cast slightly conical, I have no doubt, as a general rule, merely sufficient to enable the core to leave the core-box easily.

Mr. Webbe. Under those circumstances would it not have been right to have had them rimed inside or drilled afterwards? - I think it would have been better if the bolts had been rimed. The bolt would have been a little larger, but I think it would have been a better job if they had been rimed, but they were not so specified, and therefore they were not so done.

Mr. Webbe. (Mr. Webster through the Court.) Would breaking the service be any objection—breaking the skin? - Breaking the skin always weakens either a cast-iron structure, and if we can do without it, we had better do so.

Mr. Webbe. (The Commissioner.) Do you mean drilling the holes, by which you must break the skin, weaken it? - I mean to say that given a hole cast in and a hole drilled in, it is clear we should get a stronger result from the hose.

Mr. Webbe. (The Commissioner.) And it is possible, therefore, that drilling a hole is ceteris paribus a cause of weakness? - In one view of it, but in many others it is a cause of strength and improvement.

Mr. Webbe. Supposing the hoses had been cast a little smaller, and drilled, do you think they would not have been quite as good, or might have been perhaps slightly better? - I do not think they would have been any better for the purposes for which they were used. The bolts, that they put in were not turned bolts, they were hammer-fitted, and a hammer-fitted bolt you cannot drive very tight in the hole without risk of breaking the cast-iron flange in two—breaking it off.

Mr. Webbe. I did not quite follow you as to why you did not have a sniffet and flange at the bottom—you faced the flanges of all the columns inside? - That is so.

Mr. Webbe. Those that had the sniffet and flange, were those that had not? - Yes, this bottom was a flat face—all the others had sniffets and flanged joints till the up-wind.

Mr. Webbe. Why did you not have a sniffet and flange on the lower one? - Because these hoses had to fit on the square on the stone work, and there was a bevel to make the lakh of the column.

Mr. Webbe. What would that bevel be? - I cannot tell you off-hand—it tapered into a foot in the 50 feet. (Mr. Barlow.) About it in 50 would represent the slop.

Mr. Webbe. (The Commissioner.) What was the depth of the sniffet? - 14 inch, 14 perhaps, it might be 15ths.

Mr. Webbe. What would be the difficulty then of having a sniffet and flange? - This had to be chipped and faced, and it was easier to get a true face, and to fit this column well on to that without a sniffet and flange than with it.

Mr. Webbe. Why the sniffet would have acted as a guide? - The sniffet would have acted as a guide to a certain extent.

Mr. Webbe. Where would have been the difficulty? - I do not quite see it? considering the slight better.

Mr. Webbe. (Mr. Barlow.) The difficulty arises in facing the lower base piece with the lath.

Mr. Webbe. (The Commissioner.) I do not see where the difficulty is. Because these were faced up by hand, in their places.

Mr. Webbe. But even then being faced up by hand I should have thought it would have made it rather easier for the sniffet? - We did not think so, it was intentionally left off because we thought we could make a better job by making that a perfectly even plane joint, and they were very carefully levelled, and tried as we should do with a face-plate in the fitting shop.

Mr. Webbe. The inclination is very slight? - It would be enough to make a very bad job if it were not carefully attended to.

Mr. Webbe. That is your only reason? - That was the reason.

Mr. Webbe. You said you relied on the sniffet for a steady pin? - I said that was the chief use of it.

Mr. Webbe. A steady pin was quite sufficient for the bottom of the column as any other part of it, was it not? - It was not so much there as higher up.

Mr. Webbe. Why not? - We have a greater weight below—the lower we go the greater the weight on these flanges and surfaces. These flanges would be almost enough to prevent any shifting, quite irrespective of anything else.

Mr. Webbe. With respect to the cause of the accident, which I should not have asked you any questions about if you had not given your opinion upon it. You said you agreed with Sir Thomas Booth that it was due to the train coming into collision with the girder; but as I understood Sir Thomas Booth’s evidence, his suggestion was not a check at that time but the carrying away of some of the ties and struts of the, headwork, girder, and that that would have brought down the girder. It was subsequently suggested on the part of Dr. Pole and Mr. Stewart that it was due to a shock, which, as I understand, you agree with. I am now wrong in quoting Sir Thomas Booth, allow me to correct it. I mean that I consider the last two carriages which would have less to keep them steady on the rail than the forward part of the train, nothing being behind them, were first tilted, and under the action of the wind both against the upwind bottom of them and the side, they were sent to the eastward girder with such force as to knock them off the track.

Mr. Webbe. What do you mean by “them”? - The two carriages.

Mr. Webbe. You have not answered the particular question which was in my mind, namely, if it your idea that these carriages broke one or two spans of the girder, and that that brought the girder down, or that
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19,984. A good deal of it would go in their own destruction, would it not? Some of it would, not a sufficient portion of it to do away with the detrimental result of the shock which would be felt throughout the whole structure by the sudden cessation of the motion of 15 tons which had been going at the rate of 25 miles an hour.

19,985. You adhere at the present time to the theory of the shock, and not to the theory of the breaking of the ties? The shock might have broken the ties, I suppose.

19,986. But that would not have brought the bridge down? If two or three ties had been broken, that would have brought the bridge down.

19,987. Why do you believe, then, that this shock was the cause of the destruction? And not the breaking of these ties? That may have been a secondary result of the shock; I cannot separate them in my own mind the one from the other.

19,992. We were told that the direct effect of the breaking of two of these ties would have been to have brought the whole bridge down upon the lower one and so to have brought the bridge down. The next theory is this, that the shock would be transmitted down the piers, and so bring a great strain upon the ties at the lower part of them, and thus break away the lugs. Which is the theory to which you have adhered? I do not know what is a very careful selection of the two theories. I have rather supposed in my own mind, looking at it not with the carelessness that Dr. Pole and Mr. Stuart have looked at it, that the shock would partially break the girder, and would wholly result through the girders into the piers; it could not do otherwise.

19,994. (Colonel Volland.) I think I understood you to say that this giving way of the structure was probably produced or, by the breaking of the lugs at the base of the pier, and thus causing the pier to give way rather than the girder by the shock? I do not think I said so: I made no reference to the lugs.

19,995. I think the term lug was used? you said that the shock was transmitted into the pier?—Yes.

19,996. What is the use of the term lug? You said that the shock was transmitted into the pier?—Yes.

19,997. What is it that you would like to see? It is necessary, do you think, that any shock whatever should be transmitted into the pier to cause a fracture to take place there, when by Mr. Kirkaldy's experiments on the lugs, where a tensile strain is brought to bear upon them, without any shock whatever, the lugs break? Are you aware of the assumption the weight of causes?—I have seen the results of Mr. Kirkaldy's experiments, and they please me a great deal. They do agree with the tensile strains we see from other parts of the same metal, that is to say, other parts of the same column; and I do not see any good reason for the difference unless it is that those columns were not equal in weight, which may have been expected from them afterwards. I do not look at the result of those experiments as satisfying my own mind, because it does not do so.

19,998. The story in Mr. Kirkaldy's experiments was produced, not by any shock; but by a steady strain?—Yes.

19,999. And that seems to be less than a third of the usual assumed breaking weight of cast iron?—I do not remember the exact proportions; I suppose you are right.

19,100. (Mr. Barlow.) Can you supply the Court with information upon the quantities of material that were used in the work? That is to say, what quantity of cast iron was used in the piers and base plates in the whole bridge, and also the quantity of wrought iron used from the ties and struts of the piers, the weight of the bolts and nuts in the piers, including, of course, those in the cross bracing and struts; the weight of the wrought iron in the holding-down bolts separately, and then in one sum the total weight of the girders?

19,101. You mentioned that cotters were used for the purpose of tightening up slackness arising from any cause; have you ever used cutters in any other bridge than this? Did you use them in the Beelah?

19,102. (Colonel Volland.) The term of your contract had expired?—Yes; but I was interested in it as a structure, and took pains to examine it, and personally inspected it six or eight times after it was finished.

19,103. (Mr. Barlow.) Do you remember whether the cotters there required tightening up from time to time?—It is a number of years ago. I do not remember that.

19,105. Do you remember any case in which, where cotters have been used in works executed by yourself, they have required to be tightened up after the bridge had been opened for traffic?—I have no case before me at the moment, but we have not usually the care of structures after we have finished them. We have put cotters in for the purpose of tightening up slackness. That is, slackness which is necessarily there at the moment of constructing the bridge?—To make all taut.

19,107. They are not there for what may be termed maintenance purposes?—They are not there for what we may term maintenance purposes; but they are used to allow for taking up any slackness and they would be used for that purpose should such slackness arise.

19,108. You would not expect to see it arise?—I would not expect to see it arise without some abnormal state of the structure.

19,109. (The Commissioner.) With regard to the Beelah Viaduct, you say some of the piers were very high. I think the spans were 60 feet, were they not?—65 feet.

19,110. Whereas these are 245 feet?—Yes.

19,111. (Mr. Barlow.) You said you thought lugs might be used in low columns, but that they were not desirable things in high columns?—Yes.

19,112. Is that because you consider the strains that arise in high columns are greater than those which arise in low columns?—That is so.

19,113. To put your answer in other words you mean this: You think lugs may be used wherever strains are slight and that they should not be used where the strains are heavy?—If you word it that way, that is what it practically does mean. With a very severe strain perhaps it is better not to depend on a lug cast on, but to some attachment to the column of some other kind.

19,114. Can you form any opinion as to whether the strains arising upon the wind ties of this work would be greater or less than in the case of the Beelah, bearing in mind that the span of the Beelah, as the Commissioner has said, is only 65.5 feet, and its height 196 feet; whereas the span of this is 245 feet, and its height about 90 feet?—The wind strains would not be affected much by the spans, except that there would be more girder surface to each pier, but I have no strains of measuring in my own mind as to the relative forces of the wind strains in the Tay and in that valley.

19,115. You would not like to give an opinion upon that?—No.

19,116. (Mr. Webster.) I do not propose to call any further witnesses. (The Commissioner.) I have just consulted with my colleagues whether it is necessary to call those elsewhere.
two gentlemen whose names you have mentioned, we think it would not be necessary under the circumstances, as we have examined Mr. Gilkes at considerable length. The calculations of Dr. Pole as to the upsetting of the carriage they have not been given in yet.

(Mr. Bidder) I will hand them in after lunch time.

(The Commissioner to Mr. Belfour) Have you any witnesses to produce?

(Mr. Belfour) No, all the information we had, we supplied to the Board of Trade, and so far as bearing upon the matter, any witnesses whom we might have called have been called by them.

(Mr. Bidder) I am afraid that I shall have to trouble the Court with a good many remarks, because I can most sincerely say that I do not think any case in which I have ever been engaged has caused me to feel the responsibility and feeling of responsibility that this case, and I would wish to say at once that if I may have seemed at any stage of the inquiry to have been unduly sensitive or to have interfered, when the Court might have thought that I ought not to have interfered, I trust the Court will understand that it has been from my great anxiety in the case and my being, in consequence, evidence or matter should be upon the notes without due consideration, which might have a weight attached to it, which under the circumstances, I did not think it was entitled to.

(The Commissioner) We can quite understand the feeling by which you are influenced.

(Mr. Bidder) I feel that the anxious desire of every member of the Court is to arrive at the truth in this case, and to make a report which will be the best judge, and, not according to the feeling of responsibility that this case, and I would wish to say at once that if I may have seemed at any stage of the inquiry to have been unduly sensitive or to have interfered, when the Court might have thought that I ought not to have interfered, I trust the Court will understand that it has been from my great anxiety in the case and my being, in consequence, evidence or matter should be upon the notes without due consideration, which might have a weight attached to it, which under the circumstances, I did not think it was entitled to.

(The Commissioner) We can quite understand the feeling by which you are influenced.
attempt to include them within that description—but it believes us who are amanuenses, and the public, in general, to be very careful indeed how we apply our criticism—how we put our finger upon a particular point in the design, and say such and such an alteration, would have given you a broader base—and such and such an alteration would have given you more direct action of the ties, and that would have been a very great advantage. I say it becomes us to be very careful in examining the work and saying that such and such a improvement upon the work of the engineers is responsible for it. There are many things and there must be many things that did not enter into our minds which did him. It may be we are right, and that he is wrong—at the same time I say we should be very cautious how we yield to the demand for alterations. We must not allow any one to have the power of making alterations in a structure of this kind. But after all I say the thing the Court has to deal with is not the question whether the Tay Bridge might have been designed otherwise, but whether it was, but being designed as it was, and executed as it was, and with such improvements as there were in it—and I should like to see the question put in the form of the greatest importance and the highest magnitude that that has not imperfection in it—being such as it was, and in the condition it was, on the night of the accident, what are the causes that led to the accident, under those circumstances. That seems to me the question, and any other conclusions drawn from that that may come in the scope of the inquiry of course may be drawn.

Now, Sir, I appear for Sir Thomas Bouch, and of course a very large share of the responsibility for this bridge is upon the shoulders of Sir Thomas Bouch. He is responsible, in the first place, and I might say solely responsible for the design of the bridge, and of course, no one of those things, no one of the important things, would have been done under the circumstances, called to his aid assistants. No great engineer does all the detail of his work with his own hands; but Sir Thomas Bouch is the person solely responsible for the design of this bridge, and he does not shirk the least degree that responsibility. Again, with regard to the execution of the work—the construction of the bridge—no doubt Sir Thomas Bouch was not the constructor. The persons primarily responsible for that are the contractors, Messrs. Hopkins, Gilkes, and Company; nevertheless again I admit to the fullest extent that Sir Thomas Bouch, as the engineer-in-chief of the railway company, who employed him, and I may say to the world at large, for taking care that the work proceeding under his supervision was properly executed and that his designs were properly carried out. And further, under the arrangement that were made in this particular case, between Sir Thomas Bouch and the North British Company, Sir Thomas Bouch was responsible for a limited time, which time had not expired at the time of the accident; and therefore I may say that up to the time of the accident he was responsible to the railway company for the maintenance of the bridge in a proper working condition. He had undertaken that superintendence and he was responsible for the maintenance of it; there also Sir Thomas Bouch does not desire for a moment to shirk the responsibility in that respect. When I say that of course I make an observation which is obvious to every one but without detracting from the least from the importance of the engineer, not only for his designs and his superintendence over the workmanship and execution of them and for the maintenance of the bridge, it is obvious in these matters of workmanship and maintenance his duties must be discharge in a different manner to the way in which he deals with the design itself. What I mean is this—"that engineer with his own eyes sees everything that is done and be on the spot at every stage of a work like this—the engineer sees every cylinder cast and every hole drilled and every surface planed. He must act through the eyes of others—he must depend on assistants and subordinates carrying out the details of that inspection. It would be absolutely impossible, even if he were to devote himself to that work and nothing else, that everything under his superintendence, his personal observation down to the minutest detail. It is quite possible, with the greatest care, with the most perfect system of supervision and inspection (and, if you please, with the assistance of the contractors also, who are most anxious to do their duty and to put no faulty work into the bridge) that there may be, notwithstanding everything, imperfections on the part of anybody, imperfections there and here. I mean to say if a workman should set himself to deliberately conceal imperfections of work, I suppose it would be possible under certain circumstances for a workman occasionally to deceive, even the most vigilant inspector and the most careful of engineers. But I venture to think, when we come to discuss the facts of the case, that the evidence with respect to the structure of this bridge and the condition of the work, by no means justified the very severe attack which was made upon it in the early stages of this inquiry. In dealing with the question on the part of Sir Thomas Bouch, I think it is of the greatest importance (and I refer to Sir Thomas Bouch), that we should keep two questions entirely distinct. I mean the question of the design and the execution of that design. If this bridge failed because the bridge was a bad design, Sir Thomas Bouch, and no one else, is responsible for that. If this bridge (I am only taking a hypothetical case) failed from some lack of illustration, because some workmen in the foundry or workmen fraudulently put in bad work, and concealed it from the eyes of their immediate superiors, the inspectors of Sir Thomas Bouch if they put in (though I do not admit there is any evidence of that) logs that were cracked or columns so riddled away that language might have strength in them, you may say, and with truth, Sir Thomas Bouch was responsible for that because he was responsible for the supervision—that the inspectors are responsible for that because it was their duty to inspect, and that the railway company are responsible because it was their duty to give the public an efficient bridge; but though everybody must feel that is so, in a sense, the responsibility attaching to those parties who had been deceived in the hypothetical case I am putting, under circumstances under which they could not help being deceived, is of a very different character indeed from that which attaches to Sir Thomas Bouch if he is responsible for designing a bridge that does not stand. (The Commissioner.) The Court goes with you entirely in that—that is to say, for the design: Sir Thomas Bouch absolutely is responsible for the minor details in the execution of the work— he is not responsible.

(Mr. Bidder.) With reference to the design, then I propose to offer some observations first. The question of the design divides itself into two branches; that is to say, the girders and the piers. As regards the girders, I think after the investigation of the Court, and after the evidence which has been given on both sides of the table, I may rely myself of the necessity of making any observat on that subject. The evidence shows al round that the girders were amply sufficient for every purpose which they had to fulfil. I do not think from beginning to end of the inquiry there has been the slightest attempt to suggest that the bridge failed because the girders were not strong enough for their work. Then I come to the piers—and again in discussing the des of the pier workmanship and execution of them and for the maintenance of the bridge, it is obvious in these matters of workmanship and maintenance his duties must be discharged in a different manner to the way in which he deals with the design itself. What I mean is this—"that engineer with his own eyes sees everything that is done and be on the spot at every stage of a work like this—the engineer sees every cylinder cast and every hole drilled and every surface planed. He must act through the eyes of others—he must depend on assistants and subordinates carrying out the details of that inspection. It would be absolutely impossible, even if he were to devote himself to that work and nothing else, that everything under his superintendence, his personal observation down to the minutest detail. It is quite possible, with the greatest care, with the most perfect system of supervision and inspection (and, if you please, with the assistance of the contractors also, who are most anxious to do their duty and to put no faulty work into the bridge) that there may be, notwithstanding everything, imperfections on the part of anybody, imperfections there and here. I mean to say if a workman should set himself to deliberately conceal imperfections of work, I suppose it would be possible under certain circumstances for a workman occasionally to deceive, even the most vigilant inspector and the most careful of engineers. But I venture to think, when we come to discuss the facts of the case, that the evidence with respect to the structure of this bridge and the condition of the work, by no means justified the very severe attack which was made upon it in the early stages of this inquiry. In dealing with the question on the part of Sir Thomas Bouch, I think it is of the greatest importance (and I refer to Sir Thomas Bouch), that we should keep two questions entirely distinct. I mean the question of the design and the execution of that design. If this bridge failed because the bridge was a bad design, Sir Thomas Bouch, and no one else, is responsible for that. If this bridge (I am only taking a hypothetical case) failed from some lack of illustration, because some workmen in the foundry or workmen fraudulently put in bad work, and concealed it from the eyes of their immediate superiors, the inspectors of Sir Thomas Bouch if they put in (though I do not admit there is any evidence of that) logs that were cracked or columns so riddled away that language might have strength in them, you may say, and with truth, Sir Thomas Bouch was responsible for that because he was responsible for the supervision—that the inspectors are responsible for that because it was their duty to inspect, and that the railway company are responsible because it was their duty to give the public an efficient bridge; but though everybody must feel that is so, in a sense, the responsibility attaching to those parties who had been deceived in the hypothetical case I am putting, under circumstances under which they could not help being deceived, is of a very different character indeed from that which attaches to Sir Thomas Bouch if he is responsible for designing a bridge that does not stand. (The Commissioner.) The Court goes with you entirely in that—that is to say, for the design: Sir Thomas Bouch absolutely is responsible for the minor details in the execution of the work— he is not responsible.
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I was not abundantly and simply strong enough for that purpose. In fact it has been pointed out by the witnesses that the work the piers had to do under those circumstances of carrying the vertical load, simply and almost exclusively falls upon the columns, and the duties of the bracing and struts are more, as one may say, the duties of regulating the shape of the superstructure than of carrying it. So when, therefore, we look to the columns, and we find that the weight put upon the metal of the column is something like between one and two tons to the square inch, whereas they are capable of taking a crushing strength of thirty-five or thirty-six tons, that sufficiently shows that there was an abundant margin of safety in the use of the piers. But of course the more important question that has to be discussed here is what was the efficiency of these piers to resist a strong lateral strain in a time of severe wind. Now, Sir, you have had a good deal of evidence about it and for the present please to remember, because I have made a distinction purposely, I have desired to discuss the question without reference to imperfections of workmanship, as a question of design. The answer to the question, was the pier efficient for resisting lateral strength is a question of design which seems to me to depend on two things, namely, what lateral pressure it was capable of resisting and what lateral pressure could possibly be expected to be brought upon it. What was its duty and what was its power to discharge that duty. As regards the efficiency of the pier and the design of the pier, you have had a good deal of evidence, not altogether in accord, but still, to some extent in accord, and I wish to draw your attention to it. Several gentlemen who have been called have given us their judgments upon the question of the power of these piers to resist lateral strain. No doubt a pier of this kind is a complicated structure—I mean a complicated structure for the purposes of calculation. The moment you try, as I attempted to investigate the question, you very soon realize that fact, and perhaps, therefore, it is insensible that different gentlemen may arrive at somewhat different results, as they have done in this case. It is not a little remarkable that the gentleman who I myself have called as witnesses—I mean, Mr. Pole and Mr. Stewart—seem to have arrived at a lower result as to the stability of the bridge than anybody who has been called before you almost, being to Dr. Pole’s result the pier would have failed with something like 45 lbs. to 50 lbs. of wind.

(Dr. Pole) 60 lbs.

(Mr. Bidder) You must remember that I am talking apart from imperfections of workmanship. I dealt with the question again with reference to Mr. Kirkaldy’s tests—I am merely talking now of the question of design. I did not know the figure was so high as 60. That being so modifies the observation I made last night. That their estimate was lower than that of many other gentlemen. Let us see what other gentlemen are, because it may happen Mr. Pole and Mr. Stewart might take a favourable view of the whole matter which was a considerable extent interesting from the view Mr. Brancà was examined, and you find his opinion at Question 15,510. He is asked—

"Have you made any calculation, or have you put yourself in a position to answer the question one way or another, whether assuming it to be properly constructed, this design was sufficient to withstand the strongest stress that could be expected to be brought upon it?"

And he replies, "No, I could not say that it was designed to meet the strongest wind; but I can say that it was designed to meet 40 lbs. of pressure, that is what I make out it would take to fail the other, whether assuming it to be properly constructed, this design was sufficient to withstand the strongest stress that could be expected to be brought upon it."

Now afterwards Mr. Brancà qualified that answer to some extent of mine, because it was explained, if you look at the next page but one, page 302, that that was without allowing anything for the anchoring of the columns to the stonework by bolts, and that, whatever the value of the holding-down bolts was, must be added to that 40 lbs—he had not calculated it out. At Question 15,543 he is asked this: "Their resistance must be taken into account?" to which he answers—"Yes, Q. I may fairly put it as a qualification of your evidence that whatever that amounts to should be added to the 40 lbs.?—That may be so?" Therefore Mr. Brancà’s estimate of the stability of the bridge as designed is 40 lbs. plus the bolting, and therefore that makes 40 plus 30. Now that is the bolting over that is Mr. Cochran’s, I think, had not gone into figures, and therefore he did not give an absolutely definite answer; but I will draw your attention to his evidence so far as it does go. In Question 16,040 he says, "Not having gone into questions of straining that came upon those particular parts, and not being able to say whether those parts have been strained or not, I should say that the structure was "ample strongly enough for its purpose." That is his opinion, qualified in the way that it is qualified in that answer, by his guarding himself by saying that he had not gone into the calculation as to whether the sectional area of the tie-bars was sufficient for its purpose.

Then we have General Hutchinson’s opinion, and I cannot help thinking that General Hutchinson’s opinion is one that should carry considerable weight, because General Hutchinson studied this bridge with an official responsibility upon him, and it is quite evident that General Hutchinson has a great deal of pains, and exceptional pains, at the time that he inspected this bridge before its opening. You will find General Hutchinson’s evidence upon this point at Question 16,084, where he is asked by Mr. Bidder:

"With regard to the width of base, if everything was made strong and good, with proper holding-down bolts, and with very sufficient wind, did you think that width of base insufficient?"—his answer is, "No, I think not insufficient if everything was thoroughly good, and made as solid and substantial as possible. There would be I should imagine quite 50 lbs. or 70 lbs. stability to overturn, laterally, supporting those works as they are supported by holding-down bolts good. I have not made the calculation with regard to the holding-down bolts; I have made it with regard to these things standing, and I make it something over 40 lbs. without taking in the holding-down bolts." That is General Hutchinson’s view, not greatly differing from that of Mr. Brancà and Mr. Stewart, and the holding-down bolts, 60 lbs. to 70 lbs. (without having made an accurate calculation) with the holding-down bolts was the stability of the pier.

Lastly, we had Mr. Law. Mr. Law’s estimate of the stability of the piers originally was the lowest by far; but, finally, by far the highest of any that has been put before us; because, if you recollect in his printed report, I think his conclusion was that the bridge would turn over and ultimately fall with 80 lbs. of wind. At page 29, in the very last paragraph of the appendix to his Report you will find a heading with a little letter "b," "Pressure of wind required to overturn the pier with a train upon it, the bolts and struts and the abutments of a design involving 30-84 lbs." I cannot help saying that I think, judging from Mr. Law’s Report, unconsciously his mind has got a twist in this matter, and a bias which honestly I am sure he would not have permitted to have influenced him on an inquiry of this kind, because everything seems to me to have been put, and every figure seems to have been assumed in the most adversary way possible against the bridge. So it was, if you recollect, that as soon as Mr. Law’s calculations were corrected by facts (I mean, of course, the tests of Mr. Kirkaldy), all those figures had to be altered very much in favour of the bridge; and the primary attention illustrates what I mean, because as Mr. Law explained in his evidence, there is that superstructure which he took as the ultimate resisting power of the tie-bars in the fourth head of his Report viz., 16,120 lbs. (which was the foundation of all those calculations), because experiments showed that instead of being 16,120 lbs. it was 64,000 lbs. You will find all
that in Mr. Law's evidence, I will give you the reference to if you please. You will find that Mr. Law was asked if he took in the answer at Question 14,921, he is asked:

"What did you say that the final compression of this was? I mean the 'outer'?" and his answer is, "An eighth of an inch was the extent of the compression, and the stress which produced that was 56,488 lbs."

There you see he also took in the other experiments withreference to the bolts, and he says further down, "When obtained an answer what would be the tensile moment of stress of the bolts in a 16-inch column, taking the buckling line, the line on which they would turn, the line called in my Report A A, I find that the moment of resistance of the other six bolts in the 16-inch column would be 197,710 foot-lbs."

The general view of these experiments will now be calculated, according to our face according to the face described the action of the wind which he had assumed would be 6,000 lbs. for a 16-inch column, and taking 31 tons as the breaking strain, the figure I gave in my calculation at page 119, for the 15-inch columns in 143,985 which would now come out to 197,710. Proceeding in the same manner the 16-inch column gives 336,963 foot-lbs. instead of 336,962 foot-lbs. Then another figure, becomes 365,000 foot-lbs. instead of 356,000 foot-lbs. you find in another place that 18,600 lbs. had been altered; and then, following on from page 303, you will see at page 306 that the figure of 386,88 lbs. will take the place of 304,82 lbs. that is the overraving figure of the breaking strain.

(Mr. Barlow.) I understood you to say just now that it was increased in the ratio of 15,000 to 56,000?

(Mr. Bidder.) That is the tension on the tie-bars. The 386.56 will take the place of 304.82; that is the number of pounds per square foot of wind which he thought would overtop the pier. The question had better be recast.

(Mr. Cooper.) At Question 14,308 Mr. Law is asked this: "I do not want to take that into consideration, answer my question as nearly as you can." The breaking strain being 16 tons instead of 4.54 tons, what is the reduction of 4,494,904 foot-lbs. becomes? And his answer is: "Upon your assumption it would be 15,000 lbs."

(Mr. Bidder.) My learned friend, Mr. Macorkey, has helped me. It is on page 218. I like, when I make a statement about the square. At Question 14,189 Mr. Law is asked this: "There is a square of 15,000 lbs. pressure." He is asked, "Do you give the resistance of the tie-bars and the capacity of the pier?" He answers, "Yes, I do.

Not the tie-bars, the surface of the key which has been used in these three quarters of an inch. Q. Taking the compound arrangement of the tie-bars held in the way that is described, with that, gib and coppers you give us the ultimate strain that are calculated to sustain. 15,120 lbs. Yes. Q. You now know that that is wrong, do you not? No, I have no reason to know that that is wrong at all. Q. These very tie-bars, with these very gib and-coppers have been experimented on by Mr. Kirkaldy, and they have experimented, as we have experienced, that it is purely the strain that this bridge, if constructed according to the design, required 70 lbs. pressure of wind to every square foot to overturn it?" And Mr. Law's answer is "Yes, that appears to be so."

(Mr. Barlow.) That is upon the assumption that it was held and, what is termed, firmly rooted down.

(Mr. Bidder.) That is upon the assumption that it was held and, what is termed, firmly rooted down.

(Mr. Barlow.) I think that is the opening of Mr. Kirkaldy's experiments to the centre ties, that is, without going on to the outside ties, because it is a complicated and troublesome piece of figures, and I admit that I shirked it. However, finding Mr. Law's ideas and his experience derived in Yarmouth to be so much in excess of everybody else's, I thought it was worth while to work the calculations in such a way that they would supplement the ultimate result at Question 14,812. The previous questions will give you the details of the calculation.

Suffice it to say, that it simply consisted of this: simply applying to the ties the real strains that they would bear before breaking instead of an assumed four tons, which Mr. Law had assumed as the maximum that they could take. At Question 14,612, which is the summation of a long cross-examination, you have this: "That makes the aggregate of the ultimate wind pressure 110 lbs. Therefore." Q. Have you anything to say against that result? Not at the present moment. I may have when I come to go through the figures. And perhaps you will remember (because I think you said that I have confused a witness in cross-examination, and caught or trapped him into an answer which he did not mean to give) that Mr. Law was requested by the Commissioner, and he promised to go carefully through those figures in the evening, and to correct them, if they needed correction, the next day; and perhaps you will see that he has not corrected other matters, but from that time to the present he has not corrected or altered those figures. Therefore the result of Mr. Law's calculations (and, I suppose, his calculations) must carry considerable weight in your minds, as he is the engineer whom you yourselves selected to report upon the bridge) is that by far as design is concerned, 110 lbs. of wind on every square foot of girders and pier is requisite to
overturn one of those piers. That is the result of Mr. Law's evidence. It is an estimate, a good deal higher than that of either Dr. Pole, Mr. Stewart, Mr. Brunelles, or General Hutchinson; and if Mr. Law is correct it follows that all those gentlemen have taken a very moderate view of the capabilities of those piers.

(The Commissioner.) I would only make one observation in reference to that. It is suggested to me by Colonel Yolland that that answer which is given by Mr. Law was upon the earlier experiments made by Mr. Kirkaldy, and not upon the experiments that had been made by Mr. Kirkaldy. That is so, because, if I recollect rightly, those experiments had not then been made.

(The Commissioner.) It would modify it to that extent.

(Mr. Bidder.) I am very much obliged to you, Sir, because Colonel Yolland's observation is a correct one; and, of course, when I made this cross-examination, I had not the other materials. We had better deal with it at once, because it is a materially relevant observation, therefore let us see what it amounts to. The earlier observations which we were dealing with then gave 56,000 lbs. as the limit of the tie-bars. The later observations which show the fracturing of the lug give, speaking from memory, a minimum in one case of 44,900 lbs. and in all other cases higher, and ranging up to 60,000 lbs.

(The Commissioner.) Yet, upon the total area.

(Mr. Bidder.) As the breaking strain. If we took the worst case of all those lugs, without taking a mean, it would reduce the ultimate breaking strain in the proportion of 56 to 45, say 20 per cent. off. That would be the effect of that. 56,000 lbs. was the assumed breaking strain that Mr. Law was dealing with, and I take the very worst against myself 44,900 lbs. so, that it would reduce the ultimate breaking strain of the proportion of 56 to 45, or, let us say, about 20 per cent. off. That would bring Mr. Law's estimate, modified by these figures, to something between 60 lbs. and 90 lbs.

It is impossible altogether to keep the two things separate, and it has been led to talk of the thing as it was when I referred to Mr. Kirkaldy's experiments when I intended to be only talking of the design as it should have been. Of course, discussing it as pure design one would rely naturally upon the full breaking strain that you would expect from these things; but I am content for these purposes to take it upon Mr. Kirkaldy's experiments, and one must not forget that Mr. Kirkaldy's experiments represent what the thing was, with all its imperfections; that is to say, the lugs, with conical holes, and screws and bolts, and everything that Mr. Law's ingenuity could suggest as a point of criticism upon the bridge, and with all these imperfections, the result is that a minimum of 21 tons is shown to be upon that assumption.

Of course it is open to this observation also. I do not know that we have exact information as to what part of the bridge these lugs came from; but if they are survivors of the thing, it is not to be very much wondered at if they do not fight with such energy as it probably did upon the day of battle, and if they have suffered something from the previous strain that had been brought upon them. I do not know whether they have or not, but they have come from the bridge.

(Mr. Barlow.) There was nowhere else for them to come from; they were taken from the wreck.

(Mr. Bidder.) They must be survivors, and it seems to me in the ordinary course of things that they must, as long as you keep them, more subject to very severe strains on the night of the accident. Therefore, when I take, as against myself and as against the bridge, the very worst of those tried under these somewhat adverse circumstances, I think I am taking the worst view, as against myself, that possibly can be taken.

By-the-by, whilst I am upon that, let me make an observation upon a matter connected with that which appears to me to be worth making. I think it is well founded, and I hope I shall be corrected if it is not well founded, so far as I recollect, on one of these lugs that Mr. Kirkaldy has tested tore away from the column. A good deal has been said about the possibility of an imperfect junction between the column and the lugs, and a breaking strain. I think you will find that in Mr. Kirkaldy's experiments in every case, speaking from memory, the fracture is through the holes; as Dr. Pole describes it, "a good honest break through." What was the minimum section through the holes in the lug? And I think that is not an unimportant observation, if it is correct, and I hope nobody will correct me if it is not. What I mean is that in every case it broke through the hole.

(The Commissioner.) You mean that they did not separate from the column nor from the flange.

(Mr. Bidder.) Quite so, Sir.

After a short interval Mr. Bidder said:

(Mr. Bidder.) Now, Sir, I have drawn your attention to that evidence, and I will only point out further how I roughly corrected Mr. Law's figures with reference to that which undoubtedly was a very proper correction, which Colonel Yolland drew my attention to. There is no difficulty in applying the exact correction if necessary. I know my learned friends are anxious that one should not occupy an undue length of time, and I will not trouble you by going through all the detail; but I will just say what will be quite sufficient for anybody to check it for themselves, that you will find in Mr. Law's evidence about the place that I referred to before, he has given the mode in which he has calculated for the section upon the principle of calculation contained in his report. You will find that in his figures he had taken the ultimate strains on the tie-bars at 4 tons; and the altered figures that he and I arrived at were got by substituting for the 4 tons as the ultimate strain that the tie-bars would bear, the 16 tons, which was the horizontal component of the 24 tons at which the tie-bar broke.

(Mr. Barlow.) In the way in which you now put it, do you mean 4 tons to the square inch?

(Mr. Bidder.) No, Sir; 4 tons altogether. Mr. Law's evidence was that when he worked out the overturning force at 36 lbs. to the square foot, he assumed that the ultimate strain that the tie-bar would take was 4 tons.

(Mr. Barlow.) Under which it would be acting at the time.

(Mr. Bidder.) Under which it was capable of acting, because everybody is agreed that the first thing that has to break is the case of lugs, with conical holes, and screws and bolts, and everything that Mr. Law's ingenuity could suggest as a point of criticism upon the bridge, and with all these imperfections, the result is that a minimum of 21 tons is shown to be upon that assumption.

(Mr. Barlow.) Of course that assumes that everything else holds. There are other things besides the tie-bar.

(Mr. Bidder.) Yes, Sir, but that is the first thing to give way, and it must be in the ordinary course of things. You may assume that a column has been sawn through, or that something else is wanting, you may make a hundred assumptions of parts being absent from the structure which would make it entirely different way; but, assuming the structure as a whole, speaking entirely with reference to the design, the first thing to give way is the tie-bar.

(The Commissioner.) The passage is at page 222; you will observe that at Question 14,303 you say: "If the ultimate strain is 16 tons, must it not be multiplied by four?" Yes; but you are putting in something which does not exist. We may say "ratio," but it would not be exactly the same. Then he argues upon the question.

(Mr. Bidder.) I am much obliged to you for referring me to that, Sir. Then at Question 14,405 I say to him, "We are talking of ultimate strain. Your figure is taken, you tell me, by assuming a breaking strain of 4 tons. If the breaking strain is 16 tons instead of 4 tons those figures must be in
It was stated by Mr. Baker yesterday, with reference to American engineers that in applying a high wind pressure, they assumed a high strength of iron, or rather, they applied a low factor, that they applied 70 tons as the strain per square inch.

(Mr. Bidder.) So far as my ignorance enables me to judge, it does seem to have some common sense in it. However, so far as the design is concerned, and the efficiency for its purpose, the bridge stands or falls in this case, avowedly upon the fact that it was designed to meet a maximum wind pressure of 20 lbs. to the foot over the whole of it. If that was wrong, it was wrong; if it was right, I think the figures show that the result was accomplished.

It is necessary to connect with that, to trouble you with some observations, of what Sir Thomas Bouch ought to have provided for. What does the knowledge and experience of engineers teach us is to be expected, and provided for in a structure of this kind? We have had very valuable engineers here, both from engineers and from purely scientific men. Dr. Pole has told us that so far as he knows in this country there are no adequate data, and there is no fixed practice of engineering upon the subject; and I think I may sum up the evidence of Dr. Pole in this way; that, according to the judgment and the experience of engineers and scientific men, a structure that provides for 20 lbs. of wind pressure is abundantly and simply sufficient. Now, although my learned friend Mr. Todd, in a question of Dr. Pole, prompted thereto, I suppose by Mr. Law, he would not have done so if he had known him better, as to the extent of his experience; I am quite sure that he would not do so if; he could have seen the evidence presented before the Court that stands unanswerable, although Mr. Law promised that if there was anything wrong in it, and if I had brought it unanswerable, he would put it right the first time.

So much Sir, as regards the facts. As regards the object and intention of the designer of the bridge, it was designed to stand 20 lbs. of wind pressure, and it was judged (and I shall have a word or two to say presently whether it was rightly judged) by Mr. Thomas Bouch, and those who were helping him, that if they provided 20 lbs. of wind, that was sufficient. That was the judgment of those who were responsible, and with all the knowledge and experience that they had got. And again I say, not Mr. Law's figures, but those, which are, if I may say so, most adverse, viz. Dr. Pole's and Mr. Stewart's figures, the end of their inquiries is:

"You know it was pointed out that with 30 lbs. of wind pressure, the maximum stress on the diagonal tie would be in tons per square inch of section 5.21 without a train, and 6.79 with a light passenger train on the main. That would be taking 21 tons to the bridge, and breaking again with a strain of the bridge without the strain is a thing of continuous occurrence so long as the gale lasts. I do not know whether, under those circumstances, an engineer is justified (I know that there have been put forward in cases similar to that) in taking a somewhat higher figure than he is meeting with which is an extraordinary occurrence than breaks when he is meeting with which is in the nature of continuous and permanent strain. I do not go so far as to say that, but I do say that I am going to take attention to it.

(Mr. Barlow.) It was stated by Mr. Baker yesterday, with reference to American engineers that in applying a high wind pressure, they assumed a high strength of iron, or rather, they applied a low factor, that they applied 70 tons as the strain per square inch.
TAY BRIDGE DISASTER:

have great respect for the Astronomer Royal, because we all know that he is a man of very great attainments, and at the same time, as I have lived for many years, and I may say that he has forgotten probably more than many people ever knew in their lives, and amongst other things he had forgotten that he had dealt with this question in the year 1873. The entire circumstances attending it had wholly been overlooked, and the late Mr. Barlow, when he saw the circumstances, the bridge, had no knowledge, no new facts, and no extended experience now; he had no means of speaking at the present time, as he was in 1873. If you look at Question 16, 186 you will see that I asked him this question, "That is to say your knowledge "what it is now?" and his answer is: "Yes," and it was, because he said in 1873, "We get pressures of 40 lbs. or 50 lbs. in Scotland, or perhaps more," and so he says now.

I must draw your attention, Sir, to the Report of the Astronomer Royal in 1873, and it is very important that the Report should be in your minds, because the Report is a report, which was in Sir Thomas Bouch's hands at the time, he was designing the iron column bridge; because, although the bridge was originally authorized and designed, as you know before 1873, it was not until a later period, in 1873, that the nature of the foundations made it necessary to substitute the columns for the bridge. Therefore, when I say that Mr. Thomas Bouch designed this part of the structure, he had this Report in his hands, and whatever is the measure of the value which you yourself would attach to the official scientific opinion of the Astronomer Royal, I think you will be agreed that Sir Thomas Bouch would be entitled to attach the same weight to it. Now, let me draw your attention to that Report, and remember the circumstances under which it was made, a bridge of a far more gigantic character than this, of an entirely exceptional and novel character, and of most daring conception, namely, a suspension and girder combined, which was to be the bridge of Thomas Bouch in the face of some 1,600 feet, and had been designed by Sir Thomas Bouch; and certain railway companies, the North British and certain other allied companies, who were proposing to fund the money for the construction of that bridge, desired to satisfy themselves of the opinions of independent engineers in favour of that, that was the sound design, and that the engineering. Now, let me say, in a way, to his judgment and accredit his money upon. Accordingly certain eminent engineers (one of whom, Sir, was your colleague on this side of the river), were invited, and, on the invitation of these companies, proceeded to inquire into the stability and safety of that design; and amongst other things which is appeared to them was of great importance to inquire into was the question of wind pressure. Accordingly, as you know, Mr. Barlow, associated with him Dr. Pole, went into the details of these calculations, and they were not content to rest upon their own judgment and their own knowledge and experience, but went to what they believed to be the nearest and best informed person, Sir, and the Astronomer Royal; and as we know, there was a conference with him, and received this Report. That, Sir, I cannot help thinking from reading this Report, that the Astronomer Royal has somewhere been a bit biased in his present views in the way that he has pointed out at the outset of his Report, and I am very different. Dr. Pole is being biased by inferences being drawn from what has happened from the accident itself. But here we have the cool judgments of the Astronomer Royal, as at a time when there was no such disaster to warp his judgment or to make him attach undue importance to military defects. What does he say? "We know that upon very limited surfaces, and far very limited times, the pressure of the wind does amount to sometimes 40 lbs. per square foot, so far as Scotland is probably more. So far as I am aware, "our positive knowledge, as derived from instrument record goes no farther. But in studying the record, we observe great and a very sensitive, and these high pressures are extraordinary." (Now, Sir, I do not mean meaning other people may attach to the word "momentary," I understand it to mean; that which lasts for a moment); and it seems most probable that they arise from some irregular whirlings of the air, which extend to no great distance, I should say certainly comparable with the dimensions of the proposed bridge, and the "faintest estimate of the pressure on the entire bridge "would be formed by taking the mean of the recorded pressures at one point of space for a moderate extent "of time representing the mean pressure upon a "moderate extent of space at one instant of time "(that is very intelligible, and, if I may say so, a "reasonable assumption say so, it seems to me a very reasonable principle). "Adopting this consideration, I think "that we may say that the greatest wind pressure to "which a plain surface like that of the bridge will "be subjected on its whole extent is 10 lbs. per "square foot." Now, Sir, that was the deliberate "conclusion of the Astronomer Royal, and the circumstances of that Report he had entirely and absolutely "forgotten; but when I reminded him of it I think "he was inclined to suggest (I think it was in answer, to a question of yours, Sir,) that the locality which he was then dealing with, viz., the Firth of Forth, was "more favourable than that of the Tay. Sir, I confidently venture to answer the..."
That would be the Forth Bridge.

(St. Bidder.) That would be the Forth Bridge. It has nothing to do with open lattice work. I think it was the intention of the Board of Trade to have the Forth Bridge as a suspension bridge, if anything...

(The Commissioner.) That is a mistake; it was not a suspension bridge, but a lattice bridge.

(Mr. Bidder.) I think it is the duty of those who have to decide this case to point out any difficulties that occur, I do not wish to disturb the thread of your argument, but I thought possibly it might be a question of point it out.

(The Commissioner.) I shall be much obliged to you, sir, you will do it now.

(St. Bidder.) The Astronomer Royal says, "The Forth Bridge was a suspended bridge in which there was no question of anything failing of supports or the like for the space of 1,000 or 1,200 feet. It will be remembered that the Forth Bridge was a bridge in which there were no supports, not even a support of 1,000 or 1,200 feet. The Astronomer Royal says, "The Forth Bridge was a suspended bridge in which there was no question of anything failing of supports or the like for the space of 1,000 or 1,200 feet. It will be remembered that the Forth Bridge was a bridge in which there were no supports, not even a support of 1,000 or 1,200 feet."

(The Commissioner.) The Astronomer Royal, no doubt, says that in this room; but with great deference to him, remember, he had entirely forgotten all the circumstances, that he had ever met. Mr. Barlow, and had anything to do with the Forth Bridge, but he is referring to the circumstances which he threw out, there had been no bearing or weight in his mind at the time he made his Report, because again I drew attention to this; this Report has, but one interpretation in this respect: "The greatest wind pressure that could be used was 10 lbs. per foot, and in the case of this bridge, there were no supports, not even a support of 1,000 or 1,200 feet. The Astronomer Royal says, "The Forth Bridge was a suspended bridge in which there was no question of anything failing of supports or the like for the space of 1,000 or 1,200 feet. It will be remembered that the Forth Bridge was a bridge in which there were no supports, not even a support of 1,000 or 1,200 feet."

(Mr. Bidder.) The Astronomer Royal, no doubt, says that in this room; but with great deference to him, remember, he had entirely forgotten all the circumstances, that he had ever met. Mr. Barlow, and had anything to do with the Forth Bridge, but he is referring to the circumstances which he threw out, there had been no bearing or weight in his mind at the time he made his Report, because again I drew attention to this; this Report has, but one interpretation in this respect: "The greatest wind pressure that could be used was 10 lbs. per foot, and in the case of this bridge, there were no supports, not even a support of 1,000 or 1,200 feet. The Astronomer Royal says, "The Forth Bridge was a suspended bridge in which there was no question of anything failing of supports or the like for the space of 1,000 or 1,200 feet. It will be remembered that the Forth Bridge was a bridge in which there were no supports, not even a support of 1,000 or 1,200 feet."

(The Commissioner.) You must also take into consideration what he said at first, which you read, "I really cannot say that I have any very definite opinion."

(Mr. Bidder.) He merely named these things, looking to the facts, as considerations that might possibly be of weight.

(The Commissioner.) I think in the first instance, which you read, he gave his opinion clearly, namely, that the weight would be over the whole area, he says, 40 tons, and he left it to the engineers to say how they are going to meet it. Then to pick up that observation of the Astronomer Royal, that you might have 40, 50, 60, or 70 lbs. over 100, 200, or 300 feet of that bridge without doing any damage, the Astronomer Royal was taken if I may say so, at a great disadvantage, and for once in his life he said that which I am bound to say was absolute nonsense; and I will tell you why, because, I must admit he said that 64 tons was the aggregate pressure, to be expected over the whole of the Forth Bridge, and that 40, 50, 60, or 70 lbs. on one of the girders of this bridge would have given him more pressure than he has put upon the whole of the Forth Bridge, and I venture to say that he gave an answer which was absolute nonsense. You can test it for yourselves, there is no trouble about it. His report says that on the whole of the lattice work of the Forth Bridge, it is 40 lbs. per foot. Now this is a lattice work girders too—a similar one, but not so deep. With 40 lbs. of wind upon one girder of this bridge you have got, without the train, over 60 tons. Mind you this bridge is not so deep by a long way as the Forth Bridge, because this is only 27 ft. deep, and that is 40 feet deep. If he could have 40 lbs. or 50 lbs. upon 200 feet of his Forth Bridge, he would really have had more wind pressure upon that 200 feet than he has told you in his Report you could have upon the whole 1,600 feet:

(The Commissioner.) Let me see if I quite follow you. He says that you might have 40, 50, or 70 lbs. a pressure of 40 lbs. or 50 lbs. upon the square foot. Then let us all agree that it would be over 200 feet. That would be dividing the number of lbs. by pressure, by the square foot. Wouldn't it? Then sights into fifty would give us a pressure of about 6 lbs. upon 1,600 feet, assuming there to be no pressure among the rest. That, I suppose, must have been passing through the Astronomer Royal's mind.

(Mr. Bidder.) I follow it my way, Sir, because I take these structures to be both of a similar character in this sense, that they are open lattice girders.

(The Commissioner.) I want simply to confine it, now to the Forth Bridge, and to his Report upon that bridge. He says that there might have been a pressure taking the extreme of 40 lbs. to 50 lbs. over a space of 200 feet.

(Mr. Bidder.) That is a convenient way of looking at it, if you like. I will first make clear my view. With 40 lbs. or 50 lbs. upon one of those girders, you get more pressure than he got upon the whole of the Forth Bridge. That, I venture to say, is a fact.

(The Commissioner.) 1,400 feet with, say, a pressure of 4 lbs.
that he had no very definite opinion upon the point, and therefore we cannot take the Astronomer Royal's authority for saying that in his opinion the gusts were either momentary, or in fact that they extended over very, very small areas.

(Mr. Bidder.) But at the same time we have the determination of the Astronomer Royal in 1873, that if you are dealing with a structure of the extent of the Forth Bridge of 1,600 feet span, though you may have gusts of 40 or 60 lbs. (and he cannot say now to what extent they will extend), yet their extent is so limited that over that average of that structure you will never have more than 10 lbs. Now, then, let me draw your attention, sir, to the fact that this structure was not so greatly in dimensions as this, as has been supposed; because, if the first place, as Dr. Pole very correctly pointed out yesterday, it is not enough to have the wind pressure over a space of one girder; it must be over two girders, because every girder is carried by two piers; and every pier has got to carry the thrust of two girders, and unless both of those girders are carrying the full maximum pressure of the wind, the pier will not have the maximum tension due to that pressure upon the girders. Consequently, in order to get the effect of the wind upon the pier it must extend over two girders, or 600 feet. That is not all. That is supposing that the girders are discontinuous, as Sir George Airy states, and that the evidence of the witnesses is uniform, I think I may say, that that continuity of the girders would come into play, resisting the wind as it comes into play, and assisting to resist the vertical forces.

I will draw your attention, first, to the evidence of the Astronomer Royal himself upon that point; I do not know that I ought to press very much upon that, because he said that he was not aware of the circumstance, and he put it very vaguely, and therefore I do not think it would be fair to attach too much weight to it. You will find that in answer to questions 18,189, 16,410, and the succeeding questions, Dr. Pole, yesterday (but he is not alone), General Hutchinson, who had studied this structure very carefully, pointedly referred to this question, not in answer to any questions of mine, but I may say of his own accord, that this was a matter which had been dwelling in his own mind; and with all the care which General Hutchinson had taken in studying the structure, he would certainly, if he knew which we knew, possess, his opinion, I think, will carry great weight with the Court. There are one or two answers of General Hutchinson's to which I want to draw your attention, and if you will turn to page 532, question 16,037, you will see this, which, although it is not a very striking reply to the question, is a very important piece of evidence. "I wanted to have brought before the Court: What I have not seen alluded to in the evidence, although it may have been, and that is with regard to the effect of the wind pressure upon the continuous girders. Supposing, for instance, that those five girders were really a continuous girder, and that you had a gust of 40 lbs. per square foot upon one girder; then assuming (which I suppose may be assumed) that the wind in gales acts in gusts and points— I have not seen this taken into consideration, although it may have been, that a point of wind, a high gust, taking the middle of the girder or a certain part of the surface of the girder, would have its impact distributed throughout the whole of the continuous girder, and that its full force would not be felt upon this pier and upon that (pointing to the model) supporting the immediate bay upon which the thrust of the wind came. Of course it would be a very difficult calculation to say to what extent, a high gust of wind of 40 or 60 lbs. would have to be reduced so as to distribute its effects upon the girder supporting the pier and upon the pier itself, and then you, Sir, said this, 'That would of course depend upon the width of the girder,' and his answer was, 'Quite so; but from what we know about the wind, or from what I have understood about the wind, even if you took a girder 345 feet long you would hardly get a gust so long, as that girder would be, and much more so' (I think he must have meant to say much less) "if you look upon the five girders as one girder. Much less, therefore, would you say gust of 40 or 60 lbs. over the foot extend over 1,200 or 1,000 feet." Then further down there is another answer of his in which I had better read. In answer to question 16,038 he says, "Yes, I am assuming of course that the wind acts in points. Then I wish further to say that that would be the state of things with no train upon the girders. If you assume a train to be upon the girders, and that a gust of wind comes, say when the train is in the middle of this girder, again the force of that gust upon the train would have to be distributed throughout the whole length of the continuous girders in order to get the pressure resulting from that gust. It is a different problem; but still I think it is fair to take that into account, and we should consider that the pier would have to bear the full thrust of any particular point of the gust. So that General Hutchinson is quite in accord with Dr. Pole, and to a certain extent, and more generally with Sir George Airy, that these being continuous girders they do distribute more or less the pressure of the wind, and that you must not regard them as separate pairs of piers simply had to deal with the gusts, but that they are distributed throughout that portion of the bridge immediately over and between.

(The Commissioner.) Before you leave that, let me correct one of your calculations, if you will allow me to do so, with reference to Sir George Airy's evidence. Assuming that there was a pressure of 60 lbs. over 600 feet, you must recollect that the pressure varies with the square of the velocity, and that a pressure of 6 lbs. to the square foot would represent a velocity according to Hutton's tables, and I think even according to Housse's tables of something like 60 miles an hour; it is 66-69 miles.

(Mr. Bidder.) Less than 40, I think. I will give you the figures at once; 20 miles an hour is 1-81 lbs., and if you take 40 miles the pressure will be four times that, or 7 lbs.

(The Commissioner.) It is as the square of the velocity. At any rate, whatever it is, from the tables which I have before me according to Hutton's calculation, a velocity of 50 lbs. would correspond to a pressure of about 6 lbs. Now, taking 18 lbs. for the weight of the surface, and 60 lbs. over 4th, that would give us 92 (42-60)—divide that by 8 and that gives you a pressure over the whole surface of about 11 lbs.

(Mr. Bidder.) I do not quite follow your calculation. I think you are going into a separate calculation. I have not troubled my head about velocities at all.

(The Commissioner.) I am not speaking of all of the velocities, but simply about pressure. Assuming that there was a pressure of 50 lbs. upon the 4th of the girder, and that there was a pressure of 6 lbs. upon the 3rd of it, the sum total of that will be a pressure, we will say, of 56 lbs. over the whole of the surface, and that would give us a pressure upon each eighth of about 11 lbs.

(Mr. Bidder.) It is a very simple question in the way you put it before. If you put 60 lbs. of wind upon the 2nd of the span.

(The Commissioner.) And upon the other 4ths.

(Mr. Bidder.) Upon the other 4ths you must have less than 6 lbs. of wind in order to make it 10 lbs. over the whole. I said a little over 4 lbs. and I think you will find I am right. You need not trouble yourself with velocities, I think.

(The Commissioner.) I think we must consider velocities because of the relation that there is between velocity and pressure, and that apparently a slight increase of velocity increases very considerably the pressure, because the pressure increases as the square of the velocity.

(Mr. Bidder.) That is perfectly true; but that has nothing to do with uncertainty what is the pressure upon the rest of the girder. This is simply a question of pressure.
The Commissioner. All that I mean to say is this: I do not wish you to repudiate the opinion of Sir George Airy, as he is a man of authority, and that there could be a pressure of 50 lbs. upon one eighth of it, and only a pressure of 4 lbs. to the square foot upon the remainder of it simultaneously.

Mr. Bidder. I venture to say that it is not a correct statement.

The Commissioner. I am not denying it.

Mr. Barlow. And not an unlikely fact in certain gales of wind.

Mr. Bidder. There would be a pressure of 60 lbs. upon one eighth, and a little over 4 lbs. on the other seven eighths. My way puts it, I think more conveniently; that it would result in having a greater lateral strain upon one of the girders of this bridge than upon the whole Forth Bridge.

The Commissioner. In fact, taking for instance some of Professor Stokes' calculations, if you have over 200 feet; a velocity of 150, that would give you something like a pressure of about 60 lbs. to the square foot, and over the rest of it there might be a velocity of from 40 to 60, which would give you a pressure of from 4 lbs. to 6 lbs.

Mr. Bidder. The one velocity would be three and a quarter times the other.

The Commissioner. We are all very anxious, of course, to support, as far as we can, the reputation of Sir George Airy.

Mr. Bidder. I am much obliged to you for drawing attention to that, Sir, which I have not drawn attention to. Nobody has a greater respect for the opinion of Sir George Airy than I have.

The Commissioner. We all have. All those who have seen Cambridge must have.

Mr. Bidder. All I venture to say is that I think hastily said, unanswerable, Sir George Airy, who said he had entirely forgotten that Report, made suggestions as to the figures which, if he had had an opportunity of working them up, he would not have put forward. At any rate, Sir George Airy's opinion, whatever weight is attached to it, and very great weight must always be attached to it, carried very great weight with Mr. Barlow here; Dr. Pole, so much so that they added upon it, and it carried very great weight with Sir Thomas Bouch, so much so that he acted upon it, or was influenced by it; and if Sir Thomas Bouch were not in such that weight to the Astronomer Royal's opinion, I sinced in common with a great many other eminent men in the profession, and I am afraid we should have to trace back to the Astronomer Royal the ultimate cause of the disaster that has occurred to the Tay Bridge. But in point of fact I do not think he did lead us astray, and I venture to say, now, with all the evidence before us, that the opinion of the Astronomer Royal may be, as somebody said, a little low, but that it is not very far wrong; and that it is, in accordance with the facts, and with the experience that they had then, and that we have now.

Now let me bring your attention to this: I have recently seen a description of General Hinchliff's, which show you clearly that it is in accordance with his view so far as his experience has taught him. I remind you also of this; The fact is stated by Colonel Yolland, in correspondence with Mr. Fowler, for which he is not personally responsible, because he knows that it was in such a state as to lead him to the general view of the engineering world, that for girders under 200 feet it has not been the practice of the Board of Trade to take into consideration wind-pressure at all.

Mr. Barlow. That was the girders; I think, not the structure. It had reference to the cross beams of the girders.

Mr. Bidder. But if the girders blow down, it is as damaging to the structure as if the view blew down. I do not suppose that the Scientific Disasters of the Board of Trade are likely to lose any importance in this world.

The Commissioner. Would you be good enough to refer to what Colonel Yolland did say upon that point? Does it refer to a dimension of 200 feet or 100 feet?

Mr. Bidder. Of 200 feet.

Colonel Yolland. Is it 200 feet.

Mr. Bidder. But it is hard to see how that would bear with Colonel Yolland's name, because it was no rule for which he was responsible. He was simply announcing that which was the practice of the Board of Trade, and, as I venture to say, the wise practice in consonance with the opinions of engineers generally: I only draw attention to that as an indication of what have been the mature judgments, so far as they have had an opportunity of forming it, of scientific men upon the subject.

Now I wish to draw your attention to a little error in the evidence of Mr. Scott upon the matter. Mr. Scott, I think, gave several instances, and I will first draw your attention to this: He gave us some facts with reference to this particular storm at Glasgow and Aberdeen, which appear to be the most convenient meteorological stations practically lying on opposite sides, but on the same isobar as, I believe, the technical phrase is now; and you will find that picking out the velocity for a very short space of time, three minutes at Glasgow, and about a quarter of a minute, 60 miles an hour, or rather 190 miles an hour, the velocity was 96 miles an hour at about the same time at Aberdeen the velocity was 96 miles per hour. That is question 16, 325. Then you must remember that you have to correct these two figures by Professor Stokes' evidence, because Professor Stokes tells you that these figures have all got to be reduced by one-fifth. The old multiplier of three was too great he says in Stokes, and it is only two-fifths. When you make that correction the velocity at Glasgow is reduced to 96 miles per hour, and at Aberdeen is reduced to 77 miles per hour; and if you take the trouble to work out what the wind pressure are, bearing in mind Professor Stokes' rule that for 20 miles an hour it is 1/8 lb, and that it alters as the square of the velocity, the pressure at Glasgow was 41 lbs., and the pressure at Aberdeen was 27 lbs. This place being intermediate one might say perhaps, guessing at large, that it was something between the two. That may or may not be. These are pressures on the anemometer: these are the maximum pressures of the gust upon the anemometer so far as we can ascertain them. There is a good deal that is interesting upon this subject in the evidence of Mr. Scott further on, because he shows us what his view is as to the extent, or the locality of these pressures. At question 16, 325, in his report he said this: On November 16th, 1877, the Sandwich anemometer registered 88 miles in a minute. The Commissioner: It should have been "for 60 minutes." It might have been a rate of 83 miles; for perhaps only one or two minutes.

Mr. Bidder. He means, I think, Sir, what he said that the wind travelled 88 miles in 60 minutes, and in this case also the gusts must have been very heavy. A two miles' trace gives an hourly rate of 180 miles, and a four minutes' trace one of 120 miles. It is not a little remarkable that these very high velocities at Holyhead (which he said he thought rose to 200 miles an hour) "and Sandwich did not do material injury to buildings situated close to the respective anemometers." It is perfectly true (he says), that the photograph of the Sandwich anemometer, and the building which stood that gust of wind, shows that it was an ordinary Scotch manse house, and it was not particularly knocked about by the wind. And then he also, I think, produced a photograph of the building in which the anemometer itself stood. It was very difficult to understand what should have become of it under the circumstances. At question 16, 327 you find another master illustrative of the same point. Mr. Whipple says that: As an example of the effects of gusts, he
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"had recently, upon the roof of the Kew Observatory, a massive wooden tripod with heavy iron legs, but loaded at the base with sufficient weight to keep it steady, and probably necessitate the strength of three men to overturn it. A gust of wind blew it down, although the anemomter, a few feet distant, failed to register a higher velocity than 30 miles in the hour in question."

(The Commissioner.) Then he speaks of the Walmer whirlwind, which had a trek 700 feet wide.

(Mr. Bidder.) I have a special note to talk about Walmer. You may rely upon it that I will not forget Walmer. At question 16,389, I say: "The opinion of the prompter, Mr. Bidder, is, that it was full�áed, or not, is this, that although you may have from 40 lbs. to 50 lbs. upon the anemometer, yet, taking a force, such as the Fort bridge, you cannot have over the whole of that an aggregate pressure of more than 10 lbs. how far do you agree with or differ from that view?—A. The statement that I have myself published on the subject is, in the Quarterly Journal of the Meteorological Society, and it is this:—It appears to me, that the extraordinary record of the pressure of 50 lbs. per square foot, recorded at Sidford, observed on the 9th of March 1871, may be taken as a correct indication of the force exerted upon the plate, but not of the violence of the wind at a distance of only a few feet from it. Q. That seems to be a valuable paper, because I see you say that the pressure in stones is evidently exerted in distinct and separate gusts, each affecting a limited superficial area—A. Some of the records appear to prove that when, for instance, the mean 200 or 300 feet, because he gives instance after instance, one being the tripod that was knocked over, when the anemometer two or three feet off it was not; and that last passage that I have read shows the same, because he says, "The pressure of 90 lbs. per square foot was not recorded at Sidford, nor was there any judgment whatever on the 9th of March 1871, may have been a correct indication of the force exerted upon the plate, but not of the violence of the wind at a distance of only a few feet from it."

Then at question 16,389 I say, "Because you say it is inconceivable that if the pressures which are sometimes recorded by our instruments were derived from the same small or chilly breeze, the "structure", could stand.—A. That is what I think, again, shows what he means by the word, "limited." Then, at question 16,389, I say, "When you say that these extreme pressures are local, you mean that they may be felt on the instrument, though they may not be acting upon chimneys or walls in a few feet of it?—A. That is as far as we know; we cannot be sure. Q. You do not mean local in the sense of half a mile in breadth, but local in the sense of a few feet in breadth. I see you go on to add that you have been yourself a witness of the way in which damage may be done to buildings by whirlwinds, while objects adjoining are not damaged. A whirlwind, uninflicted, that is, a whirlwind unconfined, that is, does not generate in such a manner, of common observation, is it not?—A. It is certain trees are picked out, and others stand.

(The Commissioner.) We must not take the first part of it, because that is your own observation.

(Mr. Bidder.) Why not, Sir? It is ascertained to.

(The Commissioner.) It is only the latter part which is ascertained to.

(Mr. Bidder.) It is put by me interrogatively to him, and it is ascertained to, and no exception is taken to it. This is not my observation.—So that, if the anemometer be in the heat of the storm, so to speak, it will register pressures that do not exist except over areas of a few feet. —A. That may be so, but it does not prove that the pressure a few feet off may not be greater. That of course is a logical proposition. The two propositions are not necessarily convertible together. He gave some other instances; he gave, for instance, this, at question 16,389: "The highest pressure, that has been registered in Calcutta 60 lbs. to the square foot, but this was in a storm of no considerable violence, and one which did but little injury in Calcutta—that is to say, an extraordinary pressure was registered at a time when little sea was running, and when little damage was done."

(Mr. Bidder.) 30 lbs. to the square foot. Then, on the other hand, he gives you another—"In the far more severe storms of the 2nd of November, 1887, the 8th of October, 1884, the anemometer was blown away under a pressure of 36 lbs. to the square foot."

(The Commissioner.) Then he talks of the correctness of the observation of the Astromer Royal, and the soundness of his judgment in 1873, that these extravaugant pressures are, to use his own language, which is much better than mine, the mere effect of momentary whirlings of the atmosphere. It is impossible, he says, and I think anybody else who chooses to look into the matter will come to the same conclusion, not to see that these high pressure are momentary, and it seems most probable that they arise from some irregular whirlings of the air, which extend to no great distance.

All these illustrations show the same, and when we say, "no great distance," it is only a few feet, not hundreds of feet. So that an anemometer of the registering kind 30 miles an hour, whilst on the same roof a tripod is being swept away, or at Holyhead it may register 50 lbs. to the foot, while neighbouring buildings suffer no appreciable damage. The same thing may be illustrated in amazons cases, and, as you reminded me, Sir, of the whirlwind of 1872; I did not intend to pass over without taking note of it. That the wind was not confound the width of damage done there with the width of a gust of wind, because it has nothing in the world to do with it. The Walmer wind was a whirlwind, and is so described by Mr. Scott and others.

Of course, in one sense all winds are whirlwinds. We say, it is a whirlwind, whereas, if you know the wind, it is a whirlwind, whereas, if you know it is a whirlwind, whereas, if you know it is a whirlwind, whereas, if you know it is a whirlwind. But the Walmer storm was what we mean to call a whirlwind in the ordinary sense, that is to say, it was a whirling cyclonic storm, the nucleus of which, was a whirlwind. In the circle of the storm there was not the wind of the gust, but the diameter of the circle of the whirlwind; just as you sometimes see in a farmyard, a little chimney of wind which catches up the hay and straw and dust, and whirls it round and raises it in the air, so it sweeps away laterally across the surface of the ground. The Walmer whirlwind was of an entirely different character from the great cyclonic storms, and as I say the track of the storm was the diameter of the whirlwind. That has no analogy whatever to this case, because if you call this a whirlwind, it is a whirlwind certainly, as we know from the weather diagram of the day of something like 80 miles radius; but the Walmer whirlwind was unconfined, that is, it is no information whatever as to what may be the width of a maximum whirlwind in each a storm as this.

(The Commissioner.) Except that the Walmer whirlwind carried away everything, and the nearest part was 400 feet, and the broadest part 700 feet. (Mr. Bidder.) Yes, but the two things have not the least relation to each. In any case it was a familiar illustration; the Walmer whirlwind was very, very, much like, what the carpenter calls a stock and bits, where you have a tool with a narrow cutting edge, which sweeps out a big circle, by its rotation. This is a cyclonic in one sense, but it is a cyclonic, the centre of which is 600 miles off, and you have simply to do with the lateral width of the gust and not with the area of the circle, which may be described by the diameter of the whirlwind.
answer that uniform pressure or wind must have been provided for, and that the "General" Royal ought to have known of, and that it was his fault that they were not provided for. In point of fact, such pressures of wind were not provided for, and nobody knew, and I venture to say nobody knows now, that they ought to have been provided for.

Let me refer you again to the evidence of General Hutchinson, sworn before me, if I may refer you without presumption, give his evidence with remarkable fairness, as well as with remarkable ability. At question 16,010, I ask him, "Do you not know whether you are able to answer this question? In considering structures of this kind, have you adopted any rule or practice as to what wind pressure you ought to be prepared for?" I say no; we have no data to go upon with regard to wind pressure."

(The Commissioner.) I think you may take that for granted. That seems to be universally acceded to.

(Mr. Bidder.) So far as you know is there any guide on the subject known to engineers? I have not heard of any reason to believe in any uniform pressure as these, and we have to infer them, we must not too hastily assume, or rather we shall be assuming the thing that we want to prove, if we deduce from the Tay Bridge accident that such pressures existed.

(The Commissioner.) I have not said that there were any data for it. I have only said that the engineers did not allow for it.

(Mr. Bidder.) General Hutchinson not only said that they did not allow for it, but that they had no data to go upon, and that the only authentic opinion that he knew of was the Astronomer Royal's 10 lbs. And remember this General Hutchinson is not a mere amateur, but he is a man of great ability and experience, whose duty has been for years to represent the Government in inspecting the efficiency, and safety and stability of all railways and works of this description; it is particularly his business and his duty, and everybody who knows him knows that it is a duty which General Hutchinson has always discharged most carefully and conscientiously, and with great ability. You have only to look at the evidence in this case to see that, Sir Thomas Bouch tells you, the contractors tell you, and everybody tells you, that they never knew of any specific and careful inspection of a railway work in this sense; in which General Hutchinson subjected them to it. Therefore you must take this as the opinion, not of a casual or bystander, but of a man whose life's work it is to deal with questions of this kind, and who is competent for properly dealing with questions of this kind, and when he tells you that it has not been the practice of engineers to allow for such wind pressures as they have no data to go upon, to infer such wind pressures as he does, you have as good evidence of the greatest weight, because whatever your own views or theories may be, you are sitting here, say, have to deal with the evidence that you have before you. Therefore you must make sure that you do not beg the question, because up to this night of the 16th of November, 1879, there is no evidence of either such high winds or such high pressures as you are speaking of. And when you are told, that deduction from the distance, you are inferring the supposition upon which you are going to base your conclusion, if the Tay Bridge fell under a high wind pressure, then, no doubt, it shows that a high wind pressure ought to be provided for; but the question has to be decided, did it fall from that, or from an entirely distinct and different course? Therefore you cannot, for the purpose of this inquiry, assume that you have further data than those which General Hutchinson, the Astronomer Royal, and others, tell you that you have, and when the Astronomer Royal's opinion is put before you, and when General Hutchinson's opinion is put before you, you must not brush that aside as if it was of no weight, and say notwithstanding, I come to the conclusion that there were data upon which these wind pressures might have been calculated, and that in this case those data were not applied.

(The Commissioner.) I am sorry to interrupt you, but you will observe what General Hutchinson says, 16,071, and 16,072.

(Mr. Bidder.) I am much obliged to you, Sir. I have made a note to read that, indeed, I had scored it, but I had forgotten it. At question 16,059, you ask him: You thought the bridge sufficiently strong for the purpose?-"A. I did." And then: did you not know whether you are able to answer this question? In considering structures of this kind, have you adopted any rule or practice as to what wind pressure you ought to be prepared for? I say no; we have no data to go upon with regard to wind pressure."

(Q.) How did you judge, then, of the stability of the bridge, if you made no calculations? The Commissioner.) That is to say, that it has not been the practice to allow for it.

(Mr. Bidder.) Then let us take care now that we do not reason in a circle, because having it taken for granted and agreed that up to the night of the 28th of November, 1879, there was no data for such high pressures as these, and we have to infer them, we must not too hastily assume, or rather we shall be assuming the thing that we want to prove, if we deduce from the Tay Bridge accident that such pressures existed.

(The Commissioner.) I have not said that there were any data for it. I have only said that the engineers did not allow for it.

(Mr. Bidder.) General Hutchinson not only said that they did not allow for it, but that they had no data to go upon, and that the only authentic opinion that he knew of was the Astronomer Royal's 10 lbs. And remember this General Hutchinson is not a mere amateur, but he is a man of great ability and experience, whose duty has been for years to represent the Government in inspecting the efficiency, and safety and stability of all railways and works of this description; it is particularly his business and his duty, and everybody who knows him knows that it is a duty which General Hutchinson has always discharged most carefully and conscientiously, and with great ability. You have only to look at the evidence in this case to see that, Sir Thomas Bouch tells you, the contractors tell you, and everybody tells you, that they never knew of any specific and careful inspection of a railway work in this sense; in which General Hutchinson subjected them to it. Therefore you must take this as the opinion, not of a casual or bystander, but of a man whose life's work it is to deal with questions of this kind, and who is competent for properly dealing with questions of this kind, and when he tells you that it has not been the practice of engineers to allow for such wind pressures as they have no data to go upon, to infer such wind pressures as he does, you have as good evidence of the greatest weight, because whatever your own views or theories may be, you are sitting here, say, have to deal with the evidence that you have before you. Therefore you must make sure that you do not beg the question, because up to this night of the 16th of November, 1879, there is no evidence of either such high winds or such high pressures as you are speaking of. And when you are told, that deduction from the distance, you are inferring the supposition upon which you are going to base your conclusion, if the Tay Bridge fell under a high wind pressure, then, no doubt, it shows that a high wind pressure ought to be provided for; but the question has to be decided, did it fall from that, or from an entirely distinct and different course? Therefore you cannot, for the purpose of this inquiry, assume that you have further data than those which General Hutchinson, the Astronomer Royal, and others, tell you that you have, and when the Astronomer Royal's opinion is put before you, and when General Hutchinson's opinion is put before you, you must not brush that aside as if it was of no weight, and say notwithstanding, I come to the conclusion that there were data upon which these wind pressures might have been calculated, and that in this case those data were not applied.
TAY BRIDGE DISASTER:

May 1869.

"Famous judgment; and I may refer to Mr. Griffith's evidence. Of course everybody knows that Mr. Griffith was a very able man, though I do not pretend that his opinion would carry the same weight as General Roberts'. But he was of the same opinion that the wind, or one of the winds, was insufficient to carry the bridge down. He also says, in his evidence, that the design of the bridge was sufficiently safe to meet the wind, or else he would not have taken part in its construction.

So much, therefore, with reference to the opinions and the information that we have got. I will only in addition remind you of this, that Mr. Baker (and every other person who knows anything upon this question) has been to the spot; he has examined the locality, and he tells you his deliberate judgment. There is another piece of evidence which is valuable in reference to this question, and that is Mr. Edwin Clarke's evidence with reference to the Britannia Bridge. There you have a tube 450 feet long, and, in describing its behaviour under a very heavy storm, he says, one of the most remarkable things was, how very local, along the tube, the heavy gusts of wind were, that is to say local with reference to the total length of 450 feet. I have shown you the tube of Mr. Scott's meteorological findings at Glasgow of some 414 lbs., and at Aberdeen of 274 lbs. Mr. Baker goes to the place; and he says, having seen the structures, structures which infallibly would have gone to the earth with pressures such as have been mentioned in this case, "I have come to the conclusion that the bridge was not have been subjected to a force in excess of the girders to a wind pressure of more than 15 lbs. per foot." You have heard the grounds upon which he based that conclusion. Mr. Baker is a man who has made the subject a matter of study for years, who has, as it were, held himself in his observations for years. It is perfectly open to observation, of course, that some of the observations which were necessarily made, were not seen as the girders in the middle of the Tay; but Mr. Baker, I suppose, is as competent to take all that into consideration as anybody else, and taking all that into consideration, he gives us his deliberate judgment that the wind pressure could not have been more than 15 lbs. to the foot. That causes me to work in very well with the Astronomer Royal's views as expressed in the Report of 1873. The maximum pressure here is pretty well the maximum pressure that he was contemplating there; namely, about 41 lbs. to the foot. That is the Glasgow record; and if he reckons that figure of 10 lbs. over the Forth Bridge, it is very nearly the same. Mr. Baker, he says, 15 or 20 lbs. would be excessive. If that is right, it is accurate. You are going contrary to all previous evidence and to the opinions of those who are competent to form opinions, to say that you believe that that was the highest pressure upon this night, recorded at any town or place. What I mean to say is that the pressure prevailing the whole of this bridge, or the whole at any rate of the group of continuous girders, you have, as it were, inevitably to the conclusion that so far as design is concerned, and so far as the execution of the bridge is concerned, and so far as Mr. Kirkaldy's tests throw light upon it, there was no wind force upon that night that could possibly have overthrown that bridge, and that whaling was the cause of the failure of the bridge. I was not, and it could not have been the mere lateral action of the wind upon it. As Mr. Baker says, if you are to assume anything like 40 lbs. of wind upon the extent of that bridge, you have only to go to Dundee to satisfy yourself as to the immovable structures that are existing there, that it would have been swept away from the face of the earth.

Under these circumstances, Sir, I must say that I decline to go into all the suggestions that have been made of alternative designs. A great many people have been tinkering at the design of this bridge. Everybody thinks he can suggest something that would make it better. It pleases anybody to suggest that the base should be broader, or that there should be eight columns instead of six, or a light brick pier instead of an iron pier, they are perfectly welcome to do so. My business is to discuss the design of the bridge as it was, the failure being what it was. I must say a few words, and I will try and make them few, with reference to the question of construction, because I am quite aware that in discussing this question upon the efficiency of the design and the efficiency of the work as indicated by Mr. Kirkaldy's tests, I have not covered the whole ground. There have been a great many suggestions on the part of — (I was going to use a phrase which would have been very unfair to my learned friend Mr. Trayner, I was going to say "on the part of the prosecution," because he has dealt very fairly with us all through, but I am afraid my friend Mr. Law has unconsciously put a gloss upon some of the columns had been cut in two, if it had broken right through transversely, you may make a thousand hypotheses; if half a dozen of the tie-bars were gone, if somebody had with impunity and maliciously gone and cut a dozen of the tie-bars, any one of those hypotheses would account for the fall of the bridge. But there is not a particle of evidence to support them, and what I am struck with more upon this part of the case than anything is this: I feel I am rather trespassing upon my learned friend Mr. Webster's case, because although I accept for Sir Thomas Bouch the responsibility for the supervision of this work; of course primarily the responsibility rests upon the contractors. But I was very much startled in this case in dealing with the evidence brought forward principally by Mr. Law, and the other evidence which was given previously at Dundee, which all seem to point to this conclusion, which I knew was the impression made upon the minds of the public generally, owing to the reports in the public prints that the bridge in its execution and construction was one of the most disgracefully scamped, slipshod, and inferior pieces of workmanship that ever was put together; and I did feel on the part of Sir Thomas Bouch that I had a heavy charge to meet of carelessness or want of proper supervision. I have been on many occasions in a position of imputation upon him and upon his care and skill as an engineer that he should have allowed such a disgraceful piece of work to be passed off on the North British Company, under his supervision. You know that the number of charges that have been made against this bridge is infinite; that the cast-iron was rubbish, that the observation stations, if any proper care had been taken in testing it, and that the bolts were inferior. We spent a whole day with witnesses brought up here to prove that the bolts had been bought cheap and made of bad iron, and that people had been bribed to pass bad iron, and so on. You know the sort of stuff that evidence was calculated to produce upon everybody's mind. I do not know what the columns were; I take it, subject to cold shots, and bundling, and I have put aside the names of which I know, but the reasons of which I
an not sure that I do know. The lugs had been
bored so, columns that had got no lugs on them had
been put in place by a process which made them totally unsound, and
a thousand other things which were suggested by Mr.
Law, the holding-down bolts had drawn through the
cement, the cement would not hold the masonry
together; there was a rough butt left on the edges of
the stones where they were drilled, and some things
have produced upon those in order to get this had been drilled, and,
for all that tremendous onslaught which I say must
have, and which I know has, produced upon those
out of doors, the impression that the contractors in this
case were the most scandalous swindlers that ever
undertook a public work, and that Sir Thomas Bouch
was the worst, as incompetent and incompetent an
engineer that was ever appointed to supervise it, Mr. Glitke, the con-
tractor, the man who is responsible for all these
inquiries, was put into the box to-day, and there was
not one question asked him in cross-examination about
anything in the construction of the bridge except one
matter, namely, whether the columns had been cast
with two, two, or three, from which it appears that the
colonies with them, I mean the connection of the girds
and the attachment of the ties, what effect could that
have in interfering with the stability of the bridge? I
venture to think that upon the evidence it is pretty
clear that that has been very greatly exaggerated.
I do not mean to say that if a great number of the ties
were allowed to give way and were left loose, that
would not seriously affect the stability of the bridge.
I think Mr. Stewart was a good deal misunderstood
by Mr. Trayner yesterday, because he lead him, or tried
to lead him, and very nearly succeeded in leading
him, into what appeared to be an absurdity; and
therefore let me say a word about that: "If a tie is
loosed, it may do no harm," Mr. Stewart said.
It may be "or an absurdity if you please, but it does increase
the horizontal forces resisting lateral strain.
There is no doubt about it. It is a mathematical
propagation, about which there can be no doubt, and
it can be put very simply: obviously, the strain on
the tie being the same, if you loosen the tie in any
way, the heads of the columns move over a little;
more flexure of the columns means more resistance of
the column so being bent. "Well, then," says Mr.
Trayner, "if that is so you had better leave the ties
loose, and you will have a more stable bridge.
"No," the answer is (although Mr. Stewart did not
see it at the moment) "because the moment
you loosen the tie you decrease the power of the
attachment of the girds, and it is a very important operation,
although it is not so severe a strain upon the
attachment of the column. The moment you loosen the tie, it
allows the beginning of that buckling which Dr. Pole
explained yesterday, and so deprives the bridge of its
power to do what is its normal and primary duty, and
that is to carry the vertical load. That is the
explanation of that. It is perfectly true that a loose tie
does bring into play greater forces to resist the wind
pressure, but at the same time it is equally true that it
would be a very damaging thing to the bridge,
because while it does that, it allows buckling of the
columns, and so makes the bridge incapable of
properly carrying its vertical load.
I think it is not unimportant to follow a little
further the history of the bridge in the latter part
of its construction. If you remember, it appears on the
evidence that when the bridge had been completed,
and before the inspection by General Hutchison, Mr.
Maceath, with several of the engineers, were about
months carefully going over the whole of the bridge,
and tightening up all the tie-bars and struts through-
out the bridge. If you wish for a reference to that
it is at Question 15,740 of the evidence of Mr.
Maceath, where he is asked: "Can you give us any
idea how long you were occupied upon that work?"
and his answer: "About two months previous to the
Government survey or going out the week, and
in three months afterwards." This is no mere docu-
May 1860.

TAY BRIDGE DISASTER:

...ing up of the bridge to satisfy General Hutchinson; it went on for three months afterwards. The inquiry was asked at Question 16,742: "During those five months what were you employed in doing?" and Mr. Macleod's answer was, "In examining the work, tightening up the gibbs and catchers, that were loose in any way, and tightening the bolts." He examined every strut and tie-bar from the bottom up. Sir, what was the condition of the bridge after that? We have got the best possible evidence, because we have got the report of General Hutchinson and his evidence here. General Hutchinson went to discharge his duties as an officer of the Board of Trade in inspecting and reporting upon the bridge. We know that by General Hutchinson's own exceptionally severe character, it spread over three days. You know the sort of tests that the bridge was subjected to—six engines of the heaviest description standing together; four engines running over it backwards and forwards at a speed of 40 miles an hour; General Hutchinson, content with simply watching the effect from any one point, but testing it by theodolites at the heads of the piers, having himself lowered down to different levels and inspecting and trying the bridge in every possible way that man can think of, and the result is that General Hutchinson reports that the rigidity of the structure was remarkable; that it was very stiff, more than he could have expected, and that there was extremely little vibration, and that it was satisfactory. At Question 15,966 General Hutchinson was asked this: "I think I am not wrong in saying that the conclusion you came to was that it was a remarkably stiff structure!" He said, "I think that was my impression at the time." "And that it was much stiffer than I had anticipated it would be?" He then took it to examining the construction and the workmanship of the bridge as carefully as a man in your position could do it, and he is not satisfied with the evidence of the Hands. He says, "I have not found any evidence that he was impressed with anything at all."

Now, Sir, of course it is quite consistent if you choose to surmise it, that somebody may have put a cylinder with a hole in it and painted it, so that neither General Hutchinson nor any other man might have been imposed upon; but after all these severe tests it is a structure which General Hutchinson reported as being stiff and satisfactory. And we do not think that you are engaged to investigate the evidence of any of the Hands. For the evidence of the Hands is the most direct and the best and the most reliable, which went to the discount of the manufacturer of it? If we are to believe that, it was such a loose ramshackle affair, that all its rigidity was gone, and it was ready to fall at the slightest touch almost, General Hutchinson, instead of being the skilled and experienced officer that he ought to have been, may say it without offence, a perfect fool in the matter. We cannot believe that, for a moment, and I venture to set the evidence of General Hutchinson's careful report after all inspection, as against the surmise and criticisms of Mr. Law, who went down after the bridge was destroyed; and I think it will have, and must have, the greatest weight of the two. I stand upon that very careful and long inspection of General Hutchinson's. I say, saving, if you please, concealed defects, which of course it was impossible for him to see, and saving (I say it advisedly) the conical holes in the legs which he certainly could not see, you have the strongest evidence in the world that there could not be any weakness in that.

There were conical holes in the legs, and there was a certain amount of looseness in the tie-bars. I do not deny it. Was that altogether unexpected and exceptional in the case of this bridge? Again, I draw your attention to this, that it is a thing to be expected and a thing which need cause no anxiety if you pay attention to it and tighten them up. I want to put before these suggestions of Mr. Law, because they are principally his suggestions, the evidence of the man of weight and experience who speak passionately upon this matter, and I will draw your attention to General Hutchinson's evidence again upon this point. If you look at Question 15,970 you will find, this: "You know how these tie-bars are fastened with gibbs and catchers?—Yes. Is that a matter which, in your opinion, required careful attention after the bridge was opened?—I should think so certainly. Of course the object of putting the catchers in was to have the means of tightening up as slackness occurred. Q. In a bridge of this kind, if you look in general together in that way, did you anticipate that that would be a matter receiving careful attention from those in charge?—Certainly, it seemed a very important point. Q. At the time you examined it, they were tight enough to satisfy you?—Yes, I observed no instance of any more slackness than you would naturally meet with in any large structure of the kind. Q. Would the action of the trains passing over the bridge naturally lead to loosen these catchers to some extent?—I have no doubt that it would, and especially the higher the speed, the more rocking motion, so to speak, would be produced upon the structure. Q. Had you, however, an idea at all when you anticipated the limit of 25 miles an hour as a limit which should not be exceeded?—I had that in my mind; that it was not a structure with a wide base, and that therefore it was very desirable to limit the action of passing trains to as great an extent as was reasonable; and I therefore thought it more than possible that at a speed of course, the higher the speed or the higher the momentum brought to bear upon the columns the more tendency there would be to give it a rocking motion. Q. But even with that limit of speed, uniformly observed, would there have been from natural action the probable result that I have pointed out?—Loosening these catchers to any extent, a certain amount of vibration and oscillation introduced into the columns, and hence a tendency to loosen all the different joints of the structure. Q. Would the probability of that loosening be enhanced by the high winds blowing at one time from the east and at another time from the west? Doubtless that would also tend to produce a rocking motion. Q. If you had found any of these catchers in a condition which would have admitted of the insertion of a packing piece, would you have passed that as being sufficiently tight to warrant the bridge being used?—I should have called attention to it if I had seen it, and requested that the question should be tightened or replaced by a proper base, but the presence of two or three loose bars, had I seen them, would not have led me to think that the bridge was an imperfect bridge and could not be passed. Q. But supposing that you multiply two or three into 100?—It would have very much depended upon the nature of the slackness to be found. So much depends upon what you see when you examine the structure. Q. It was necessary, I suppose, to the satisfying of your mind that all these ties should, when passed by you, be as tight as they could be?—Certainly. Then I think there was something more that he said. At Question 16,000, I asked him this: "Now at any particular reference to those tie-bars at the time of your inspection, did they appear to be carefully tightened up?—So far as I saw, Q. I understand that your experience would lead you to expect, in structures of this character, that the user of the pier and the vibration of passing trains would in time slacken the ties and the rigidity, and would have that tendency I should expect. That is what you would expect as an ordinary consequence of the user of the bridge?—Yes. Q. And if that slackening was watched, and the tie-bars were tightened up whenever any slackness appeared, you would not be apprehensive of any serious con-
sequence, would you—No. One would think that the structure would remain as it was at the time; but those points were improperly attended to. Q. It has been suggested to you that if 100 tie-bars required packing, this would indicate looseness or inferiority in the construction of the bridge. I do not know whether you know how many tie-bars there were. I think there were something between eighty and one hundred of these, or eighty-four. I do not know if the precise number—I do not know. If at the period of my inspection I had found out or known that during the short time the trains had been running over the bridge 100 of those tie-bars had required packing pieces, it would have made me a little suspicious about the ultimate durability of the bridge.

But the fact is not what was the case, because it was not until long afterwards that the 100 were packed; in fact, nearly a year afterwards. Then I asked him this: I think there are something like 5,000, and 100 out of 5,000 is only 3 per cent. No. But still it would have been unsatisfactory to find that there was any looseness of this nature. Q. At the time that you inspected the bridge there had only been ballast trains running for two months?—Yes. Q. But you would expect that with heavy gales and constant traffic more of the tie-bars would show looseness?—I should expect, of course, that there would be looseness occurring from the effect of the wind and water; but it cannot be supposed; would you, if a year's work of the bridge in the first instance, (of course I mean when it was new) showed looseness in about one hundred of these tie-bars?—It would depend upon the amount of looseness that was produced. A year is a very short time in the life of a bridge. I can very well imagine the effect of getting tightening of the bridge, naturally of course, but when you come to the introduction of packing-pieces, of course it is a different matter. Q. If it was one-eight of an inch, would that be a very large amount?—I do not know. If one-eight of an inch would be a very large amount, but one-eighth of an inch would not render packing-pieces impermissible; I apprehend. I do not know what the thickness of these packing-pieces was.

From that evidence it is perfectly clear that in General Hutchinson's judgment, with a new bridge, you must expect a certain amount of loosening of the bridge, even when you send it to the pedestrians, the locomotive occurs; and watch the bridge, there is no causes whatever for anxiety.

At the time when my learned friend Mr. Trayner asked the question of General Hutchinson I know that he was under the impression (for he showed it by his questions) that this bridge, when once opened, was left to the care of miss; and that although Mr. Noble, from the order of the Government, and watch for scouring, and took the highest care of the rest of the bridge, you know that was an entire mistake of my learned friend's, because it is perfectly clear that not only was Mr. Thomas Booth engaged by the North British Company to supervise the maintenance of the bridge, Mr. Noble himself had a special staff, whose duty it was to watch over the bridge, not only as regards that which was under water, but as regards the ironwork, and who were constantly going over the bridge, and who did, in fact, report on their work, and time to time went over the bridge, tightening every one of the tie-bars. When Mr. Noble, by the order of the Government, went over the bridge, he had a specific duty, a special care, of the highest care of the rest of the bridge.

I think there was nothing wrong or loose up to the time of the collapse; that is my firm belief.

Q. Did you make any examination of the ironwork of the bridge except in those places where the movement of the bars and the noise made by that movement attracted your attention?—Yes. Q. Did you examine it from end to end?—Yes. Q. When did you make this examination?—Examinations have taken place in the bridge during these last 12 months on several occasions at intervals. Q. I mean before the catastrophe. What examination did you make with a view to find out whether the cotters were sound and tight, apart from those places which you had repaired with packing pieces?—It made up my mind, I think, to look at the columns I think in the month of October last, the latter end of the month and the beginning of November, and I went through the whole of the work, and we found then that I think a cotter or two loose. I think they had been all made good previous to that. Q. All but those that you made good?—Yes. Q. Will you give me an idea of what you mean by saying that you found one or two of the cotters somewhat loose in October, immediately before the catastrophe?—In examining the columns of the bridge we tried the braces with a hammer, and we found, I think, only two loose during the month of October. Q. Did you put the right—Yes. Q. Were those in the upper tier?—No. I think it was on the standing portion of the bridge towards the north side; it was not in the large column at all. So that in the whole of the 18 high girders there was not a single cotter found loose; the only ones found loose were in the northern part, and it appears from Mr. Noble's report, if you will remember that they had had, as he describes it, a hurricane, I think in September, as bad, he says, as the one which blew the girder down; and yet in October, these things having been cotted up tight in the early part of the year, it finds only two loose in the whole of the bridge, and that is not the part which broke down. And yet this is a structure which, if you will believe Mr. Law, is of such a remarkable description that the whole thing was ready to topple over on the least provocation whatever.

Then, to follow that up, you have the evidence of the engine drivers, the men who worked over the line, brought up to the very latest, even those who were懂ing the one to which the accident happened, who tell you that there were no signs of oscillation or looseness at that time. One of them is Kennedy, who was the driver of the preceding train, and who, when he was asked at Question 1076, whether he had found the train vibrate more than usual, said, "No, not in the least." Then you have the evidence of Brand, who was the driver of another preceding train.

(The Commissioner). You will find also the evidence of two persons who travelled with the guard in the train which immediately proceeded this.

(Mr. Bidder). There we have a body of evidence beginning with the inspection of General Hutchinson. You know that a certain number of these cotters did come loose, and that they were all cotted up tight; that it was tight at the time of the accident, that it had stood a very severe hurricane in the autumn, and only two cotters in the whole bridge had shown loosenesses afterwards; and that up to the last moment there was no sign of looseness or oscillation.

I must make an observation or two more with reference to the theories of Mr. Law, because I feel that it is important that I should do so. I think one may very fairly infer that Mr. Law would say something like this: "I make these observations because I know it is suggested that although it is all tightened up, and although to the eye of anybody he be engineer or not, it is as sound as strong, and as rigid as any bridge could possibly be, I must deny that the whole bridge is a hollow sham and a farce."
(Mr. Barlow.) You are not quoting from Mr. Law's report now, are you?

(Mr. Bidder.) No, I am putting what I take to be the substance of it. You know Mr. Law is compelled to do this, because he has shown you that if this tightening of the tie-bars is real tightness, 50 lbs. of wind would not really over-tighten them. You seem to think that in condemning Mr. Law, I have put it in more evident than there was in the original, but I do not know that that is so. I read his last report, in which he says this: "I would sum up by the statement that, in my opinion, the base of the pier was too narrow, occasioning a very great strain upon the struts and columns, and the angle at which the struts were disposed, and the mode of connecting them to the columns, were such as to render them of little or no use, and that the other imperfections which have been pointed out lessened the power of the columns to resist a crushing strain. I consider that the yielding of the struts that was the immediate cause of the disaster, but that the other circumstances stated contributed to it." See the dilemma in which Mr. Law is put. At the time he wrote that report, he had comfortably demonstrated to his own satisfaction that 30 lbs. of wind would turn over the bridge, if everything was in good order, and, therefore, he could not go too far in what Mr. Kirkaldy's testimony as to what was the real strength of this bridge has altered his figures, that when I came to drive home to him the conclusion arrived at by the application of these tests to the bridge, instead of the assumed figures which he had previously taken, he is driven to the conclusion that if these ties held, and if they did bear what Mr. Kirkaldy has shown that the tie-bar was the immediately cause of the disaster, but that the other circumstances stated contributed to it. The dilemma in which Mr. Law is put.

(Mr. Bidder.) However loose a thing might be, it does not chatter until there is something to be put in motion; so long as all things are quiescent it remains still; it does not of its own wonton motion go rapping against another tie-bar.

(The Commissioner.) I have not made myself quite understood. If the tie-bar was lengthened in any way, whether the pillar was hanging over or whether it was upright, there might be a chattering if the pillar was shaken?

(Mr. Bidder.) Yes, if the tie-bar is lengthened, then the length between its attachments. The tie-bar, being originally tight, the strains are lengthened. The tie-bars do not grow longer like vegetables in the ground, and a strain that lengthens it will keep it tight until the strain is taken off, and it can only become loose by the head of the column which strained it coming back to some extent.

(Mr. Barlow.) That particular bar.

(The Commissioner.) The theory is this: that in the event of the head of the column being forced out by the lengthening of the bar, the column immediately above it being vertical, pressing down upon it, might, as I understand, tend to keep it in that position; and that then, in the event of there being any vibration, this might vibrate, but still the permanent position would be at the extreme, holding the tie-bar tight.

(Mr. Bidder.) Of course I follow that. My answer for that is that there are forces on all sides. If you assume that the head of a certain column has been displaced through a certain distance, nearly all the forces are connected with the remaining part of its own flexion, which is one of the most important things of all, is tending to bring it right, certainly the tension of the tie-bar, which is by presumption strained, is tending to bring it right.

(Mr. Barlow.) Tending to bring it right to a certain point. The tie-bar will cease to bring it back, if you approach such a limit as that you require to put in a
packing-piece afterwards. That was a permanent stretching of the bar.

(Mr. Biddell.) In the case of the bolt, obviously it is as if you had to go to the limit of the elasticity, because a bolt once bent will never unband, but when you put in the packing piece you take that in.

(Mr. Barlow.) It all really turns upon whether the pier has elastic action enough to return to its original position.

(The Commissioner.) And consequently the only power—which would tend to bring it back to its original position—would be that elasticity which was excluded in the observation that you made. No doubt it is a power to be taken into consideration.

(Mr. Biddell.) And the strain.

(Mr. Barlow.) Not the strain of the tie any further. The elasticity of the tie will carry it. If it is permanent set in the tie, then the elastic action soon passes away.

(Mr. Biddell.) Under ordinary circumstances the elastic force of the pillar is a quite sufficient force to bring the pillar back to its normal position.

(Mr. Barlow.) If you had put it upon that condition, you should not have shaken my head.

(Mr. Biddell.) Then, Sir, I will put it on that condition.

(The Commissioner.) The elasticity of the pillar would only tend to bring it back, not to its original position, but only so far as the elasticity had carried it beyond the point to which it was distorted by the action of time.

(Mr. Biddell.) I do not at all agree with that, Sir.

(The Commissioner.) Supposing, to take my illustration again, that by the elasticity of the tie the head of the column was thrown out, say, two inches, and that by further elasticity it was thrown out an additional two inches; then the elasticity would bring it back two inches, but not bring it back to its original position.

(Mr. Biddell.) Of course the whole argument upon the flexion of the columns assumes that for this purpose each column may be regarded as firmly rooted to the column below it; and I think Dr. Pole and Mr. Stewart satisfied you that, comparing the force upon the column, which they calculated at only one ton and a fraction, with the holding-down power of the bolts, it is so far below them that there is no question that this margin is so great. If you assume a cylinder, a column which is fairly anchored at its base and is standing vertically with its head in a certain position, you may by lateral forces change that position; but it will never be happy unless the head of the column is in its original position. It will be always trying with greater or less force to recover its original position.

(The Commissioner.) No doubt.

(Mr. Biddell.) I think the question of uprooting is eliminated by the comparison of strength, but if it were not, then the force of gravity would come to rectify it. If you put in this instants, the moment I lost go, the instant tends to right itself. That is another force that would come into play if it were in any sense uprooted.

But now let me suppose that all these things are away, and I like to look at the worst conceivable situation. I suppose that all Mr. Law's suggestions are realised; that all these tie-bars were wrong in the sense, and that they had all been slackened up, and then tightened up afterwards. What is the maximum amount of distortion that is possible? It is limited in another way, the approach of the column is limited by the struts. Now, there is a certain amount of play possible in the struts, as Mr. Law suggested, and I will assume that it is so, because the bolts not being so big as the bolt holes, and he says that the nip would not hold, though Mr. Baker tells you that the German engineers have come to a different conclusion—one-eighth of an inch on each side is a quarter of an inch—unless you fractured these struts, nothing would permit any one of these columns to approach nearer by a quarter of an inch than it was intended to be to the column contiguous to it—that is the maximum of the distortion of any joining columns are never distorted, relatively more than a quarter of an inch, yet if you have canted a column, and continue the same thing, you will get seven quarters of an inch at the top. Take two inches at the top, what does it do? I desire Mr. Barlow's and Colonel Yolland's careful attention to this. Supposing that you have distorted the heads of the columns to the extent of two or even three inches, and then have tightened it, presuming that those things have given way, and that the result is distortion, you have weakened the stability of the bridge to this extent; that you have brought the load so much to one side of the centre, and you get less stability from the load. But with that exception it is very difficult to show, assuming that all is carefully tightened up, and that the tie-bars are bearing the strain, the stability of the bridge is in any way impaired. I admit that to that extent, if the thing has a permanent set over to the one side or the other, proportionately you diminish its stability in that sense. But I know of no particle of evidence that was the condition of things here. It is incredible that this gentleman, Mr. Noble, who is admitted by everybody to be a very careful and efficient man—even Mr. Law himself says he is a most careful inspector, and one whom he would trust to inspect anything.

(The Commissioner.) For brickwork, I think, he said.

(Mr. Biddell.) For this very work. It is incredible that if there had been any distortion of any such magnitude as has been suggested now, it should not have been noticed by Mr. Noble. Here is not one particle of evidence that there was such distortion in the tie-bars. Let me suggest how I would build up a thing of this kind, and the bridge, which according to Mr. Law was capable of resisting 80 or 90 lbs. of wind, went down with something which was a mere fraction of that, is to build not upon evidence, but upon more surmise, without any foundation whatever. I set against the opinion of General Hutchinson and of the witnesses whom I have called, Dr. Pole, Mr. Stewart, and Mr. Baker, all of whom say that if you take care and cotter up, and keep the structure tightened up in good order, there is no fear whatever of any damage being done, even if you have to some slight extent to introduce some slight distortion into the structure.

Sir, there were many points that I might attack. There was a question of cracked columns. I just notice that in passing, but I do not think I need trouble you about that. Three columns were found cracked altogether, all cracked in the same way, all cracked vertically—there was no trace of transverse cracks—only one of those was within the area of the high girders, and every one of them had been carefully observed. It is quite possible that there may have been another column, or more than one other similarly cracked; but even assuming that, I think I may say from memory that that could not have been regarded as in any way contributing to the accident. A vertical crack would theoretically weaken the column, for it is known that as the tension is increased the strain is more and more concentrated. I think Mr. Law himself admitted that he did not regard that as in any way contributing to the accident.

After some conversation as to the further proceedings—

(Mr. Balfour.) We have been carefully considering whether it would be necessary for me, on the part of the railway company, to detain the Court with any observations. All these matters will be, I think, fully placed before the Court by the designer on the one hand, and the contractor on the other, and the Board of Trade; but I should like to reserve it until I hear Mr. Webster.

Adjourned till to-morrow at half-past 10 o'clock.

7 May 1880.
TWENTY-FIFTH DAY.

Saturday, 8th May 1860.

(Mr. Webster.) With regard to the information which was asked for by Mr. Barlow yesterday, it did not occur to Mr. Gilkes, when he said he could get it by this morning, that it would not all be in the hands of his own firm, because a part of the bridge was not built by the firm of Hopkins, Gilkes, and Company. It shall be supplied, of course, to the fullest extent, but he will have to get that information from Mr. Yelken, and therefore it cannot be completed so as to be furnished to you this morning.

(The Commissioner.) Some portion had been erected which he took over; something like 600 tons.

(Mr. Webster.) I believe that is so, Sir.

(Mr. Bidder.) Before I go further, Sir, I will make one or two observations upon one or two matters that I have referred to, and the first is with reference to the Astronomer Royal's suggestions that you might have on a certain extent of this bridge 40 lbs. or 50 lbs. of wind, which, I ventured to say, seemed to me to be contrary to reason, and I should like to explain it clearly, because you, Sir, put it in another perfectly fair way.

(The Commissioner.) I am glad to hear you say that, because I have worked it out since, and it seems to me that the conclusions to which I came were perfectly just.

(Mr. Bidder.) The Astronomer Royal suggested that it was quite possible that you might have on the extent of some of those girders 40 lbs. or 50 lbs. of wind. What I meant by saying that appeared to be inconsistent with his Forth Bridge Report was this: that if you take the trouble to refer to Mr. Law's report, which gives you the surface of this girder (remember that the two are both lattice girders of a similar character), you will see at page 24 that the surface of the girder without the pier (for these purposes I put aside the pier) is 3,750 feet; and that consequently a pound of wind is represented by 14 ton upon the surface of the girders, taking the lower figure, and not the higher, if you only take 40 lbs. of wind upon that, it amounts, without counting in the pier at all, to something like 67 or 68 tons upon one of those girders. Now the Astronomer Royal's Report in 1873 contemplates that the greatest aggregate of wind pressure that could come upon the whole of the Forth Bridge, 1,600 feet long, is 64 tons. That is what I mean when I say that, it seems to me that observation is inconsistent with the Forth Bridge Report. To my mind it is impossible to conceive that a whole span of the Forth Bridge would not be subject to more than 64 tons pressure, and that a span of a bridge, which is between one-sixth and one-seventh of the length, and not so high, of a similar nature, open lattice work, would be subject to an actually greater pressure of 68 tons. I hope I make myself clear.

(The Commissioner.) No, I do not understand you. I should prefer to amplify the problem in this way: you seem to think that that appeared to be inconsistent with the Forth Bridge, possibly having to do with the Forth Bridge in 1873 any templates that the greatest aggregate of wind pressure that could come upon the whole of the Forth Bridge, 1,600 feet long, is 64 tons. That is what I mean when I say that, it seems to me that observation is inconsistent with the Forth Bridge Report. To my mind it is impossible to conceive that a whole span of the Forth Bridge would not be subject to more than 64 tons pressure, and that a span of a bridge, which is between one-sixth and one-seventh of the length, and not so high, of a similar nature, open lattice work, would be subject to an actually greater pressure of 68 tons. I hope I make myself clear.

(The Commissioner.) No, I do not understand you. I should prefer to simplify the problem in this way: I need hardly say that all those who have, I have more than 40 years ago, studied Airy's Tracts, must have been very high opinion of the Astronomer Royal, and must be very jealous of his reputation, and therefore think, or at least I, speaking for myself, think that any observations which would tend to lower his reputation are, to say the least, uncalled for, and deserve most careful examination. All the Astronomer Royal said was this, that he believed that for from 150 to 200 feet, that is to say one-eighth of the Forth Bridge, there might be a pressure upon that bridge (confining his attention to the Forth Bridge, and to the girders of the Forth Bridge with no pier or anything of the kind) of from 40 to 50 lbs. Now, assuming that upon one-eighth of the girder of 1,600 feet long there was a pressure of 50 lbs., and assuming that upon the other seven-eighths there was a pressure of 6 lbs., or multiplying that by seven, that there was seven times the quantity, which would be 42 lbs., that would make a pressure of 92 lbs. upon the whole one-eighth; or dividing that by eight that would give us an average pressure of 11 lbs. But supposing, on the other hand also, that we take a pressure upon one-eighth of 40 lbs. and upon the other seven-eighths of 32 lbs., that gives 6 lbs. and dividing that by eight that gives us 11 lbs. I think therefore that the Astronomer Royal was justified in saying that whilst there might be that pressure of 50 lbs. over a space of something like 200 feet (he said from 100 to 200 feet) it did not follow at all that there would be on the whole 1,600 feet more than a pressure of 10 lbs. to the square foot. And when I take 6 lbs. as the pressure upon seven-eighths of the girder as distinguished from the 50 lbs. upon the one-eighth, we must recollect that 6 lbs. pressure is a very considerable and a very high pressure. A 6 lbs. pressure is equivalent to, in a very well-known table, a table that is known to all persons who have made the subject of the laws of storms a study; a pressure of 6 lbs. is equal, according to Rouse, to 35 miles an hour, and according to Hutton's Tables, to 38·65 miles an hour, and that is described as being a very high wind. If we increase that to 10, assuming the pressure upon one-eighth to be 60 lbs., and upon the other seven-eighths to be 10 lbs., which is equivalent to a great storm, we then get an average over the whole girder of 14 lbs. to 15 lbs. upon the square foot. Therefore, I do not think the Astronomer Royal is open to any animadversions for the statement that he made in the report which he gave to Mr. Barlow and to Dr. Polo, that they would be safe in calculating that there might be an average pressure of 10 lbs. over the whole of the girder of 1,600 feet. I think it necessary to make these observations.

(Mr. Bidder.) I have followed your observations, Sir, and I do hope it will not be supposed that, to use your expression, I made any observation which tended in any way to lower the reputation of the Astronomer Royal, for whom I have so great a respect as you can possibly have, having also studied Airy's tracts as well as yourself.

(The Commissioner.) I am sure you have.

(Mr. Bidder.) What I thought I explained yesterday, and what I desired to make clear, was this, that that particular answer, and one or two answers in that matter of the Astronomer Royal were answers to results put to him without any opportunity for consideration as to how they bore upon and were consistent with his report. As I explained before, if the Astronomer Royal had had time to consider the matter he would not have given those answers. I do not think it is in the least degree derogatory to say man's reputation to suggest that and upon the strength of the moment, without having the slightest opportunity of giving the matter careful consideration, he has given an answer which, if he had had time to think over it carefully, he would have seen was not, as I think, consistent with the Forth Bridge Report. I quite follow the way in which you put it, Sir.

(The Commissioner.) I do not want to interrupt.
you, but I should say that the question of wind pressure and the course of storms is not a subject that I have newly taken up; it is a subject that I have pursued for nearly 40 years, and I think there are very few books upon the subject that I have not read; and therefore I was quite prepared to accept a good number of the statements that were made, and to understand them also.

(Mr. Bidder.) What I wish to point out now, not for the sake of justifying my remarks, but for the purpose of the matter that we are discussing, is this, Sir, and I must press it upon the consideration of the Court, because there are two statements, if you please, in the Astronomer Royal’s Report, and you have once referred to them; this is to say, an average pressure of 10 lbs. upon a plane surface of equal extent to the Forth Bridge. There is a subsequent statement of the Astronomer Royal that, taking into consideration that it was open lattice work, and making deductions for that, in his judgment the entire pressure upon the whole bridge could not exceed 64 tons. That is a distinct and independent statement of the Astronomer Royal’s as the result of his judgment of the maximum pressure of the wind that could be expected upon the side of a lattice-girder bridge whose length was 1,600 feet and whose height was 100 feet.

(The Commissioner.) Were there not two girders upon the Forth Bridge plan?

(Mr. Bidder.) Yes; Sir, there were two.

(The Commissioner.) Does the Astronomer Royal apply that to the one or to the two?

(Mr. Bidder.) If I took in the two it would make it much worse. I prefer to take it simply as a lattice girder like this; if there were another girder beyond to catch more wind it would make it better for that.

But putting that on one side, the aggregate wind pressure, which is the judgment of the Astronomer Royal—is the maximum to be ever expected to be borne by a lattice-girder bridge, 1,600 feet long, and 40 feet high, the Forth Bridge was 64 tons. If it be possible that upon one girder of this bridge 40 or 60 lbs. of wind pressure can be sustained that results necessarily by mere arithmetic, applying it to the surface of the bridge in a pressure, taking it at the lowest of 68 tons. My observation was that the two things appeared to me to be inconsistent. Insanely as the use of the smaller bridge is, less than one-sixth the length of the girder of the Forth Bridge, and instead of being 40 feet high, is only 27 feet high, to my mind it is incredible that if in the bigger bridge, which is something like nine times the area, you can only have 64 tons, you can have upon the smaller bridge 68 tons.

(The Commissioner.) As regards that I follow you.

(Mr. Bidder.) Now I have one or two observations to make, with reference to the way in which you put it yesterday, and to-day, and which bears more upon the first of the Astronomer Royal’s expressions of opinion, that the average over a plane surface occupying the position of the Forth Bridge would be 10 lbs. to the foot, and to this very fair way of putting it, and I do not complain of that, only I do not quite agree with the force of your figures, or rather perhaps with the deductions that you draw from them. If you have a pressure of 50 lbs. upon one-eighth of the Forth Bridge, insanely as you are only to have 10 lbs. over the whole, you must only have a little over 4 lbs. on the rest—4 or 2 lbs. If you treat the bridge as being 8 units long, and you have got to have 80 lbs. pressure over the whole, if you have 50 lbs. on one unit, there are 38 lbs. left for the other seven, and that of course is 4.2 lbs. on each; a pressure of 4.2 lbs. is something over 30 miles an hour; I do not care to inquire exactly what it is. It is quite true that 30 miles an hour is a brisk strong wind.

(The Commissioner.) I admitted that at once. Limiting it strictly to 10 lbs., I said that with a 6 lbs. pressure it would give 11 lbs.

(Mr. Bidder.) I am discussing of course what he said. If he had said 11 lbs., then the observation would have been to some extent modified. It is quite true that 4 lbs. of wind is a good strong wind, but to my mind it is impossible to begin with. I think that you could have 40 lbs. or 50 lbs. of pressure on 200 feet, and then on each side of the wind it would immediately fall down to 4 lbs. or 5 lbs.

(The Commissioner.) Yes, there are the whirls of which he had been speaking.

(Mr. Barlow.) I do not know that that is at all impossible or even improbable.

(The Commissioner.) Nor is it unusual.

(Mr. Bidder.) I will simply say, Sir, that it is a thing that I should not have expected.

(The Commissioner.) But it is a thing that is borne out by the evidence that has been given in this case. Mr. Scott has given evidence as to that.

(Mr. Bidder.) However, I was dealing more immediately with the second part of the report which assumed the aggregate wind pressure to be 64 lbs. That was what I meant when I said that it seemed to me to be a thing that I could not reconcile under the circumstances, that a bridge with one ninth of the area should be actually subject to a greater pressure than a bridge with nine times the area.

(The Commissioner.) I am very glad we have had that explanation, because I am quite sure that you have as much respect for the Astronomer Royal as I have.

(Mr. Bidder.) I need not say that I have as great a respect for the Astronomer Royal as anybody. Now there are one or two other matters that I want to refer to. One word more with reference to the Walmer case; you remember an observation, I think it was made by Mr. Scott, that you must not assume that all the devastation, whatever the width of it was, was simultaneous. I am afraid I cannot give you the reference to the answer. Of course for the purpose of this question the whole point is whether it was simultaneous, and I will refer you to one other of Mr. Scott’s answers which I do not think I read yesterday. At Question 16,386 he is asked, “But are we to conclude that the impression upon your mind from the very large experience that you have had is that these gusts have a very small lateral extent?—I think some of them have a small lateral extent. Q. Do you mean to the extent of 80 or 90 yards, or only a few feet. I should think that some of them have an extent of a good many feet, some 30 or 40 feet, but one cannot be sure.”

(The Commissioner.) Then you will observe that Mr. Scott says that the breadth of the track of the Walmer whirlwind was in no place less than 430 feet, and in no place greater than 700 feet. He went also into the Ballochulish storm.

(Mr. Bidder.) I did not trouble you with every one of the illustrations.

(The Commissioner.) There was another case in which he said it was likely at any rate that it extended over about 200 yards.

(Mr. Bidder.) There, again, I should make the same observation, but I now assume that damage was done simultaneously to the two houses which are in the position which he indicated. It would not follow that there was one gust of that width. At Question 16,387 as regards the Ballochulish Valley, he says, “We do not know that it was the same gust that unroofed the two houses at the same moment of time.”

(The Commissioner.) That is the one that I was referring to.

(Mr. Bidder.) Whether he said it or not, I should say that the observation applies equally. Then, with reference to the breaking of the lugs and the rest, there was another observation that I wish to make: Mr. Baker pointed out that in his judgment (and I think Dr. Pole said the same) the fact that in every case it was the cast-iron lug that had broken, seemed to indicate to him a shock, and Colonel Yolland pointed out (and a very pertinent observation it was) that that inference would seem to be affected by Mr. Kirkaldy’s tests showing that the lugs broke with a
less ultimate tension than the tie-bars (I think that was Colonel Yolland’s observation) and that being the case, it does not require the assumption of a shock to the tie-bars for the tie breaking at the lug instead of the wrought iron. That is a very pertinent remark; that if you look at Mr. Kirkaldy’s tests it is quite true that some of the lugs broke with a less tensile strain than the tie-bars; but you also find that a good many of them required a much higher tensile strain than the tie-bars, they rose up to 50,000 and 60,000.

(Mr. Barlow.) Higher than the tie-bars.

(Mr. Bidder.) The tie-bars were 56,000 lbs. I think.

(Mr. Barlow.) But they were broken by means of the tie-bars; were they not, and not by any independent thing?

(Mr. Bidder.) Yes, Sir, that is quite true; and therefore that particular tie-bar must have stood also over 60,000 lbs.

(Colonel Yolland.) Some of the tie-bars broke at the same figure exactly.

(Mr. Bidder.) It is quite clear that some of the lugs broke at considerably higher strains than some of the tie-bars. Of course in the particular instance that Mr. Kirkaldy tried it was the lug that broke, and therefore that tie-bar stood more than the higher did; but inasmuch as we have the fact from Mr. Kirkaldy’s experiments that it is by no means uniform that the lug breaks at the lowest figure, and that we know the higher of the tie-bars have a lower at lower figures than a good many of the lugs, one would have expected, if it had been a fair pull that smashed them all, that in some of the instances it should have been the tie-bar and not the lug which should have broken.

(The Commissioner.) At the same time, as far as I remember the evidence, there was no instance of a tie-bar having broken.

(Mr. Bidder.) I believe the evidence is that in every instance it was the lug that went.

(Mr. Barlow.) I do not think that is so according to these experiments of Mr. Kirkaldy on the 30th of April.

(The Commissioner.) But I meant on the bridge itself.

(Mr. Bidder.) In the ruins there is no single instance in which it was the tie-bar that broke.

(Mr. Barlow.) In these experiments it was sometimes the one and sometimes the other.

(Mr. Bidder.) Yes, Sir, and I say that, judging from Mr. Kirkaldy’s experiments, if it had been a fair pull, one would have expected that in some cases it would have been a tie-bar that would have given.

(The Commissioner.) That is a fair remark; that under Mr. Kirkaldy’s tests the tie-bars did break on some occasions, whereas on the bridge, so far as we know, the tie-bars did not break.

(Mr. Bidder.) Then, Sir, with reference to the point that was raised by Mr. Law, and which has been adverted to, of the possibility of the shearing, the lateral shifting of the columns interfering with the stability of the bridge although the tie-bars were tightened up, Mr. Law has made what seems to me a very strange oversight, because he says that insomuch as, especially at the bottom, there was no spigot and flange and the bolts were not the actual size of the holes, I think he says in one place there was nothing but the pinch of the bolt to resist the lateral motion or shifting of the column on the base piece below it. Now it is a simple fact to Mr. Law should have overlooked the friction, the necessary friction, due to the weight which presses vertically upon the column, which friction is itself more than double the maximum lateral pressure which even Mr. Law assumes the wind to have exerted upon this bridge; because, as Dr. Pole pointed out to you, the vertical pressure upon the columns is 417 tons. I think.

If you take one-fourth of that for friction, you have got something like 130 tons, whereas, even with 40 lbs. of wind, the aggregate pressure upon one pier is only 70 tons, so that the friction alone is equal to nearly double the maximum wind pressure that anybody suggests could have been brought to bear upon the bridge.

(The Commissioner.) I would only make one observation, which I made to Mr. Barlow first, with respect to the friction, which no doubt Mr. Law did not mention. The friction, no doubt, would act so long as the surfaces were directly in contact; but if from any cause the surfaces were separated, even by the hundredth part of an inch, the whole force of the friction, so far as those surfaces were separated, would be destroyed. Do I make myself understood?

(Mr. Bidder.) You make yourself understood, Sir; but I cannot say that I agree with that observation, because, unless the cause which separated the surfaces was something in the nature of a balloon, which lifted the one column from the other, there must be contact.

(The Commissioner.) No, not lifted—meant.

(Mr. Bidder.) If the column is tilted, you have not destroyed the contact of the surfaces altogether; you limit it to a certain area.

(Mr. Barlow.) Could you refer me to that part of Mr. Law’s evidence of which you are now speaking?

(Mr. Bidder.) Mr. Macnery will find that for me. Meanwhile I will say that if you assume the column to be tilted, you have limited the surface; but remember that the generally accepted principle is, that friction is proportionate to pressure, and not to the extent to the surface.

(Mr. Barlow.) But I would call your attention to this: that in Mr. Law’s report he says that a beam in a compressive action in the outer columns when the pressure of the wind exceeds a certain amount, I think 20 lbs.

(Mr. Bidder.) The windward column. That is quite true of a particular column; but one is entitled to treat it as a whole in this way: that column shifting alone, brings it nearer the others, and that is limited by the struts.

(Mr. Barlow.) That is going away from the point. If you destroy the weight on the outer column, you destroy the friction.

(Mr. Bidder.) It is quite true that friction will not come into play in that windward column. If you could regard that column alone as free to shift without reference to the other, that would answer me as regards that column; but you must remember that at present we are talking of the thing before it is upset.

(Mr. Barlow.) This is not upset; this is a mere action arising out of the elastic properties of the material with a wind pressure of 20 lbs.

(Mr. Bidder.) That is quite so; I quite admit that there is no friction beyond the case of that windward column, but the strain determined the distance between that column and the column to windward of it. It cannot approach the other column without throwing the lateral strain, the sheering strain upon the heeward column; and therefore you must, ultimately bring that strain upon the column where the friction is.

Then with reference to the observation that suppose a column has been subjected to the same force, you must remember that that does not apply. For this reason: because we have shown already that assuming the tie-bars to hold up to the strains that we know they bore, the play upon the head of the column, the flexure of the head of the column is quite insufficient to produce the uprooting, having regard to the holding power of the bolt, and therefore uprooting, that heeling over, under those circumstances, cannot come into play. Mr. Law’s suggestion on this point was rather to account for how the thing might have been given way, although it was true that the tie-bars had not given way and the uprooting action had not commenced. Consequently you must not pry in &c. of the uprooting action, and the suggestion is at Question 18,937., “There was nothing to resist that motion, and in every case it took place.” And upon that let me make another observation. It seems to me to be entirely fallacious to draw any inferences, as Mr. Law does, from what he knew.
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I venture to say that even if you find cases, I think there are very few indeed if you look at the photographs, where there is any indication whatever, of there having been a lifting, you cannot possibly argue from what happened in a shock, a general collapse of anything, that such a thing happened before.

(Mr. Barlow.) I do not think Mr. Law intended to imply that at least that was not the impression I got from my own mind.

(Mr. Bidder.) I think it is the inference that one would draw from that answer. Then, as I pointed out, in the examination of Mr. Baker, Mr. Law seemed to infer from the fact that he had found bent bolts, that that was an indication of shifting. I venture to think it is not of the kind, because ultimately we know, when the thing came to smash, many of those columns were turned over, and as I pointed out, the other day, it is almost inevitable if you do turn over a column that you must bend some of those bolts — those that are on the fuller side; and consequently it is by no means an astonishing thing, but what you would expect, that you do find bent bolts, bent, not by any shearing action, but by the wrench and twist, when they get as the column is tilted over. I think if you pinned a thing down by four pins, and then turned it over, you would find that two of your pins at any rate were bent.

(The Commissioner.) All of them, I should think.

(Mr. Bidder.) They would be bent in different degrees.

(Mr. Barlow.) I think what Mr. Law rather meant was (though of course one ought not to interpret what another man said) that if the bolts had fitted closely, if they had been turned bolts with bored holes, they would have sheared and not bent; but to some extent they would undoubtedly have bent then.

(Mr. Bidder.) At any rate, it is sufficient for me to say that being bolts in holes larger than themselves, they would bend.

(The Commissioner.) As soon as the surfaces were separated.

(Mr. Bidder.) And that bending would be due to an entirely different action from any shearing. I wish also to make a reference to an observation of Mr. Baker, with regard to the efficacy of the pinching action of the bolts themselves, which Mr. Law seemed to infer very slight indeed. If you look at Question 19, 443, he says, speaking more particularly with reference to the struts (but it applies of course to each case in which the same action obtains): "You have no right to assume that the struts would slide.

"The friction is simple to hold them. Experiments have been tried over and over again upon that point.

"And quite recently some German engineers went very carefully into the question, and they found that the friction was equivalent to a shearing strain of seven tons per square inch upon the bolts holding it together. For instance, if it were an inch bolt the friction would be sufficient to withstand a pull of 7 tons."

That shows the size of the pinching action of the bolts, even if they were alone, is sufficient for the purposes for which it was called into play.

Then, Sir, I must notice with reference to one or two of the suggested imperfections of the structure, such as the inequality of the columns in the casting, that it must be argued as if those are, if I may so say, cumulative defects, because what determines the stability of a pier would be the greatest part of it, and granted, if you please, that any of the columns were weakened, if they are by the eccentricity of the castings, or by a crack in their sides, yet if, as is the case, the margin of strength in the column for doing its work and if other parts, it is quite clear that that weakness in no way contributes to the accident. I mean to say (I trust I make my meaning clear) that even if the column be weakened, yet if the column in its weakened condition is far stronger than sufficient to do the work that it can be called upon to do before the tie-bar snaps, the weakness of that column has nothing to do with the accident.

That being so, Sir, it seems to me, as regards the bridge and its condition, that I arrive at this point; that even taking into consideration all its imperfections, which I admit were unusual or more than necessarily occur in the construction of any great work, it requires, applying Dr. Kirkaldy's tests, nothing short of 40 lbs. of wind to overturn any one of the columns in the most moderate calculation; and if you accept Mr. Law's figure, it requires a great deal more — more like 84 or 90 lbs. As designed it would require a great deal more. What I mean is this: Mr. Law's 110 lbs. reduces itself to between 80 and 90 lbs., because Mr. Kirkaldy's tests show, that the worst of these huge would break at 21 tons; but as designed, those huge ought to have borne a good deal more, and, therefore, instead of 80 or 90 lbs. of wind being requisite to break the bridge, according to Mr. Law's calculations, it should have required at least 110 lbs. But, speaking of it now, not as designed, but as it was, and applying the result of Mr. Kirkaldy's tests, Mr. Law's calculations come to the result that somewhere between 80 and 90 lbs. of wind are requisite.

(Mr. Barlow.) Always going back to the idea that the columns were firmly rooted down, which in point of fact was not the case, they were only rooted down to the extent of 3 feet. Therefore it is rather an imaginary ground that we are dealing with just now.

(Mr. Bidder.) I hope not, Sir. I thought that I had cleared that up.

(Mr. Law.) You are assuming, are you not, that the columns are bolted down too.

(Mr. Bidder.) Firmly rooted at the idea I think was my expression, and I submit to you that the evidence shows that for the tension that would be brought upon the bolts before the result would happen of breaking the tie-bars, they were firmly rooted down.

(Mr. Barlow.) I am not prepared to say that at the moment, but I will not interrupt you.

(Mr. Bidder.) As far as the bolts are concerned I refer you, if you remember yesterday, to Mr. Law's report, which shows the holding-down power of the bolts between the flanges and between the columns and the bases, and then, if you recollect, Dr. Pole tells you that it would have been 40 lbs., and that, strangely enough, is the more adverse calculation to me; we are accustomed to see one's witnesses give one the most favourable view, but according to Dr. Pole's calculation it would have been 40 lbs. of wind. Dr. Pole in arriving at that result only gives the head of the column credit for 2-8 tons.

(Mr. Barlow.) The 18-inch columns?

(Mr. Bidder.) And the 15-inch columns less.

Now I will leave that question in your hands, Sir, with the greatest confidence, with simply this observation: if you are dealing with Dr. Pole's figures, remember that the only work that the column does is by its flexure resisting the horizontal force from the columns of 2.3 tons; and if you have any doubt about the correctness of my statement that the column was firmly rooted for the purpose of resisting the tensions that would come upon it, you can try for yourselves what strain a lateral pressure of 2.3 at the head of the column would have put upon the bolts and compare it with what Mr. Law himself gives you in his report as being the holding-down power of those bolts.

Then if one goes a step further down with reference to what you said just now, and inquires once more about the final attachment to the masonry, it seems to me that you will satisfy yourself that it is sufficient; but I would rather rest it upon this, if you look at the photographs of what happened. I do not think there are more than two or three instances throughout where the masonry is lifted.

(The Commissioner.) Two. You are quite right it is all separated at the base of the columns.
in almost every case the base is shaken, but in the case of the two piers at the expansion junctions the stonework is completely lifted up. That is No. 5 and No. 9, I think.

(Mr. Bidder.) In pier No. 5 and in pier No. 9 there is a lifting of the masonry.

(The Commissioner.) If you look at pier No. 6 you will find that in almost every instance there is a tendency to lift there.

(Mr. Barlow.) There is a loosening of the masonry.

(The Commissioner.) You will observe in the second course a tendency to loosen.

(Mr. Bidder.) I see what you mean, Sir, now; you mean that there is a crack under what we call column No. 6?

(The Commissioner.) That is quite right.

(Mr. Bidder.) The observation that suggests itself there is this: True, there is a crack, but where did that column give way?

(The Commissioner.) It will give way at the lower bolts in almost every instance. That was the weakest point, and the holding-down bolts were rather stronger in fact than that.

(Mr. Bidder.) If there is no question about it that the strength of the holding-down bolts was greater than the play upon the columns would bring upon them under the circumstances of Dr. Pole's calculation, it shows me that my observation is well founded.

(The Commissioner.) If you will look at column No. 10 you will find again that that is all shaken.

(Mr. Barlow.) I do not know that much can come out of that; that is a result of the fall.

(Mr. Bidder.) It is so difficult to argue from the ruins. One must not forget this: that according to Dr. Pole, and I think I may say according to Mr. Law, and according to everybody, the point to give way is the tie, as you would expect. We know that they did all give way, or rather that the lugs broke. Once assume that that has happened, what is going to happen next? The columns are as weak as water standing by themselves, and they all snap like so many reeds; and therefore my answer is that we have the fact that in every case the evidence of the ruins is that it was the lugs which gave, and consequently we infer, and I think rightly, that all that happens afterwards is of ulterior consequence, the snapping of the columns after they are left to themselves, and amongst other things the yielding of the masonry, or the start-rise of the masonry in one or two cases. It seems to me that that is a fair inference, and therefore the evidence from the ruins is that the structure did not fail by way because the weight was a weight, which would have allowed it to be torn out of its foundation, but that it gave way because the lugs broke.

I think I am justified in saying as the result of all this, that we have a structure, taking it as it was on the lowest estimate that anybody could give as the power of resisting wind, that could not have broken unless you had a pressure of 40 lbs. of wind, and that pressure of 40 lbs. of wind not only upon the girder but upon the whole of the continuous girders. I showed you yesterday that even if they were not continuous it must be upon two girders of 480 feet, and I am fortified in that opinion by the opinions of both the Commissioners, and, as far as I can consider it, I do not think it is fair to attach too much weight to an opinion hastily given, and of the other witnesses. As regards its condition all the loosening of the tie-bars had been carefully attended to, and had all been tightened up. So far as it could be made rigid by tightening up of the bars, it was rigid. The only place of loosening, because, as I showed you yesterday, the principal loosening of the tie-bars took place at the first, just as one would expect if there were some power of yielding in the bolts which would very soon develop itself and which once taken up, could not occur a second time; and when those bucking pieces had been put in and the tie-bars tightened up by Mr. Noble, months passed, and at the end of that time there was a heavy storm in September and then in October there were only two cutters found loose in the whole bridge.

(Mr. Barlow.) Where do you find that in Mr. Noble's evidence?

(Mr. Bidder.) You will find that in the answers that I read yesterday. I need not read them again because they are down on the notes, and in order to save time I will not go back to them. And, Sir, that is very important evidence; because, if after these loose cutters were once tightened up you have the bridge subjected to all the wear and tear of traffic, and as Mr. Noble says in one of his reports to the inspector, he states the case was left for three days, the bridge blown over, and you arrive after that in the whole bridge only two tie-bars slack, it shows that there is no further process of disintegration going on. It shows that the bridge is in a very good condition as it seems to me. All the evidence goes to show that the bridge is carefully tightened up and is in a very rigid condition at the time of the accident. There is no evidence whatever, and there is no reason to suppose that it was in a distorted condition. That is a suggestion, a surmise, and it has nothing to support it in the way of evidence. Consequently I say that the result of the evidence is that nothing less than 40 lbs. of wind blowing over a group of girders could have brought that bridge down.

As I showed you, I think, yesterday, and as I think you will yourselves conclude, insomuch as the maximum pressure of this storm at a point anywhere recorded is just over 40 lbs. of wind, and having regard to the evidence of Mr. Baker, who carefully examined the bridge, and who says that it is impossible that more than 15 lbs. of wind can have been on the whole surface of the bridge, I think you must come to the conclusion that mere wind pressure, such as the bridge was subjected to on that night, could not have brought it down. I am told that I was wrong in saying that the storm was in October, 1879; it was in October, 1878. I confused the two Octobers together. However, the other observation, of course, is equally pertinent.

Having arrived, Sir, at that point, we now come to this. Of course, the fact remains that the bridge fell in the night of the 28th of December, and if the evidence shows that it could not have fallen with less than 40 lbs. of wind (and it is impossible to believe that there was 40 lbs. of wind over an extent of the bridge sufficient to produce an average of 40 lbs. of wind), one is driven to look for some other cause; and these gentlemen who have been called here, men of science and experience, such as Mr. Noble, who is a weighty, do express their opinion that there must have been something in the nature of a shock, something in addition to the normal or the statical pressure of the wind. You, of course, know, Sir, what is the view of Sir Thomas Bouch and some of others upon this subject, namely, that the train which was upon the bridge at the time of the accident did leave the line, or that at any rate a part of it, I should say, left the line; that the carriages did come into violent collision with the girders; and, if they did, I may say there is a consensus of opinion on all sides that that is enough to account for what happened. You will remember that Dr. Pole has expressed that opinion; Sir Thomas Bouch has expressed that opinion; Mr. Law has expressed that opinion; Mr. Baker expressed that opinion; and Mr. Law expressed that opinion.

(The Commissioner.) I do not know that Mr. Law has expressed that opinion.

(Mr. Bidder.) I think, Sir, I can satisfy you as to that. If you look at Mr. Law's evidence, Question 14,468, you will not see going on, because, as I showed you yesterday, the principal loosening of the tie-bars took place at the first, just as one would expect if there were some power of yielding in the bolts which would very soon develop itself and which once taken up, could not occur a second time; and when those bucking pieces had been put in and the tie-bars tightened up by Mr. Noble, months passed, and at the end of that time there was a heavy storm
lead me to think that the girder broke and then

brought down the structure."

(The Commissioner.) That is simply the destruction of the girder.

(Mr. Bidder.) I suppose it will be admitted that if the girder is destroyed the bridge is not in a satisfactory condition, but I will read on, Sir, if you please:

"You have asked me, do you mean a sliding blow?—Yes, it must be that;

it must be that having left the rail it would be carried forward."

Then I, rebuking myself, said,

"You never ought to use poetical phrases in cross-examination. I will put it in the most prosaic form:

"Assuming a momentum represented by 16 tons per square foot, the rate of the wind it would be destroyed by impact with the leeward girder (and destroyed suddenly—I do not mean by putting on the brake) would be in your judgment, be it made what it must be, sufficient to destroy the structure of the bridge under those circumstances, it being already in severe tension with the storm. I think it would have destroyed the girder. Whether that would have brought down the pier or not, I can hardly express an opinion, but I must say this: such a supposition as yours is utterly incompatible with the framework of the framework of the carriage.

I said that Mr. Law traversed the fact, but I am just going to say that he agrees in the opinion that if it occurred it would have brought destruction upon the bridge.

(The Commissioner.) No, he said that it might have destroyed the girder, that is all.

(Mr. Bidder.) Well, Sir, if the girder is destroyed, I will have you and everybody else to draw the inference as to what will happen to the bridge; because, if it is destroyed it falls, and I would not give much for the pier after it has fallen.

(Mr. Baring.) I understand Mr. Law to have been dealing with an abstract question, a hard, heavy mass of 16 tons moving with a given velocity. He is not dealing with the question of the roof of the second-class carriage.

(Mr. Bidder.) Mr. Law says, "I do not admit it," and he gives reasons why he does not think it.

(Colonel Yolland.) I do not think you are correct in quoting Mr. Baker in support of your view.

(Mr. Bidder.) I think you will find, Sir, that is your Mr. Macauley to look at it, and I will refer to it in one minute, if you will permit me for the moment to pass on.

Now, Sir, I must ask your attention very carefully for a little time to this part of the question. It has been said that there are two theories; I do not know quite that there are two theories. The view that Sir Thomas Bouch and other gentlemen have taken upon the facts is, that the two last carriages of this train got off the rails, being in all probability blown over by the wind, and that they came into collision with the girder; and there seems to be some indication which raises the question whether it is not extremely probable that the former carriages went also off the rails. At an earlier stage of the case I was not aware of that evidence. Whether they destroyed the girder, which would, of course, destroy the bridge, or whether, without destroying the girder, the impact of the blow was transferred to the pier and snapped the bracing, I should think it is very difficult to tell; and as any other hypothesis would explain the destruction of the bridge. This much is certain, if the impact of the carriages takes place the blow must ultimately be transferred to the pier. Just as the lateral pressure of the wind is transferred to and felt by the lowest brace, so it is equally true that a sudden blow must ultimately be transferred to and felt by the lowest brace upon that pier, and of course, passing in succession through all the parts of the pier, whichever is the weakest part will give, and the weakest part we know was, especially in the case of a sudden blow, the lugS themselves.

The question first arises, Was it likely or not that that second-class carriage to which our attention has been more particularly drawn should overturb? There is a discrepancy in the figures between Mr. Pole and Mr. Stewart on the one hand and Mr. Law on the other, as to what would cause the overturn of that second-class carriage. Mr. Law says that under the shelter of the girder he does not think that less than 40 lbs. would do it, whereas Dr. Pole and Mr. Stewart say that 32 lbs. would be sufficient. Their calculations have been made upon the notes, and you can examine them for yourselves. I do not propose to go through the calculations in detail, because it would be a very long job. I think you will find that in almost every case Mr. Law has taken his figures a little full, if I may say so, and especially there is a great disparity between the shelter of the girder which the girder would afford. Mr. Law makes an enormous deduction from the force of the wind upon this carriage in account of the shelter of the girder, and Mr. Stewart and Dr. Pole told you that they had made a drawing, and they had put the girder in the position in which of course the carriage would be least sheltered, and had calculated out the moments and the areas of the parts of the carriage covered by the girder. I have here the drawing, and it may be convenient to hand it in, and I do not think anybody can examine that carriage, and take the trouble to calculate it without concluding that Mr. Law's allowance for the sheltering of the carriage is too much, even if you are to take the assumption that the carriage is completely sheltered by those parts of the girder in front of it. That, I think, is not the opinion of the Astronomer Royal, because if you look at Question 16, 161, he has expressed an opinion on that point.

(The Commissioner.) You are quite right; he said so.

(Mr. Bidder.) The question to which I have referred you is one which I was going to read to you, so I may as well read it now: "Taking such a limited surface as the side of a railway carriage, which, as compared with the side of one of these, great girders is a very small surface in comparison, what do you expect to have a much greater momentary pressure upon such a small surface than you ever could upon a girder?—Yes, Q. And from what you know of the storm of the 28th and 29th of December, would it be unreasonable to assume that upon the side of the carriage you have here given 40 lbs. or 50 lbs. to the foot?—Heavier, that is to say, from all the descriptions of the storm. The storm is described as having been a very heavy one, and no doubt there was a pressure greater than that. Now then, what is the conclusion to be drawn from that? That even taking Mr. Law's figures, which I am sure, when you have compared it with that of Dr. Pole and Mr. Stewart, you will conclude is considerably in excess for several reasons, that carriage must have overturned. You must have had upon that carriage a force of wind greater than would have overcome its stability. Now what is there to prevent its overturning when its stability is removed? It is suggested that the carriages would prevent it, but a moment's consideration will satisfy you that until the carriage has canted over a considerable distance, the couplings hardly come into play at all; because the motion of the hook to which the couplings are fast is at right angles to the strain on the coupling, and therefore until there has been a considerable motion you hardly put any additional strain on the coupling. One cannot escape the conclusion that if there was on the night of this storm, as the Astronomer Royal says there must have been, gusts upon a limited area like that of 40 lbs. or 50 lbs. of wind the carriage must have turned over. There was nothing to stop it. It was said at an early stage of this inquiry, why ought not the carriages turned over in other situations? I did not at the time know that they had been, but it turns out that there are unquestionably instances which Mr. Baker gave you, in which railway carriages have actually been blown over by the wind. One cannot
escape from the logical consequences of the figures as regards the moment of the stability of the carriage and the force of the wind; and look at the dilemma in which we are placed. The bridge will not turn over until 40 lbs. of wind have come upon the whole of it. It is manifest to everybody that the gusts upon the limited area of the carriage must be much heavier than the average pressure over the greater part of the bridge. Therefore, you are driven to the conclusion that the carriage must have turned over before the bridge could turn over, unless you are going to assume (of course everything will be covered by such an assumption as that) that there is some hidden defect or servance of the parts, of which we have no evidence, which entirely destroys the stability of the bridge.

Colonel Yolland asked me for a reference to Mr. Baker’s opinion, at Question 14,492: I asked him this, “You, I believe, have had the opportunity, have you not, of seeing the markings on the girders and the other matters upon which evidence has been given, so that you are able to form an opinion as to whether they were done by the overturning of the carriages or not; but assuming, as a matter of fact, that the two last carriages of this train, going at say 25 miles an hour, did overturn and run into the heward girders, would the sudden arrestment of their momentum in addition to the normal strain caused by the storm upon the bridge, in your judgment, be a shock sufficient to account for the failure of the bridge?” and his answer was, “I do not think that would have hurt the girders at all, but I can imagine that in a very high state of tension the huds would at that time with their peculiar liability to fail (as I have instances by the turn-tables) it would be a comparatively slight jar very probably fail, with a very slight shock.” He does not believe that the girders would be destroyed, but he does believe that the shock would be sufficient to smash the lag.

Of course upon the question of fact as to the overturning of these carriages there has been a great deal of discussion, and a great deal of which is in itself any thing but conclusive; and of course no one knows better than Colonel Yolland, with his experience in investigating accidents, that it is very difficult in any cases to predict what will happen or to infer what has-happened in the exact sequence of events; but I must point out this, that in considering this point at the case you must take all the evidence that I am about to refer to, independent evidence, is cumulative so to speak, in its effect, or ought to be cumulative in its effect upon the conclusions that we draw. Let me shortly draw your attention to two or three facts with reference to the matter; I have shown you the result of the calculations. Next, let me remind you of the most recent experience that we have, viz., that of the previous train. There was a train that went over the bridge about 5.50, I think, an hour and twenty-five minutes before this train, at a time when it is clear, I think, that the storm was not nearly so severe as it was when this train went over. That we have in the evidence, and also upon the meteorological records. You have the evidence of several persons who were in that train, (and they are not nervous passengers, but they are railway officials), that that train in the first place was jummed so hard against the guard-rail that it was sending its stream of fire, and spark all the way along. It was lifting the wheels, it was to some extent tilting; although the witness would not undertake to say whether that tilting was more than might be accounted for by the compression of the springs on the one side.

(The Commissioner.) They could not say whether it was due to that or whether it might be due at all to the bridge having already got some slight inclination.

(Mr. Bidder.) Or whether it might be due to an actual meeting of the wheels of the carriage.

(The Commissioner.) Only they say that there was a tilting.

(Mr. Bidder.) They only say that there was a tilting, but notice this: So alarming and so serious was it, that the guard, himself, puts the brake violently upon the carriage, and begins signalling; the engine with his red lamp. That is not in a light second-class carriage, but in a guard’s van. I say that it is quite clear that the effect of the wind is so severe, that the guard thinks the train is in danger, and puts on his brake and begins signalling to the engine. When the last train went over, the storm was very much more severe, and therefore one naturally concludes that all these effects would be aggravated at the time of the previous train; and the carriage that we are considering more particularly, the second-class carriage, is a far lighter carriage than the guard’s van. That also would lead us to believe that these effects would be aggravated.

Then one passes on to this: Have we any evidence at all of eye-witnesses at the time? I confess that I am incapable of drawing any definite conclusions from the evidence of the people who saw lights and things falling into the river; but there is one eye-witness whose evidence is important, and that is Watts, the signalman. If you look at Watts’ evidence of what he saw, watching the train as it went on to the bridge, his evidence is very important. If you will turn to Question 402, you will find that after having said that the wind was coming in gusts, he is asked, “Did you connect the wind with the disappearance of the train at all at the time that it did disappear?” (This is, of course, before any theories had been suggested by Sir Thomas Edenhall, or anyone else.) “Yes. Q. You thought that it had been blown over?—Yes. Q. What did you consider, if you thought of it at all, to be the cause of the sparks and the great flash? that you saw before the train disappeared?—It appeared to me the same as if the carriages were skirting alongside of the girders.” That is the only evidence of an eye-witness that we have. That is the evidence of the signalman immediately behind the train, watching the receding train, and his evidence is that it appeared to him at the time as if the carriages were skirting the girders. It is remarkable evidence. I had better read on this. This is very remarkable, too, although it is not my point. At Question 406 he was asked, “On what side of the train, east or west, was it upon which you saw the flash and saw the sparks?” and his answer was, “The east side.” I do not attach so much weight to that, because wherever the sparks were produced they must necessarily blow to westward, and they might blow under the carriage.

(The Commissioner.) Then he goes on to say that he saw it on a level with the rails.

(Mr. Bidder.) He said he saw the tail lamps and be said that it was the east side of the train. I confess I do not feel that one is justified in resting so much weight upon the sparks for the reason which I have mentioned; they might be generated for instance in an earlier carriage, and at the time he saw them they might be on the east side. But that is to my mind a very striking piece of evidence given by the only eye-witness who was in a position to see anything of the train at the time of the accident.

(The Commissioner.) You will notice that at Question 428, he is asked, “I am speaking of the time when you saw it.” “I saw the train” 200 yards off. “Did you form any idea of what caused the sparks at that time?” “And his answer is,” “The wind pressing the train on to the east side;” and then in the next question he is asked this: “Pressing the wheels against the rail on the east side?” I formed that opinion,—that is to say, that it was pressing the wheels upon the rail. He says just before the answer to Question 427, “I formed the opinion that with the wind blowing towards the east side the wheels were hard upon the rail causing the fire.”
(Mr. Bidder.) He may be right or he may be wrong in that. I am not so much concerned with his theory as to the cause of the fire as with his evidence as to what he saw, and the impression made upon him as to the position of the carriage.

Now then after the accident, first with regard to the condition of this girder, it has been pointed out that it is very much more destroyed than the other girders. There has been a suggestion that one does not know how far dynamite may account for the condition of this girder. Therefore, I want to draw attention to some evidence given at a time before dynamite was used at all. If you look at the evidence of Simpson, the diver, given on the 6th of January, and therefore before any dynamite had been used, at Question 2180, he was asked, "Where did you find any part of the boom of the girder broken?" To the south, the last thing south of No. 4 pier, between that and No. 3 pier; then he describes the position of the bridge, and so, passing on to Question 2189, where he is asked, "Did you find any part of the girders broken?" and his answer was, "Not to the northward of the pier." That is the same pier, No. 4. We have, therefore, the clear fact that the girder was broken at that point long before any dynamite had been used at all. Then, if you turn to the evidence of another diver, Barlow, on the same day, Question 2418, he was asked this: "You went to the south of No. 4, how far did you travel southwards before you got to the break?"-I went about 25 or 26 feet. How far south along the whole of the beam from pier No. 4, as near as you can judge? About 40 yards. Q. South of pier No. 4 you found a break? Yes. That evidence, as far as I see, is also given on the 6th of January, and that, therefore, is clearly a break which is quite distinct from anything that is broken by dynamite. Further down he describes it, a terrible ragged mass and about 2½ feet open.

(The Commissioner.) Is not that the western upper girder which we saw?

(Mr. Barlow.) The diver referred to the uppermost girder.

(The Commissioner.) It was after we had been examining it.

(Mr. Bidder.) You are quite right, Sir. At Question 2426, he was asked whether it was "What would have been the top of the bridge when it was standing?" and he said "Yes." It does not appear, I think, whether it was west or east.

(The Commissioner.) The west would be the side which was uppermost in water.

(Mr. Bidder.) It is very difficult to say. If you look at Question 2407, he says he found a break in the bottom of the girder, and at Question 2408 he is asked, "Do you mean the bottom boom?" and he says, "The boom, so they call it." (Mr. Barlow.) That might be the uppermost part of it.

(Mr. Bidder.) It might have been the bottom of the western girder. That I cannot say. I draw attention to this, because it shows at any rate that the girder was very much knocked about before any dynamite had been used at all.

(The Commissioner.) In support of what you say, if you look at Question 2410, he was asked this: Along the top of the girder, Q. On the ground? - Yes. Q. Till you came to the break? - Yes. That looks as if it was that boom that was on the ground.

(Mr. Bidder.) That does seem to be so, Sir.

(The Commissioner.) That might be the eastern upper boom, because it turns over on its side.

(Mr. Bidder.) At Question 2407 he is asked "Where? - In the bottom of the girder. Q. Do you mean the bottom boom? - The boom, as they call it."

(The Commissioner.) I should tell you that they were unable to go above it-all their observations were to the east.

(Mr. Bidder.) Be it so. You recollect Mr. Mcleod's description of the condition of the fragments of the girder as lifted? Of course I feel that taken as a theory by itself, one cannot attach much importance to a lattice being bent under these circumstances and knowing what that girder had gone through.

(Colonel Vollard.) I think the drawing which you have produced will show that there was a fracture in the boom at the second arrot.

(Mr. Bidder.) I think it does, Sir. But what I have to say about these bendings is this. If you try to frame any hypothesis, do what you will, that will account for these bendings. I will take one in particular; if you recollect, you have evidence that the fifth street of the centre bay has the inner angle iron (I do not know what the exact phrase is) knocked quite out as by a blow coming from the south. That would clearly result from something violent blowing from south to north. That is at a spot where no column could have come into contact with it, because it is the centre of the girder, and 120 feet away from the nearest pier; it is at a spot where the whole train has passed ultimately, behind the guard's van. Now the girder simply fell from its proper position to the bottom of the river, no part of that girder being knocked off from whatever else from south to north. How can you frame any hypothesis as to it, or how can you imagine anything coming from south to north with a velocity and strength sufficient to inflict that blow? Of course in the train you have got a heavy body going from south to north with great velocity. I know it is said that timber will not come away, and I should like to put the word to say about that presently. But, reject the idea that it has been the work of the train, and I defy you to find anything that will account for a blow in that direction in the debris of the surrounding columns, or in the velocity of the girder.

I am not sure whether the evidence is clear upon that, but I do not think there is any evidence that the western girder had come into collision with the eastern girder. What could have caused that blow? It is not that only, but we have, following on along the same girder, the same thing, a similar blow. We come, then, if you recollect, to one of the suspension bars, I think it is the third or the fourth, and it is the inner one caught by something and knocked in the same direction. Further on we come to the broken pieces of lattice, bent in the same direction; but one feels less weight in that, because when once a thing has been broken, it might have been bent about in the lifting. But these things seem to me to be very striking and very difficult, I should say impossible to account for upon any hypothesis except the theory of the train having come into collision and delivered the blow that produced that effect. Then we come again to those scorings upon the inner surface of the girder, a thing upon which by itself I should not like to rely very much; but, as I said before, this is all cumulative. One does not form a hypothesis to account for these scorings. I do not say that it is impossible to form a hypothesis to account for them, but still I say it is very difficult. They do agree very well with the height of the guard's van. It was stated that those scorings at the full height of the guard's van roof are further than these heavy blows from the tie-bars, and I think on the suspension bars. How are you to account for the carriage being in a condition to make those marks upon the girders if it had previously come into contact with the girder further back? I am by no means clear that it is the same carriage. It may well be that the second-class carriage came into contact first, and did this, and that the roof of the guard's van subsequently fell against the other lattices and made the scoring.

But it is not merely the question of the evidence of these marks. There is another piece of evidence which to my mind although in itself not a conclusive piece of evidence is yet very striking when it is taken with other evidence. You remember that three scorings occur and where the scores are rather on the covering plate, the northern angle of the
covering plate is turned up, a rivet is gone, and into the crevice between the covering plate and the other iron surface they have driven a lot of splinters of timber. Again I say, I think you will find it excessively difficult to frame any possible hypothesis to account for that. You have actually got the small splinters of the iron and when people tell me that timber cannot make marks upon iron and cannot produce the results that are suggested here, I answer that in this way; whatever you believe that was done by the train or not, the evidence is conclusive that it was done by timber, because there is the timber sticking in the crevice of the iron. It may well have been the whole train, but even if it was only part of the train, if, tell please, you may account for it by some entirely different hypothesis, but the thing that delivered that blow was certainly timber because part of that timber remains there still; and I cannot help thinking that those gentlemen who talk about the body of the carriage being smashed in, reduced to annihilation without making any mark upon that girder have entirely lost sight of the fact of the importance of the velocity with which the blow is delivered, and forgotten that although one body may be much the more yielding and softer of the two, it is a pure question of velocity, and if the velocity is sufficient the softest will make its mark upon the harder body. You may take the familiar instance that I gave the other day of a tallow candle going through a deal board; or there is another instance, which is perhaps not so pertinent. But there are many instances which one might give of the same thing. That wood, as I am reminded, so far as our limbs are fetched from saw-mills, is a tough I do not think that I can form a very clear judgment, the witness said appeared to be hard wood. One does not like to rest too much upon that. It was not wood transported with the permanent way. But I am at a loss to imagine how any of the wood of the permanent way could rise up and get a velocity and delivered a blow in that direction.

Then we go on and we may inquire into the condition of the carriages themselves. Now I am justified in making the remark that although all the carriages were more or less damaged, these two last carriages are smashed and annihilated in a way that none of the other carriages are. So far as the point that the photographs of the other carriages do not altogether represent their condition when they were first found, because it appears that parts of those carriages fell off. There is evidence, for instance, that the third-class carriage in front of the second-class carriage fell off in the lifting one side of it—that is what appears to me. Do not say whether the Court are aware that what appeared to be a side of that carriage turned up whole on the Norwegian coast.

(The Commissioner.) That was mentioned; but I do not think it was given in evidence. I think it was a paragraph in the newspaper.

(Mr. Birder.) It has nothing to do with this case. I recollect it as a matter of curiosity I had it on very good authority, or else I should not have mentioned it. But certainly the side of the carriage was found at Stavanger, on the coast of Norway. Whether it had been Edinburgh and Glasgow, or North Briton, or Great Northern on it. I do not know. However I merely observe that parenthesis.

(The Commissioner.) They are bringing over from Norway, carriages in steamers, and if a steamer went down with one, those pieces might be found.

(Mr. Birder.) The next thing that I would draw your attention to upon this point of the case is this. You have got the plan before you prepared by Sir Thomas Beecham, officer of the position of the girder; because, when the carriage is in position, there are only 2 ft 6 ins. between the second-class carriage and the third-class in front of it. Now this strikes me having that omission of the plan in order, that whereas these two carriages are, so to speak, huddled together, the rear one on top of the iron, the rest of the train is spread out more or less. There is 10 feet between the second-class carriage and the third-class in front of it, and, as the plan shows, there are gaps in almost every case between the carriages, and between the front carriage and the engine. As regards the two last carriages, the deduction that I draw and think it is an irresistible deduction is that the second-class carriage was arrested before the van, and that when the second-class carriage had been arrested the van went into it with such force as to do the damage, which is seen to its rear; but as regards the rest of the carriage they were all stopped one after another from behind, and as each one had a pull back from behind, and the couplings broke (I do not know where the couplings would break, but I make it mine own) to scatter the carriages. That is exactly what you would expect, if the first thing that was arrested in that train was the second-class carriage.

If this train did not leave the rails until the whole thing went over, how can you again frame a hypothesis to account for, for instance, for the condition in which you find the other carriage fell and would not buoy them up in the water might be found. Occurrence of that, whatever th" is that timber house part of the timber engine.

(Mr. Birder.) Not at all. The position of the girder would be accounted for by some entirely different hypothesis. But that other carriages did last their bodies on and air in making the remark that though all the other carriages are in position, whereas the rest are standing upon the wheels. The position of the former part of the train is attributed, and very likely properly attributed. The photograph of the wood of the permanent way to the fact that having their bodies on and air in making the remark that though all the other carriages are in position, whereas the rest are standing upon the wheels. The position of the former part of the train is attributed, and very likely properly attributed.

(Mr. Birder.) I think it is. Make any other way, got off the line to the guard's van smashed into it and on the top of it? When the girder and the train are going over together there is no impact between the train and the girder, they are all falling over together, except that ultimately, no doubt, when they were turned over into the water, approaching a horizontal position, the train may at some time or the other part company with the girders which is quite clear. You notice this—that the two carriages to which I have referred more particularly, are on their sides, whereas the rest are standing upon their wheels. The position of the former part of the train is attributed, and very likely properly attributed. The photograph of the wood of the permanent way to the fact that having their bodies on and air in making the remark that though all the other carriages are in position, whereas the rest are standing upon the wheels. The position of the former part of the train is attributed, and very likely properly attributed.

(Mr. Birder.) I think it is.
over—and again I utterly fail to conceive or to frame a hypothesis which would bring that guard-plate and that axle-box into that trough. I do not know how you can imagine the collision while they are in the air, for the reason I have mentioned, that they are all falling together, and, if there were a collision, the axle-box and the trough would be all falling together.

What was more important, the mouth of that girder is turned away from the axle-box, and the tide, if I remember right (not that I would have much effect), was down the river, and there is no way in which we can conceive that with the mouth of the trough of the girder turned eastward down the river, that guard-plate could get into the trough. If that guard-plate and axle-box were not in the trough before it fell, I defy you to get them in afterwards, unless you are going to suggest that somebody wilfully put them in, in order to fabricate evidence, of which there is no suggestion whatever, because I need not say that not a tide five knots an hour, nor twice five knots an hour, would move, on the foundation of the river, that heavy piece of iron, which, apart from its weight, is the most difficult for a stream to move, being a great flat piece of iron. I am quite sure that everybody will agree with me that the tide could never have swept it in there, although the tide sweeps sand and shingle. Then, again, it seems to me that what Watts thought he saw was the fact, and it is utterly inexplicable on any other hypothesis. Then it is worth noticing, although it is not so conclusive, that a lot of fragments of glass were taken out of that trough, which seems to me to show that the windows of the carriages were shattered, and that the trough was still in a position to receive the fragments. I say it is not so conclusive, because the tide which swept sand and shingle into the trough might of course sweep fragments of glass into the trough, and therefore I should not have attached so much weight to that by itself, but still, taken concurrently with the other, it seems to me that it is a likely thing.

I might point out some other minor points, but I do not think that they carry the thing much farther. You have all these different indications, and, when you put them altogether, the experience of the previous train, the observation of Watts, the battered state of this girder, the condition of these carriages, the position of the carriages, the markings of the girder, the girder itself, the axle-box, the guard-plate in the trough, and the fragments of glass in the trough—taking all these things together—it does seem to me that they raise a presumption which is very difficult to resist, and when you take them in conjunction with this—

(The Commissioner.) Mr. Barlow asks whether or not the hind wheels of this carriage were found. I say they were found about 10 feet behind.

(Mr. Bidder.) We have evidence that the hind wheels of the second-class carriage were found just opposite where the van ultimately was. I asked Mr. Malk to make a reduced sketch of his drawing, and to put upon it as nearly as he could, embodying the evidence, the position of the second-class carriage, and of the guard’s van, and of the hind wheels of the secondclass carriage. It must not be taken as evidence, but must be compared with Mr. Malk’s evidence, and with the evidence that you have had here, as to the position of these things. As far as I can make out he has very truthfully shown, according to the description of the witnesses that I have called before you, the position of the second-class carriage, and he has sketched you the guard’s van overlapping it, and he has shown you where it was found (handing in the sketch).

(Mr. Barlow.) Whereabouts was that angle iron, which you spoke of as being turned out flat.

(Mr. Bidder.) The suspension bar is shown, and if you count back it was the fifth. It is not within that drawing I think.

(The Commissioner.) I think it is here, immediately under the scorings.
under those circumstances, to have let the train go upon the bridge. What I say upon that is, that it is very easy to be wise after the event, and knowing all that we do now, and all the results of these meteorological investigations, to come to the conclusion that the train should not have gone upon the bridge. But nobody can therefore impute blame to the railway company, because they did not prophesy, and become aware of the weather at the time, and not knowing that which we know, and which it was impossible they could know, they did not by a prescience which would have been supernatural, foresee that this train would have been in danger from such an extraordinary and unusual cause as that, which the result shows it was in this case. Therefore, what I came to was that conclusion that nobody is justified in saying that the railway company were to blame because they did not foresee what was in fact unforeseeable.

I am sorry, Sir, that I have been obliged in dealing with so much of your time.

(The Commissioner.) You have not occupied at all too much time.

(Mr. Bidder.) I am obliged to you for the attention with which you have listened to me, and I think I may here conclude my remarks, and safely leave the credit and reputation of Sir Thomas Bouch, whom everybody knows to be an engineer, not only of great experience, but of great care, and of great talent and ability, in your hands.

(Mr. Trayner.) The inquiry which has now reached very nearly its termination has undoubtedly been marked by very considerable length, and I am satisfied that there can be only one opinion upon this, that it has not been longer than its importance warranted. In the month of December, 1879, the Tay Bridge was destroyed, with a very great amount of pecuniary value, and what was still more important, than seventy lives. It was impossible in circumstances like these that there should be anything but one result in the public mind, a very extreme anxiety to ascertain the cause, and to lead to this三家 discretion, by precisely that desire to know what had led to that which everyone deplored, but probably a still greater anxiety to ascertain its causes, if they could be ascertained, with a view to rendering it possible in the future that such a thing should repeat itself. And with the public mind agitated as it was, it is not to be wondered at if any possible cause was put forward, and that in turn an entertained, and lopsided judgment formed, with regard not only to the causes of the accident, but the different persons who might be charged with the fault that lay at the bottom of these causes.

But I think I am bound to say this, that in the course of the inquiry, long as it has been, there has been no attempt on the part of any one who has been sufficiently instructed to say anything that would tend to mislead or misdirect the public mind, and I think that in point of fact there has been no charge made. Mr. Bidder said, and said justly, that he would use a most inaccurate expression, if he talked of his friend Mr. Trayner as appearing for the prosecution, for there has been nothing I hope in my conduct, from the beginning to the end of this inquiry, to indicate that I was ever seeking either on his or on another; I have simply been doing what lay within my power to ascertain; for the benefit of this Court in the first place, and for the public in the second, what were the facts connected with this disaster, and what were the necessary deductions to be drawn from the facts as ascertained.

But that were, as I have said, charges made in other places, and I am ready to admit that the charges and the judgments that were expressed may have been hasty. The public voice is not always accurate, when the public mind is very much stirred, but I do not think that Sir Thomas Bouch or Messrs. Hopkins, Gilkes, & Co., or the Railway Company itself have any reason to complain of the inquiry that has taken place; for, although the result may show that they have been lying under imputations which were not just and well founded, it is infinitely more important to the persons I have named to have a most searching inquiry into that order that their want of culpability may be clearly established. I say it is better for them that such an inquiry should have taken place, were such a result as that to follow, if it is to follow, than that no notice should have been taken of the manifold injudgments that have been made. We have to look at this evidence, and I shall endeavour to do it without defying any theory. I shall not prepossess any theory for the Court's consideration, although I shall call attention to the theories that have been propounded both by the witnesses adduced by the Board of Trade and by Sir Thomas Bouch's counsel. But I must say this, Sir, that although in addressing myself to this evidence I have endeavoured to do it as impartially as I can, I am afraid that I cannot concur in many of the views expressed by my learned friend Mr. Bidder; nor is it to be wondered at that I should not, for Mr. Bidder was an advocate defending his client, whereas I have not undertaken that duty. Therefore, while it was his place and his duty, not only to put before you such parts of the evidence as seemed to bear most in favour of his contention, but also to put such a gloss upon parts of the evidence as favoured that contention, it will not be my place to do either of those two things, but to address you upon what appears to me to be the real import of the evidence, and to draw the necessary deductions from it. What we wish to arrive at is, not to blame Sir Thomas Bouch or anybody else, but to reach that just conclusion which not only the evidence but the skill of the Court and the knowledge which the Court has acquired of the inspection compels them in the public interest to adopt.

There have been different views suggested with regard to the cause of this calamity, and I think I may sum them up in two sentences. The first is that the bridge came down through fault either in construction or in design, or in the want of proper maintenance of the bridge that was put into action. In the latter case, the responsibility, for no one can resist those forces to which, by Mr. Bidder's account, the fall of this bridge is solely attributable.

If there was fault, it must have been on the part of one or other of three different persons. It must have been the fault of Sir Thomas Bouch, the designer; or the fault of the contractors; or, lastly, the fault of the users and proprietors of the bridge, namely, the North British Railway Company. Those are three separate and distinct interests; they have their own views to present to you, and they have been presented. I shall not look at each of those interests separately and endeavours, if I can, to aid the Court in reaching its conclusion, if there be any fault to be found, upon whose shoulders that fault is to be laid. I shall deal with these interests in the inverse order from that in which I have stated them, because I think I can dispense with the real question of a good deal of what I might venture to call, I hope not improperly, superfluous matter, if I deal first with the case as it appears as bearing upon the railway company, secondly, upon Messrs. Hopkins, Gilkes, & Co., and, lastly, upon Sir Thomas Bouch, the designer.

With regard to the railway company, I feel bound.
representing the interests that I do represent, to say in the outset that the railway company has afforded to the Court and to those charged with the conduct of the inquiry, in the first place, every possible assistance and facility. I do not merely mean by that that they have been ready to give information when asked; but, I appeal to; the recollection of the Court how completely the whole services of the fireman, the engineer, and the conductor of the train and the driver of the engine, were placed at our disposal, and how their steamer was constantly ready to take the Court or anyone connected with the Court to the scene of the disaster. And not only do I allude to these things but I think I may say that they have acted with extreme frankness and fairness to everybody, for they have placed at the disposal of the Board of Trade all the evidence which they had acquired, evidence which they did procure and must have procured at very considerable cost and trouble to themselves. They not only sent two engineers of very high standing, Mr. Cochran and Mr. Brunlees, to examine independently of all theories and independently of every consideration the ruins of the bridge, and the result of these efforts of these two gentlemen’s inquiries, at our disposal, but they undertook to produce Messrs. Reeves and Groth, and they brought those two gentlemen, the one from Spain and the other from Portugal; and I am certain, to conclude this matter in a word, that the railway company have been just as far as was helpful in this inquiry as at their own interests, and no doubt to some extent they were, were entirely bound up in its result.

Now: with regard to the railway company, the first observation which I make upon the case, as it appears with reference to them, is this: that when I look at the specification which was prepared and approved of by them for the erection of this bridge, so important was the connecting link between the different north and south ends of their system at the Tay, one sees that it was prepared with remarkable care, and evidently with a desire to obtain an extremely good structure. According, I think, to the evidence given by Mr. Law, the railway company had a duty to answer for the specification, which they had stipulated for an iron of particularly good quality, and in other respects that they had stipulated for a bridge, which in common parlance might be called a first-class thing. It is also worthy of remark (for one desires to be perfectly fair) that there was in that specification and in the whole subsequent transactions leading up to it, by them for the erection of this bridge, so important a limitation, whatever, put upon him with regard to the expense to be incurred in the erection of the bridge. Indeed, I should have been able to say, in a word, that in my humble judgment, so far as the railway company are concerned, there did not appear on the notes a single word to indicate failure or neglect of duty upon their part, had it not been for one particular matter to which, I think, I am bound to advert. You will remember, Sir, that at Dundee, amongst many other things that were said as to the cause, or one of the causes, of this great accident, it was suggested that there had been on the part of the railway company an impropriety arising from the fact that the trains travelled across the bridge at a speed which was excessive, and it is beyond all question, I think, it was so said by Mr. Law, and it has not been contradicted, that looking to the mode in which this bridge is constructed, a continuous excessive speed would have an effect upon the -bar, which undoubtedly was un-put upon Sir Thomas Bouch, and Sir Thomas, for an annual consideration, took upon himself the responsibility of supervising and maintaining the bridge.

If, then, the Court is satisfied that the excessive speed, which undoubtedly in my humble view did take place at some times, was not one of those matters which led directly to this calamitous result, and if the company have fairly discharged themselves by what they did, of their duty to maintain and supervise the maintenance of that bridge, I venture very humbly to think that the railway company are not in any way

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upon the result of the evidence, that there was nothing in the proof which we had had before us which tended to that conclusion as at all a necessary one: that the right in question there was excessive speedily: that the previous occasions were the most rare, and, so far as I can judge, not directly connecting themselves with the calamity of the 28th of December.

With regard to the contractors, Messrs. Hopkins, Gilkes, and Company, there is, I am afraid, rather a different state of masters. At the outset we were very much impressed with the statements made at Dundee by men who ought to have known what they were speaking to; that the quality of the iron used was not decidely bad. Men after men who had been engaged at that foundry where the columns were cast, undoubtedly described the iron as being of a character, which I rather think no one could maintain was proper iron to be put into a structure of that kind; and further, it will be within the remembrance of the Court, that when Ferguson, Ferguson, who was the foreman at the foundry, was asked what he could say for the quality of the iron, all he could say was that it was not 'that terrible bad.' The question was put to him, and I think fairly put to him (it would have been unfair not to have put it to him), whether that was all that he could say on behalf of the iron that had been used; and Ferguson, either because he had expressed an opinion and did not want to go back from it, or because he had not at hand some other phrase which was convenient, which would express not by any means that the quality of the iron was good, and yet did not wish to say too much against it, maintained a discreet silence on the repetition of the question.

But I do not care so much for the evidence of Ferguson upon this matter as I do for the evidence of Mr. Beattie; and I think you will remember that Mr. Beattie suggested that it would have been a better thing to have had a different mixture of iron. Mr. Beattie suggested, if I recollect right, that there should be one-third of Cleveland iron, one-third Scotch pig iron, and one-third Scotch scrap. He said that he had suggested this to Mr. Gröthe, but that Mr. Gröthe did not accept his view, and that they went on casting with that iron which truthfully or untruthfully has been abundantly described by the evidence at Dundee.

But having heard so much about the bad quality of the iron, the Court would have been failing in its duty to us if we had not sought that matter to the bottom, so far as it could be sifted at Dundee. The air was rife with statements as to the bad quality of the iron as well as to the bad quality of the workmanship, and the Court knows very well that that same public voice which was ready to condemn Messrs. Hopkins, Gilkes, and Company for, using bad iron, would have been just as ready to condemn the Court for partiality, and unfairness if it had at the time refused to listen to the evidence which was proffered to it. But when we come here and have this iron subjected to tests which really show what its quality is, I was relieved to hear from the Court the other day that they were going to try into the quality of the iron, because Mr. Kirkaldy's tests had proved that the iron was equal to the specification: and I rather think that the expression which you, Sir, the president of the Court, used, was that the result of the tests had been to show that the iron was of very good quality indeed. Now in that view I think we must put to these tests again and I might have been more or less prejudicial views of the men who were working in the yard. Certainly the skill of Mr. Kirkaldy, in judging of the quality of the iron is a matter, which is not for one moment to be questioned by the mere statements of the workers, and therefore I suppose the Court will be satisfied upon the tests that so far as the quality of the iron is concerned, the iron was up to the specified quality and therefore good.

But then we come in the next place to the question whether, the quality being good, a good use was made of it.

(The Commissioner.) Whether it was well manipulated.

(Mr. Trumner.) Whether it was well manipulated. You may have a very good thing and make a very bad use of it, and the question is whether Messrs. Hopkins, Gilkes, and Company, having supplied their workmen with the proper material, those workmen used that material in the way in which they were bound to use it.

It would occupy the Court a very long time, and most needlessly in my judgment, to go into the faults which have been found with the workmanship at Dundee, or into the faults which have been found with the workmanship, as far as it was executed, at Middlesbrough. I would remind the Court in the most general way, that the faults that were found were inequalities of casting, improper driving or punching of holes, cutting them out with a cold chisel at some places, and elongating them, where they did not fit with the corresponding hole on the opposite side; how the lugs were in so many instances knocked off and burnt on; how the channel iron, again, had the holes punched into them, rimed out, leaving as Mr. Law explained, a burr on the inside. In short, the iron, so far as the work is concerned, seems to have been manipulated in a most careless and extremely unwarrantable way. And unfortunately it is not merely the ironwork that is open to criticisms of that kind, because a witness, upon whose evidence I shall have something to say bye and bye, but who we say is a witness whose skill or honesty cannot be impugned, and that is Mr. Law, tells you that from his own examination he found that the stonework was so imperfectly laid that the blocks of stone came away from each other at some places, leaving the sheet of cement neither attached to one side nor the other; that the junction of the stones had separated, and it was in one sheet and not adhering to the stone; and upon a review of the evidence it cannot be said, I think, by any one, however anxious they may be to defend the conduct of the workmen of Messrs. Hopkins, Gilkes, & Co., that they did their work well, unless you are prepared to go to the full length of saying that the witnesses who have been examined have not been telling the truth. That is an alternative which is almost too ridiculous to be suggested, because whilst you might have had prejudiced misrepresentation, and I will go the length of saying, for I can conceive it possible, falsehood, in other witnesses who, were examined in Dundee, and whose opinions have been given beyond all question, not only by your own inspection; but by the evidence of Mr. Law, who was appointed to aid the Court in ascertaining those facts. Now it is right that I should say here a single word about Mr. Law's evidence, because Mr. Law has been subjected to a great deal of pleasantry on the part of Mr. Bidder. I think it must have been pleasantry, but it seemed to be pleasantry which had rather an acid edge; but still I do not suppose that Mr. Bidder was doing more than using that license which sometimes counsel have a right to use, and I am afraid that counsel sometimes too freely use, when they have not a very good case, of the occasional pleasantries which Mr. Law, according to Mr. Bidder, was a gentleman who had very strong feelings about this bridge. I do not know why they should have arisen—a man who has subjected this bridge, as he has done, to a minute criticism, as if that was a fault on the part of Mr. Law—a man who did not approve of this design because it was not on what fours with what the learned friend Mr. Bidder said had been adopted by Mr. Law at Fermoabuco, a work which my learned friend Mr. Bidder further said had been somewhat frequently referred to. I am a little astonished at this line of remark on the part of my learned friend Mr. Bidder, because he of all men, practicalising so largely as he does in a Court where scientific men are being constantly examined, should have known better than any other man how very valuable are the services
and how very skilful is the character of Mr. Law. I think it not too well if my learned friend Mr. Bidder had remembered that Mr. Law was not produced to support any particular view, and was not examined as Dr. Pole and Mr. Stewart were, although I say nothing, unkindly of either of them, to support a particular theory for a private client. But my learned friend Mr. Bidder should have remembered that there was every reason to suppose that because he had been appointed by the Court, a man in whose skill, in whose power to observe, and in whose honesty to report, the Court have the most implicit reliance and confidence. It is all very well for counsel to try and raise a laugh by saying that a man has had one world, and has frequently been of opinion that moulders have gone back upon the information, which he must have had at some time or other, but which perhaps he may have forgotten. He would have known very well that Mr. Law's experience and skill had not been all expended in one work in Pernambuco, but that he had built bridges, as Mr. Gilkes told us yesterday, no further from London than Windsor, and it must be in the knowledge of the Court that Mr. Law's position as a skilled man is one which would I have, I think, entitled him to expect an immunity from those somewhat small observations which my learned friend Mr. Bidder allowed himself to indulge in. The greatest thing to be said in support of Mr. Law's attendance to this inquiry, is that he might have come forward to tender himself, nor is he put forward even by the Board of Trade, to give an opinion against any particular theory; or in support of any particular theory; he was appointed by the Court, under the power that they had, to make an impartial investigation into what were facts, and he made that impartial investigation, and has given his report upon it. I am satisfied that the Court will place implicit reliance upon Mr. Law's reports; certainly in so far as the facts are concerned, they cannot disregard them. As regards his opinions, I venture to say that they will be found in accordance with the opinions not only of the Court, but of most men who have skill enough to follow both his calculations and his views.

Now I will pass on to another matter. Let us see what the evidence is with regard to Messrs. Hopkins, Gilkes, and Company. You have the evidence of the Dundee people, and, as I have said, they might have been prejudiced, they might have been wrong, but you and the Court are convinced that it is not so, and it is impossible to avoid the conclusion that at Dundee, while these columns were being cast and the metal worked up, there were gross improprieties committed by persons who should have taken care that those improprieties were not possible. Now this is true, but it bears hard upon Messrs. Hopkins, Gilkes, and Company, Mr. Gilkes said, and I have not the slightest doubt said with perfect accuracy, that he was anxious to do this work well, and, so far as he knew it, he did it well. He is not only a man of large experience in such work, but he employed a good staff; a sufficient staff, and a able staff to look after the work. There were no complaints made to Mr. Gilkes that the work had been badly done—it was taken off his hands by the railway company after the railway company's own inspector had seen it. It was passed, Messrs. Hopkins and Company may most fairly say, by the Government Inspector sent down by the Board of Trade, and therefore as far as regards the evidence of Messrs. Hopkins, Gilkes, and Company, or the members of that firm, there does not seem to have been any desire whatever to escape from a fair and honest fulfilment of their contract. But men cannot do everything with their own hands are sometimes, white free from all personal blame, still responsible for those things which are done by persons whom they fear, and I put it to the Court to consider, whether it is possible entirely to absolve Messrs. Hopkins, Gilkes, and Company from fault in reference to this bridge after the evidence which has been laid before them. I wish again very respectfully to distinguish between those two things, the responsibility of Messrs. Hopkins, Gilkes, and Company for the result, and the knowledge of any member of Messrs. Hopkins, Gilkes, and Company's firm of what was being done. Indeed I have the greatest difficulty in understanding how it is possible that these improprieties, these gross improprieties, could have crept into the work, because Messrs. Hopkins, Gilkes, and Company, knowing very well that responsibility that rests upon them and that the nature of the work that they were undertaking, had sent down to that place most able assistants and men, not only whose examination in the witness box, but whose whole demeanour in reference to this inquiry has proved, at least in my humble judgment, that they were aware of what was being done. Mr. Grothe, in the witness box showed a little prejudice probably in favour of the bridge, a little disposition to put things well for his employers, but I am satisfied it is in the recollection of the Court that nothing could have been fairer or franker than the evidence which was given at Dundee by Messrs. Beattie and Company—given with fulness and fairness and frankness, but given with an ability which showed there was a man quite fit for the responsible position with which they had been charged. But after all, we have the fact that these things did occur, and however careful Mr. Grothe and his staff may have been, and however anxious they were, as I believe they were, to see this work thoroughly looked after, it is the fact that notwithstanding the supervision which they gave, all these terrible things happened.

Now I think it is worthy of observation that these irregularities in the castings and in the holes, and so on, were not at a matter that engineers should not have looked after, and looked after with particular care. On the contrary, my learned friend Mr. Bidder made it perfectly plain that all these things are things against which engineers are bound to take especial care, and for this reason. It has been held by witness after witness in the course of this inquiry that not only, in a large construction of this kind are defects I might almost say necessary, and almost always occur, but there is a matter of knowledge to gentlemen charged with the supervision of such works as these, that where holes are cast instead of being drilled, it is impossible to get moulders to make those holes to correspond. If that were so, and if the known carelessness of moulders makes it probable in the highest degree that these inequalities by Mr. Law were allowed to be, was, is made the duty of those men who were charged with the inspection of the moulders and with the castings, that they should have taken greater care that these inequalities should not have occurred in an erection of this kind. They were concerned in the erection of a viaduct which was to bear trains after train, day after day, charged not only with property immense in pecuniary value, but charged with the inseparable lives of the persons who were using it as a means of transit, and they were bound, for they knew the full value in a structure of this kind of the inequality of those holes, knowing that, and knowing the extreme probability of their occurrence, to have been in the inspection of the things that did not occur.

I venture to say that it humbly appears to me to be a conclusion which the Court will, scrupulously escape from, that notwithstanding Mr. Gilkes' anxious desire, and notwithstanding the ability and the attention; for I will go the length of saying that they were adequate, as far as Messrs. Hopkins, Gilkes, and Company, to things crept in, in a way for which Mr. Gilkes must be responsible, and for which even in this inquiry he must bear, I will not say fault on his own part, for he knew nothing of the matter, but he must bear what responsibility there is which attaches to him on account of the carelessness or the fault of those who represented him.

Now, so much for Messrs. Hopkins, Gilkes, and Company. I come now to what humbly appears to me to be the most serious part of this inquiry, and that is the case in so far as it affects Sir Thomas Bouch. Sir Thomas has a threefold responsibility—
he was responsible for the design, he was responsible for the execution of the design, he was responsible for the evidence that Sir Thomas Bouch gave to this important construction?— I am afraid he did not give much personal supervision, Sir Thomas Bouch no doubt has been very much distressed by this calamity; he has been thinking of it I suppose night and day since it has happened, and I do not think that Sir Thomas Bouch is the same man now as he was before the terrible disaster which has occurred, and the lives which have been lost, I will not say one word to aggravate his distress, but I must say this in justice to the case that there is no evidence from anybody that Sir Thomas Bouch ever went near that bridge, except from himself.

(Mr. Webster.) It was never suggested in cross-examination, it was said that he was there every week.

(Mr. Trangy.) I was in the middle of a sentence when my learned friend Mr. Webster interrupted. I was saying that there was no evidence that Sir Thomas Bouch was there more than once a week, and the only evidence we have is that any supervision took place was that a Mr. Paterson was placed there, who took Sir Thomas Bouch’s real position. Now Mr. Paterson’s skill is a matter of public knowledge, and we know this with absolute certainty that Mr. Paterson was engaged in what I venture to think was more than enough for one man. Mr. Paterson was supervising not merely the Tay Bridge, but as Sir Thomas Bouch put it, the whole concern—the tunneling into Dunkeld on the north side of the bridge— the suspension on the south end and of the Newport line— he was living for a great part of the time at Perth, 20 miles from the place, and we had no evidence, I think I am right in saying this, and I do not do it with any desire to press unduly upon Sir Thomas Bouch, that we have not had evidence to satisfy the Court that there was such anxious supervision in such a matter as this, as I think should have characterized its construction.

(Mr. Barlow.) You mean during the construction of the bridge.

(Mr. Trangy.) During the construction. Let me say further, though the duty is not a pleasant one, but
one must perform one's duty whether it be pleasant or unpleasant. I think there are some things during the course of the case which have indicated a want of attention which astonished me, and which is not the part of the responsibility of an engineer of a work like this. You know that, by the specifications a certain quality of iron was fixed upon—the malleable iron was to bear a certain tensile strain, the cast-iron was to be subjected to a strain up to a certain breaking point; from first to last of this contract, although a Board was entitled by the specification, from time to time to demand that tests should be made, so as to satisfy him of the character of the iron that was being used, so far as I know he never once exercised his right to do that, and never asked a single test to be made. It is quite true that he said in his examination that on one occasion Mr. Beattie had told him about a test that he had made, and I am willing to believe Mr. Beattie's statement that he made that test, and that the test he did make was entirely satisfactory, and that the cast-iron did not break up to a point to which the specification said it must go. Now, Sir, the want of these tests, it humbly appears to me, is simply an illustration of the lack of personal control on the part of this engineer in that which was going on in the construction of this bridge, for which he was himself responsible. I am told that Sir Thomas Bouch put in a set of tests.

(The Commissioner.) He did; it is referred to in his letter by Mr. Kirkaldy; the tests were not very numerous, there is the letter in question.

(Mr. Trumper.) The Court will correct me. I am not very clear. In my recollection about this, but my impression is that the tests were made before the work was commenced in order to enable him to make selections of the particular kind of iron that was to be used.

( The Commissioner.) I think you are right in that.

(Mr. Trumper.) I think I am right in saying that from the time the contract was entered into and the iron began to be supplied at Wurmit for the erection of this bridge, Sir Thomas Bouch never once applied that tests should be made of the iron to be used in the construction of this bridge. Now I have mentioned that as an instance of the want of supervision which one would naturally have expected to find in an engineer charged with so extremely important a duty, and if I find, that, with the power always at unfixed times, on unselected pieces of iron, to go there from time to time to make a test specified by the specification, I find there what warrants me in thinking that there is want of confidence upon him by his authority, by his contract, conferred upon him an authority which they anticipated would be put into use, and that authority, so important in its execution and exercise, was never once availed of by the engineer. I say it points with other things to this fact that Sir Thomas Bouch was trusting a great deal too much to those clerks, and, unfortunately, we have seen how much he has been deceived. Now I therefore say with regret, but as far as my humble judgment goes, with no hesitation, that there is upon the evidence laid before the Court unmistakable proof that although the design may have been perfectly good that there was want of supervision of its execution which was left to the, care of the Board, and that the Board were not careful enough. It is impossible to look at the work as it existed, lug after lug improperly perforated, and channel iron after channel iron improperly perforated, with all the other defects, inequalities of thickness and everything else that Mr. Law has seen and you have seen, and to say that there was carefully supervised work either on the part of the contractors or on the part of Sir Thomas Bouch, who took it off their hands. It comes to this that if they are not to bear the responsibility for the passing of this improper work, then there is no use in charging the engineer at all with the duty of the supervision of the erection of such a construction.

Now, Sir, I come to the next question which is, how Sir Thomas Bouch fulfilled his duty of maintaining the bridge?—There is no doubt whatever that the ties were essential to the bridge's existence; and we have that in evidence which my learned friend cannot question—the evidence of Mr. Stewart, who said that without these ties the bridge would give. Without these ties the columns were helpless, and therefore it becomes of the last importance to ascertain whether or not this essential feature in the bridge was supervised and kept, so to speak, up to the mark in the way in which it should have been.

Now here I come to consider General Hutchinson's Report, and with your leave before I read, as I mean to do very shortly, one or two passages from his evidence. I want to direct attention to a matter which is not so immediately germane to the inquiry as collateral to it. Some notion seems to have got abroad, that because General Hutchinson intimated that the bridge there was an end to everybody's responsibility, because the Government Inspector had passed it. Now you, Sir, are quite aware that the only authority which the Board of Trade has to inspect bridges, or to do anything in consequence of such inspection is statutory, and I may state in a single sentence, what the authority is which we have, and which is then charged with the duty, upon the Board of Trade. When a railway company has a branch of either its main line or any of its branch lines ready for opening, they give notice to the Board of Trade of their desire to open it, and the Board of Trade is then charged with the duty, within ten days, of sending an officer to inspect the construction of that railway or viaduct in order to decide whether the work is perfect safety and in accordance with the public interests that railway or that viaduct should be open for the public convenience; but prior to the time when that inspection is made there is no obligation upon the railway company to afford, and no right upon the part of the Board of Trade to demand, an inspection of the plans. During the time that work, the Board of Trade has no right to send an inspector to see whether all the parts, which when erected and put in place are many of them hidden from the naked eye, are carried out as they ought to be; no opportunity of testing whether the beams or the columns, or whatever they may be, are of proper material and properly constructed. It is only, a Government official sent by the Board of Trade can do nothing more than this, namely, look at the building and so far as the human eye can discover, see whether or not it is externally in a safe condition to permit of its being used pubically. Now, beyond that General Hutchinson had neither power nor opportunity of judging, he went down to this place of that railway or viaduct in order to see whether, in his opinion, it was finished, and I am glad that all the witnesses concurred in saying, what one would have expected and believed without its being said, namely, that the inspection General Hutchinson made upon that occasion was of the most careful and anxious character, but there was no eye so anxious as could penetrate through those columns, we have to see that they were in proper thickness, nor could General Hutchinson by the most anxious inspection have discovered that the holes in the channel iron by which these ties were connected to the structure for the purpose of giving it rigidity had been defective in their construction, and that the bridge, which was in all appearance satisfactory when he saw it, was one that would give way and show that the tightness was only seeming and would yield to pressure. General Hutchinson expected that that would be the result, and he further says that because he thought that would be the result he expected that it would be looked after. Now upon that I wish to read you General Hutchinson's evidence beginning with the day of the inspection General Hutchinson made upon that occasion was of the most careful and anxious character, but there was no eye so anxious as could penetrate through those columns, we have to see that they were in proper thickness, nor could General Hutchinson by the most anxious inspection have discovered that the holes in the channel iron by which these ties were connected to the structure for the purpose of giving it rigidity had been defective in their construction, and that the bridge, which was in all appearance satisfactory when he saw it, was one that would give way and show that the tightness was only seeming and would yield to pressure. General Hutchinson expected that that would be the result, and he further says that because he thought that would be the result he expected that it would be looked after.
which, in your opinion, required careful attention
"after the bridge was opened?—I should think so,
"certainly. Of course the object of putting the
"cotted in was to have the means of tightening up
"as slackness occurred? Q. In a bridge of that
"construction, tied together in that way, did you
"anticipate that that would be a matter receiving
"careful attention from those in charge?—Certainly,
"it seemed a very important point. Q. At the time
"you examined it, they were tight enough to satisfy
"you?—Yes, I observed no instances of any more
"slackness than you would naturally meet with in any
"structure of the kind. Q. Would the action
"of the trains passing over the bridge naturally tend
"to loosen those cotters to some extent?—I have no
"doubt that it would, and especially the higher the
"speeds the more rocking motion, so to speak, would
"be produced on the structure. Q. Had you that in
"your mind at all when you suggested the limit of
"25 miles an hour, as a limit which should not be
"exceeded?—I had that in my mind; that it was
"not a structure with a wide base, and that therefore
"it was very desirable to limit the action of passing
"trains to as great an extent as was reasonable; and
"I therefore thought it prudent to suggest low speed,
"because of course the higher the speed or the
"momentum brought to bear upon the columns, the more tendency there would be to give
"it a rocking. Q. But even with that limit of speed
"uniformly observed, would there have been from
"natural action the probable result that I have
"pointed at of loosening these cotters?—There must
"have been a certain amount of vibration and oscillation
"in the structure, and hence a
"tendency to loosen all the different joints of the
"structure. Q. Would the probability of that loosen-
"ing be enhanced by the high winds blowing at one
"time from the east and at another time from the
"west?—Doubtless they would also tend to produce
"a rocking motion." Now that was General Hutchinson's view—that was General Hutchinson's anticipation; that in a structure tightened up as this was with gibbs and cotters, and upon the tightness of which depended the absolutely entire stability of the bridge, the persons who were charged with the duty of maintaining the bridge would look after these things as they tightened up these pieces, not the only things to be looked after when the bridge had been opened and put in use. Now what was Sir Thomas Bouch's view upon that matter? Sir Thomas Bouch said he did not anticipate this loosening at all, and I put it to him: "Therefore you made no provision
"against that being done?" He said "No"; he did say, "I had no special apprehension of that,
"it has given way, the ties then came loose and I did
"not provide against that;" but he has not provided
"for the maintenance of these ties in the stiff and rigid
"condition in which they should always be maintained.
"Now I would prefer Sir Thomas Bouch's statement to
"that of Mr. Noble. Mr. Noble said that what he did in
"tightening up these pieces, he took with himself without instruction and without authority. According to his statement his duty was simply to attend to the bed of the river to see that scouring did not take place, and to do what was necessary if the scouring took place; and according to him the putting in of these packing pieces was simply an occupation or an amusement which took up the time of his men when they had nothing else to do; certainly not a thing of such importance as to induce him to communicate it to Sir
"Thomas Bouch, or even to communicate what he had done. Now, it is rather difficult to take that
view of Mr. Noble's evidence, and on the other hand to take Sir Thomas Bouch's evidence that he had
"made known this to Mr. Noble.

(Colonel Yolland.) Will you allow me to call your attention to Mr. Noble's letter?

(Mr. Trayner.) If you will allow me to finish my sentence you will see that I have not forgotten that.
"I said if you had the two things standing together it would be very difficult to have said which of the two
you would have to accept. But you have Sir Thomas Bouch's evidence that in one of Mr. Noble's letters, he has reported to Sir Thomas Bouch what he has been doing, therefore I am willing to take Sir Thomas Bouch's statement that Mr. Noble was charged with that duty, and that Mr. Noble, as far as his knowledge went, was attending to that duty. But when Mr. Noble
"(a man I am dealing with whether or not Sir Thomas Bouch fulfilled his duty in seeing to the maintenance
"of the bridge) to leave entirely in the execution of this important function? Mr. Law said, and it has been repeated more than once, if it were rather against Mr. Law, no doubt Mr. Noble was a man whose inspection was careful, and whose observation was acute, and he gave Mr. Noble every credit which it was possible to give him and which he was entitled to expect; but neither Mr. Law nor anybody else in this Court will say that Mr. Noble was a man whose position or whose skill warranted Sir Thomas Bouch in leaving him there as the irresponsible remedier of every accident that could take place to these tie-bars, upon which the stability of the bridge depended. But Sir Thomas Bouch, as he left the inspection of the work to Mr. Paterson, seems to have left the inspection of this to Mr. Noble, and because the inspection was not sufficient, or because upon the inspection was insufficient, the result, I am afraid, is that the bridge is where it is. Now it was an unreasonable thing in General Hutchinson to expect the thing which happened, was it unreasonable to anticipate that these tie-bars would loosen? Was it unreasonable in General Hutchinson to expect that there would be a tendency to loosen these tie-bars, and to take care that these defects, which in the ordinary course of natural causes would come about, would be remedied so as to keep the bridge in that state in which General Hutchinson passed it? If General Hutchinson had found any one of these ties tinkered up with a packing-piece three-eighths of an inch wide, he would not have needed the bridge to be told you, have ordered the bar out, and a new bar in—"if he had found not only one but many of these pieces, he would have taken care that not a single
"soul had traversed that bridge until it had been put beyond the reach of accident by a method suggested by himself or others. But my learned friend Mr. Bidder said that there was no such thing as a man
"or vibration, and he read or referred to the evidence of one or two of the railway guards and drivers. Now, I have, as I have said before, no objection to my learned friend Mr. Bidder reading such parts of the evidence as bear out his view. My learned friend Mr. Bidder is supporting a theory and defending a client, but it is not necessary that he should be bound by evidence of any greater value than that of railway drivers and guards, to tell you that which was likely to occur actually occurred. If you will take the trouble to refer to the evidence of ex- Provost Robertson and Mr. Hutchinson and Mr. Leng, the managing proprietor and editor of the "Dundee Advertiser," you will find that Mr. Hutchinson spoke not only to a vertical motion, but to a very obvious lateral motion on the part of the bridge, which in the case of Mr. Robertson and Mr. Hutchinson became so marked and so terrible that, having season tickets entitling them to cross the bridge, they gave up the tickets, because the mental discomfort and anxiety was so great that they rather gave up the tickets they had purchased than use the bridge from south to north. Now, in the face of evidence like that, you do not, I anticipate, put much faith in the evidence of a railway guard or driver; it is that man's business to stand upon a railway van or engine, and he is accustomed to a good deal of shifting motion, and he does not see any of oscillation; but these gentlemen, who were not there in official positions, but whose convenience it would have been to use the railway, positively gave it up because of the discomfort produced in their minds by this oscillation and vibration, and Mr. Hutchinson (and this was long before we had found out what was
the real cause of the vibration by reason of the loosening of the time), the remarkable expression
that by the thought the bridge was loosening, and my learned friend Mr. Balfour asked him whether or not
if the bridge was loosening, he did not think it his duty to go and tell the railway company about it.
Mr. Hutchinson excused himself from doing so, by saying, that his experience of complaints to public
was not equal to that of his skill and power to observe, they have practically pledged them-
selves to be bound by his statements.
(The Commissioner.) No, I protest against that; we are not bound at all by Mr. Law’s statements, but
we are very glad to take what he saw.
(Mr. Webster.) I am not to induce him to repeat it, and therefore he did not do it. Now it is obvious that
it is out of the question for my learned friend Mr. Trueman for interrupting him.
(Mr. Trueman.) Now, Sir, I am not even here desiring to support any particular theory or to press any
particular argument. I am not here relying necessarily upon the evidence of Mr. Law, for we have the
evidence of two men who have built bridges against him, one of whom is Mr. Cochrane or Mr.
Brunlee, you have absolutely nothing except the theory that the bridge was not down by lateral pressure
at all, but that it was blown down when in a state of extreme tension from lateral pressure by the coming of the
train in contact with one of the girders. Therefore I shall address myself now, I am glad to say, in the last
part of the question, to the question of whether or not the bridge was broken by the train. Now, here it is right to observe
that the evidence as to wind pressure has been very much commented upon by my learned friend Mr.
Biddie, who certainly did not express any high opinion of the views given by the Astronomer Royal.
I am not here to defend the Astronomer Royal’s opinions, either with regard to the theory of the
Thames, or with regard to the case of the Forth Bridge. I should think that the Astronomer Royal is abundantly able to protect his own opinions,
and that opinions coming from such an authority would commend themselves to you and would not suffer much
from criticism by the Bar. Indeed, if the Astronomer Royal’s own opinions were to call up an opinion favourable to one view, and contrary to another,
I do not think counsel need trouble themselves much upon this question, because the criticisms of counsel
against this view would not make you think less of it, nor would criticisms in favour of it induce you to accept
it more readily; still I think we have something of much more importance in the case of the
Astronomer Royal, and of much more importance in the case as against Sir Thomas Bouch as against any opinion which the Astronomer Royal may
now have expressed. What was this bridge designed for? To bear a lateral pressure of 20 lbs. to the square
foot, as are told. Sir Thomas Bouch had no wind pressure in his mind at all. I asked him, for I was anxious to
get that from the fountain head if possible, and with the view of putting some questions to him upon that
matter, where Mr. Stewart and Dr. Pole got the statement in their report that this bridge had been
designed with a view to stand a lateral wind pressure of 20 lbs. He did not give it to them. I asked Dr. Pole when he got it; he got it
from Mr. Stewart, not from Sir Thomas Bouch, so that we have traced back this design, as far as the
lateral wind pressure of 20 lbs. is concerned, to Mr. Stewart, and it comes out in his calculations, for
he made all the calculations for the bridge if I remember right. He have got over the whole weight as if the Cov. had seen or
saw it; therefore I say, it may seem worthy of observation on the part of my learned friend Mr. Webster,
but it is not right for him to estract these things; he may remark upon it as much as he pleased when I
have finished, but I say again, that when the Court has appointed a man in whom they have absolute con-
dence, not only in his integrity but in his skill and power to observe, they have practically pledged them-
selves to be bound by his statements.
8 May 1866.
Thomas Bouch or the engineer that 20 lbs. of wind pressure is not sufficient wind pressure to allow for Scotland. Professor Macquorn Rankin distinctly puts it at 55 lbs. Professor Rankin has been somewhat laughed at as an authority. We have here an authority in this north of this island to regard Professor Rankin as an authority. The Court will know what weight to attribute to it, but the professor of one of the Scotch Universities has put it in his book, and in his own name, that in Scotland in providing for lateral wind pressure you may have wind pressure up to 55 lbs. Then further that you have it I think set forth in Mr. Clarke's book that Mr. Stephenson, in building the Menai Strait Bridge made an original calculation allowing 50 lbs. Dr. Pol, one of the witnesses, said that these calculations were departed from, and that ultimately he made the bridge only on the view of resisting 20 lbs.; but even 20 lbs. pressure was something which, if it was in the Valley of the Tay, or which might be expected in the Valley of the Tay, was a pressure that Sir Thomas Bouchi had in his mind as a thing that might be applied to the structure for which he was responsible. Now, that again points to the absolute necessity which there was on the part of Sir Thomas Bouch of giving the most anxious care and attention to the rigidity of that bridge, which might be subjected to a pressure which according to Mr. Baker, would have blown it all to bits.

(The Commissioner.) I think there is also a thing which has not been adverted to, that in Mr. Clarke's book, reference is made to the fact that the Britannia Bridge runs east and west, and that some allowance must be made for that. I think he mentioned that.

(Mr. Trayer.) That may be so, Sir, but when Sir Thomas Bouch says that he was building for the very pressure that might be applied to the structure for which he was responsible, that again points to the absolute necessity which there was on the part of Sir Thomas Bouch of giving the most anxious care and attention to the rigidity of that bridge, which might be subjected to a pressure which according to Mr. Baker, would have blown it all to bits.

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(Mr. Trayer.) You have Dr. Pole and Mr. Baker in absolute confusion. You cannot have both of them, but if you take both of them, and they are put forward as equally valuable as scientific men, then you have my friend Mr. Bidder destroying his own case, if you take Mr. Baker that the wind was not 15 lbs. of wind pressure, and Dr. Pole stating that a carriage would require 33 lbs. to upset it, there certainly could not have been enough on these data to upset a second-class carriage; but I confess that that perhaps is just a little straying into that minute criticism which my learned friend Mr. Bidder rather deprecated, and I do not want, in an inquiry of this kind, where the results must be so important to all concerned, to put any answer to my learned friend Mr. Bidder's theory upon so narrow or so slim a ground as that. I think there are other considerations which, to my mind, make it conclusive, if I may say so, that this theory of the train going off the rails, or being blown over against the girders, is simply out of the question. Now this is my learned friend Mr. Bidder's theory, and of course it lies upon my learned friend Mr. Bidder, or Sir Thomas Bouch, to substantiate this view; it is in the last degree important for him to show that this bridge did not go down from weakness in itself, but that it did not have way to a side mountain or upon the girders, which might be subjected to a pressure which according to Mr. Baker, would have blown it all to bits.

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the only story I know equal to that is the story of a man who, when going home, complained that the pavement jumped up and hit him in the face, so I think we may pass that by. Now what else is there. My learned friend Mr. Bidder says, I think, "We find there is a piece of timber between the covering plates of the girder."

(The Commissioner.) I do not think he went so far as to say a bit of timber, but a small piece of wood splinters.

(Mr. Trayner.) I am certain he used the word "timmer," because I thought he dignified these little splinters with too important a name. Now let us see how that tells—no, but that rather a suicidal explanation on the part of Sir Thomas Bouch. Where was that bridge founded?—it was founded on these two riveted plates, which are riveted together. Now either Sir Thomas Bouch's work was very badly riveted together, or the wood would not have got in between the plates; that is the first view of it; or the next is that something has happened here of which we have no parallel as far as I know, a piece of wood of the kind described as the whole of the second-class carriage was composed, coming with the velocity considering its condition against this girder, sufficient not merely to break itself, for, that was a small matter, but at the same time sends splinters of itself within these two riveted plates, knocked down a girder, and brings down the whole concern. Will you accept that theory, I do not say with evidence of witnesses who have not examined, but against the verdict of your own common sense? Send a carriage, like this matchwood, against this enormous girder and what would happen? I venture to think it was destroyed in a totally different way from the suggested, but if the carriage had come against the girder, and made an impact at the point itself as the witness describes it, what would have been the result? Would it have been very unfortunate for the carriage, to paraphrase Mr. Stephenson's story, it would be very awkward for the carriage indeed, but not for these enormous massive iron girders. This theory, which my learned friend Mr. Bidder or Sir Thomas Bouch started, and which Dr. Pole and Mr. Biddler entirely upset the evidence of Dr. Pole and Mr. Stewart upon this matter, so far as upstairs was at all necessary. Now there is another thing upon which my learned friend Mr. Bidder relies very much, namely, that the axle-horn was found in the rough class carriage. Suppose it was; it was a light carriage. My notion is, which I submit to you as the result of the evidence, that when the girders gave way, not because the carriage went against them, but because the bridge was giving way and had given way from its own weakness, these girders upon which the second-class carriage and the wheels went down, the whole of the pieces, it came down with a smash, and that it smashed the second-class carriage at all to be wondered at. Have you kept in view which I think my learned friend Mr. Bidder did not remark upon, what was the peculiar condition of the guard's van when it was found? That being a much stronger box than the second-class carriage is found with its roof cut in such a way as one of the witnesses described as it when that train fell upon the water and floated up with the recoil, this girder following immediately upon that, struck it down, and one of these triangles caught the roof of the carriage and cut it just as is shown in this photograph—If that was what happened to the guard's van, that was exactly what knocked about the whole of this inquiry and resolve upon that, that the train knocked down the bridge, and that the bridge did not carry down the train. Still, if you are of that opinion, then how do you account for, that the tender screw coupling is found inside the trough too. The suggestion is this, that the carriage has not been driven only against the girder, but got into that position running alongside of the girder, and that the axle-horn broke off against the girder, and dropped into the trough at such a time when the axle was in a position to drop right over the trough. I think the simple explanation is this—we cannot tell what the action of the water was, or what disturbance there was at the bottom of this river, nor can we tell whether the dynamite helped it, though it was admitted that it was very clear that the dynamite was so local in its action that it could not have had that effect, but whatever led to the axle-horn being found in the trough of the girder in one place, led to the screw coupling being found in the trough of the girder in another, and there is no room for a suggestion that the tender went off the line in a place, so as to occupy a position in that way from which its screw couplings could have got into that trough.

Now I am not sure that there is anything else except one thing to be further referred to in answer to this theory of my learned friend Mr. Bidder. Is it the second-class carriage or the side bars, and had been strong enough to come in contact with it at the speed at which it was going, and not be shivered into a thousand pieces, then the result of its coming into contact with one of the side bars would have been to send it off at an angle towards the advancing carriage. If the second-class carriage was going in this direction as I say, and had struck one of the lattice bars, and was not destroyed, the result of it would have been to have turned the south end of the carriage towards the west—it could not be at right angles—the bridge was only a 14 foot bridge, and the carriage 22 foot long, but it would have turned it. Now I say that if the guard's van ran into it, it would have been all smashed upon the east side, you would have had unmistakable evidence that the guard's van and it had come into collision. It is a very curious result that so far as the framework of the carriage is concerned, that side is almost perfect. There is not much, if any, indentation in the wood—that is there is even one of these struts which Dr. Pole and Mr. Stewart threw away contemptuously by Mr. Baker, the last witness he examined. "You were at Duneds. Mr. Baker, and went with Sir Thomas's assistant to see the ruins of the bridge—" did you go to see the ruins?—No. Q. Why not? A. You know there was a theory with regard to them, but he thought it was not necessary to attack down upon the whole of these struts you like as it does not bring down the bridge. Mr. Baker entirely upset the evidence of Dr. Pole and Mr. Stewart upon this matter, so far as upstairs was at all necessary. Now there is another thing upon which my learned friend Mr. Bidder relies very much, namely, that the axle-horn was found in the rough class carriage. Suppose it was; this carriage was a light carriage. My notion is, which I submit to you as the result of the evidence, that when the girders gave way, not because the carriage went against them, but because the bridge was giving way and had given way from its own weakness, these girders upon which the second-class carriage and the wheels went down, the whole of the pieces, it came down with a smash, and that it smashed the second-class carriage at all to be wondered at. Have you kept in view which I think my learned friend Mr. Bidder did not remark upon, what was the peculiar condition of the guard's van when it was found? That being a much stronger box than the second-class carriage is found with its roof cut in such a way as one of the witnesses described as it when that train fell upon the water and floated up with the recoil, this girder following immediately upon that, struck it down, and one of these triangles caught the roof of the carriage and cut it just as is shown in this photograph—If that was what happened to the guard's van, that was exactly what knocked about the whole of this inquiry and resolve upon that, that the train knocked down the bridge, and that the bridge did not carry down the train. Still, if you are of that opinion, then how do you account for, that the tender screw coupling is found inside the trough too. The suggestion is this, that the carriage has not been driven only against the girder, but got into that position running alongside of the girder, and that the axle-horn broke off against the girder, and dropped into the trough at such a time when the axle was in a position to drop right over the trough. I think the simple explanation is this—we cannot tell what the action of the water was, or what disturbance there was at the bottom of this river, nor can we tell whether the dynamite helped it, though it was admitted that it was very clear that the dynamite was so local in its action that it could not have had that effect, but whatever led to the axle-horn being found in the trough of the girder in one place, led to the screw coupling being found in the trough of the girder in another, and there is no room for a suggestion that the tender went off the line in a place, so as to occupy a position in that way from which its screw couplings could have got into that trough.

(The Commissioner.) You refer to the second-class carriage, do you not?

(Mr. Trayner.) Yes.

(The Commissioner.) The roof of the guard's van does not appear to have come in contact with the lattice?

(Mr. Trayner.) No, it could not. The roof of the guard's van would not have come in contact with the lattice.

(The Commissioner.) Unless it got tilted over.

(Mr. Webster.) The whole of the eastern side, those planks you will find, are torn away.

(The Commissioner.) Though all to bits, and that bit of the axle-horn may have got into the girder when the whole matter was smashed up.
south to the north, strikes one of those lattice bars, it is
either smashed to pieces or it is not—if it is, we
have done with it, and it is out of the way of the
advancing van:—if it is not, it is necessarily turned
round so as to prevent its right side and be smashed
there, but that is not done, the smashing is upon the
water. Now, at this time of day it is impracticable
to account, indeed I do not know that it is desirable for
me to try to account, for how that west side got
smashed, or how the guard’s van damaged it all at;
but what I say is this, it is not unreasonable to sup-
pose that, when that bridge gave, and one of the
carriages went down with the whole girders upon it,
this would cause a complete collapse of the whole thing,
that girders and box striking upon the carriage
would produce splinters; and here the conclusions are such
that no man can ever fathom or get at the bottom of
them. It seems to me preposterous, if I may use such a
strong expression as that, to try to get at the theory of
the cause of the demolition of this bridge from the
fact that there is a fracture in this particular place or a
fracture in that, but it is quite enough, as humbly
appears to me that the train went down in a second of
with the heavy girders upon the top of it as it
turned over, to account for all the damage and smash-
ing that you see upon the train. You just super-
pose a conclusion on this in reference to some
other point which I had almost forgotten. My
learned friend Mr. Bidder says to support his theory,
that now we find from the evidence of the divers, that
the guard’s van to some extent overlapped the second-
class carriage, that so far this plan is inaccurate.
Now it may be so; that depends upon the evidence of
the divers; but I think it is right to call attention to the
fact that this plan was proved by Mr. Peddie, Sir
Thomas Bow’s assistant, and given to the Court
as accurately representing, according to the best
information they had at the time, the position of
the carriages and the different girders. It may be that
something has subsequently shifted that van over to
some extent, to make it overlap the frame of the
second-class carriage, if it did so. You will consider
whether you are perfectly satisfied, first, that there is
evidence of the fact, and in the second place, whether
if it be a fact, there is enough in that to satisfy you that
these two carriages occupying that relative position to
each other, now occupy the relative position which in my
opinion did some months ago; and then you will require to
consider this further fact, whether if the carriages
overlap each other now, they overlapped each other
upon the bridge before it fell. Now, just conceive
for a single moment that the guard’s van is to some
extent overlapped into the second-class carriage.
How will they go? They will go in this way
(indicating the same), and then they will separate.
That way, then the guard’s van will go entirely over,
at any rate very much in front of it, because upon the
theory advanced by my learned friend Mr. Bidder,
this guard’s van was not merely close up to the second-
class carriage, but the cause of its de-
struction, to some extent, coming into it when its
progress was impeded or stopped by the girders.
Therefore, I say if you had on the permanent way
the guard’s van at all into the second-class carriage,
telescoping into it, as my learned friend Mr. Bidder
once said, then you would have these two following
latticed cases in this case each case square, or any
other way, in which case the guard’s van would have
gone over the second-class carriage altogether. Now
if that is so, is it not quite as consistent and as
reasonable as the other view? The second-
class carriage is in front, it has been of course, as they all
have been, more or less smashed by the falling of the
bridge; but you think, it is possible that the guard,
probably before the train had met the water, and had been
to some extent flopped up, the guard descending with all
its weight crushed them down, the second-class
railway going sooner than any of the others, simply
because the second-class carriage was an old age, and
of a peculiarly light construction, as Mr. Drummond
said; but if they fall over in that way it is not
unlikely, as the coupling between the second-class
carriage and the one in front of it had broken, that
the guard’s van falling after the second-class carriage
would more or less overlap it when it got to a steady
surface. Whether that is so or not, it is idle to
speculate, but you have this unmistakeably proved
that whether the train swore the bridge or not, and
without anything of that kind happening, you have
enough to prove the destruction of the bridge through
the wind that night striking the bridge in its defective
condition. I say it would be very dangerous for all
future girder bridges to accept the view that this
second-class carriage was pulled upon the bridge,
and I think it is a fatal thing surely to girder bridges to say
that a carriage of such a light construction as the
second-class carriage was, if it got off the line and struck
against one or even two of these tiers, should bring
down the whole construction.
Now, Sir, I have finished the observations which is
occurred to me to make upon the proof—it remains
for the Court to determine upon the question which has
been submitted to it, but I think I may take leave
to say this, that the Report of the Court I am
satisfied will be conceived in a spirit of, I do not say fairness,
but of kindliness and indulgence to everybody concerned.
My learned friend has to report to his client, or
his client's wishes, and to make whatever full and fair
investigation, with the legitimate result, brought
out whatever that may be; I am satisfied that
my learned friend Mr. Bidder and his clients have had a very full
investigation. He must be
satisfied that he has been very fully heard upon its
effects and its results, and I am sure I may say in
conclusion that whatever the result of this inquiry may be,
as embodied in the Report which the Court
will have to render to the Board of Trade, it will be
extremely satisfactory to the public mind to have this
matter so thoroughly investigated, not merely, as I
stated in the outset, with the view of ascertaining if
there was any fault, and, if so, upon whom that fault
lay; but the public mind will be satisfied that, what-
ever engineering and other skill can do, there will not be,
so far as the Court is concerned, any stone left
unturned which may make it possible to predicate
that the fall of the Tay Bridge, as it was the first in
this country, should also be the last.
(Mr. Webster.)
Now I am concluding the few
observations I have to make before you, I desire to
thank the Court most sincerely on my own behalf for the
courtesy they have shown me, and also to my learned
friends in enabling me to fit in that time which I have
remaining to me to-day with my other engagements.
I am obliged to you, sir, for your kindness in
allowing me to follow. I do not think it will
make any real difference to him in the end.
Now, Sir, I do not propose on this occasion
to detain you at any very great length, or to examine
with any minuteness the various passages of evidence
upon which my observations will be founded. I can
speak of these passages which may be necessary to refer to, in order to support
any observations I shall make, but I shall rely in great
measure upon the great attention which has been paid
by this tribunal to the evidence of the witnesses. In
all these inquiries one or other member of the Court is
always able to refer us to the passage is, and in
this case each case square, or any other way, in
which case the guard’s van would have
gone over the second-class carriage altogether. Now
if that is so, is it not quite as consistent and as
reasonable as the other view? The second-
class carriage is in front, it has been of course, as they all
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its weight crushed them down, the second-class
carriage going sooner than any of the others, simply
because the second-class carriage was an old age, and
of a peculiarly light construction, as Mr. Drummond
said; but if they fall over in that way it is not
that I, as representing the contractors, have nothing to do with any of the functions you may have to perform; but, on the other hand you have to inquire into the circumstances of the case. The matter which is before you, and which is directly interest me, is the question of the damage which has been caused to the bridge. It is a question which I have asked you to consider in detail, and which I have asked you to consider in such a way as to make it clear that it is within their duty as reporting to the Board of Trade, and not to be regarded as bearing upon any possible trial between the company and its members of the public, or the contractors or otherwise.

Now, Sir, a variety of things have been said in the course of the inquiry, I will not say by whom, and I will not say in what spirit; I hope I shall meet fairly and frankly, and in the same spirit in which whatever charges have been made, have been made against the contractors; but a variety of things have been said which have caused a great deal of pain and anxiety to the company, and which have naturally caused the company, and which have naturally caused the company, and which I am not willing to accept, and which I am not willing to accept, and which I have pointed out, have nothing whatever to do with the fall of the bridge. Therefore, although it may be your duty to refer to these circumstances, with regard to the past and present history of the bridge, I do respectfully protest against its being thought that it is part of your duty to adjudicate upon such matters as those between the company and the contractor, or as between the company and the engineer. You know perfectly well, because I have made no concealment of the matter, that I have not thought it necessary to put before you such detailed evidence as I could have done, with regard to some of these cause or circumstances, because it has been apparent with regard to these matters one after the other, that they really have nothing to do with the subject you are examining into; that although you might refer to them as a subject of caution in the future, you could not refer to them as a matter in the past. No, my Lord; the bolts were made of bad iron, and whether the bolts were made of bad iron, and whether the bolts supplied by the Cleveland Nut and Bolt Company were or were not made of good iron, and whether they had or had not been inspected by Messrs. Hopkins, Gilkes, and Company. Now, my Lord, I do not think that I should be allowed to say, and Sir Thomas Bouch has told you, that he has spent more than £9,000, without his own expenses, on the inspection of the bridge. Now it does not do for the Board of Trade to get up now and say the inspectors were not sufficient, or not competent. I do not think Mr. Gills has ever suggested that the persons chosen to inspect were incompetent; but at least I think it is a little hard that that kind of observation should be made after the event, at a time when all the work was being carried on for a period of from four to five years, and then to say that they were not sufficient, or not competent. It would be somewhat like the case of a general who, having a large army to command, thought fit himself to be the sanitary inspector, to manage the commissariat and to be every officer rolled into one. It is only by having a proper staff of inspectors that this work can be properly done, because it is spread over a large area; it is taken in a variety of ways, and therefore I suggest that when it is said that there has not been sufficient personal inspection on the part of Sir Thomas Bouch, or if it were suggested on the part of Mr. Gilkes, that it would be impossible and undesirable that there should be personal inspection, of course they would be the first to object. It would be, I say, to say, and Sir Thomas Bouch has told you, that he has spent more than £9,000, without his own expenses, on the inspection of the bridge. Now it does not do for the Board of Trade to get up now and say the inspectors were not sufficient, or not competent. I do not think Mr. Gilkes has ever suggested that the persons chosen to inspect were incompetent; but at least I think it is a little hard that that kind of observation should be made after the event, at a time when all the work was being carried on for a period of from four to five years, and then to say that they were not sufficient, or not competent. It would be somewhat like the case of a general who, having a large army to command, thought fit himself to be the sanitary inspector, to manage the commissariat and to be every officer rolled into one. 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Now, Sir, you have it from Mr. Gilkes himself that he went almost fortnightly two or three days as a time to Warrington, and was present in the fields when he did not go. Now I do not know whether you consider Mr. Gröthe a part-time, that I think the Court will be of opinion that he gave his evidence in a perfectly fair manner as regards matters of fact. Of course he may have been attached to a particular view on this subject, but as regards matters of evidence—Mr. Beattie, who I am sure from reading his evidence, for I did not hear it, gave it fairly, and you have Mr. Campbath; therefore you have this that the system of inspection which is established is such as in the first instance would be expected to do its work well; and when I come presently to point out to you that upon the question of the cause of the failure of the bridge a variety of defects put together may almost be said

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Now, Sir, having reminded you of the way in which the staff was organised, and having reminded you, I think, of the way in which they have done their work, let me now come, as briefly as I possibly can, to the particular matters upon which it has been suggested that there is some shade of blame resting upon the contractors. My learned friend Mr. Trayner used the expression you know, which I venture to think was not in any way warranted by the evidence, though I am quite sure he would not have done so if he felt it to be too strong; but, notwith- standing the evidence thus given, I think it might have happened at Wornit. Now, I do not know, when you come to consider for a few minutes, what did happen at Wornit, whether it can possibly be represented that the conduct of those who represented the contractor justified such an expression as that; it is not for me, as representing the contractor, and seeking your fair judgement upon it, to put into words my own view of the outcome of their work. I do respectfully protest against its being suggested that that is fairly represented by such an expression as "that terrible things happened at Wornit." Now what is the first point—the casting itself. I confess one is grieved to see such a hasty and incorrect impression which is conveyed that the importance as disclosed by the evidence given in the first instance with regard to this casting. Nobody who represented the contractor, and I know I am speaking rightly here, because I am instructed by the contractor, nobody, I say, could look at the evidence given at Dundee by those witnesses, whose names I can give if necessary—an one of the public could read that without being impressed by the impression that what was meant to be conveyed was that the whole iron casting was bad, and bad in a way that must have come to the knowledge of those who had the control over it—not defects in respect of a creek here, or a cold shut here, but causing defective construction of the whole mass of iron, and I know that to have been ascertained from this evidence. I say of that now, but you were told that the iron melted and ran away; that it would not mould in the ordinary way, and that it was the worst iron ever seen, and with all this going on for months, and not a suggestion that any complaint was ever made by any single member of those who were responsible for the work. Now, Sir, we know now that whatever may have been these men's idea, I know it is only a natural inference, and I know that more than one member of this Court who has had experience of catastrophes, will know how prone people are to come forward and either make themselves heroes, or pretend that they can make themselves heroes in this particular way. I know one cannot help having a feeling when one reviews this evidence that these men did not know what they were talking about, or could not be believed in what they said.

(The Commissioner.) I believe some allowance must be made for the idea that Cast iron, upon the evidence of a competent witness, does not cast a cast so readily as Scotch iron—consequently these men being Scotch and dealing with Scotch iron, came to the conclusion that it was bad iron, because it did not flow so readily as the iron they were accustomed to.

(Mr. Balfour.) That is so.

(Mr. Webster.) I am not sure that my learned friend Mr. Balfour would be very glad of anything which should tend to remove the impression under which the contractors laboured, for some considerable time after that evidence appeared in the public prints, because it was no fault of my learned friend's that no answer was given at the time; but it has gone forth to the public that there was something wrong.

Now, how has Mr. Gilkes ventured to deal with it? I think it speaks very highly for the gentleman whose character has been severely tried when he said that those defects existed only in the ignorance of those who gave that evidence. I am very glad you have made the suggestion that there might have been ignorance on the part of the men, but the impression was so unfounded as to be covered by the statement that iron was not fit to be used for the casting. I think
there was upon the part of Mr. Law a little idea, until he got Mr. Kirkaldy's tests, that the iron was, in fact, defective. I think you cannot read some passages of his report without being under the impression that they were not quite conclusive, and that the belief, with which he risked to do him injustice; he may think I am attaching too much importance to some chance expressions which occurred in his report with regard to the iron.

(Mr. Barlow.) I do not think there is anything in his report which implies that the iron was bad. (Sir.) I am very glad.

I have not taken that expression accurately. I had thought he so contended; but however that may be, Mr. Law, not having given his evidence at that time, the contractors did for a considerable time remain under the reflection that the iron they had used in the construction of these columns was bad.

I conceive what is the point referred to with regard to this casting before I go to the bridge. It is said that these columns were cast horizontally, and that that was a bad thing and ought not to be done. Now, again, you remember that Mr. Gilkes told the Chief Commissioner yesterday that "apart from lugs and so on, I should prefer to cast the columns "vertically", but, in this case the casting was of "necessity horizontal." I speak again here with very great deference to those who are better informed, but I cannot help thinking that a considerable portion of the evidence, in this case, given in the first instance, was, intending to lead the impression that the casting was done horizontally, instead of vertically. Mr. Cochran showed that Mr. Gilkes had not acted wrongly in the matter. He said, "I "prefer vertical casting, but when you have lugs and "brackets upon the casting you cannot have vertical "casting." Now admit for a moment that it should occur to you afterwards to recommend to the Board of Trade that in a structure of this magnitude, or of a similar kind, no cast-iron lugs should be used, a matter upon which I do not pretend to make any observation, what we have to do is this—the contractor had to cast a particular kind of column. No imposition can rest upon Sir Thomas Lipton as to regard to that matter, because as one or more of the engineers have said to you in this box, cast-iron lugs have been used to a large extent in structures of this kind, and therefore it could not be said to have been an "improper thing to do. Therefore given that design to be carried out, that they should be made with cast-iron lugs, it was not a right thing in saying that they should be cast horizontally, because he says, and here again you have to judge how far that is within your province, my judgment is that the proper thing was to cast these columns horizontally said not to cast them vertically—"he is not cross-examined upon that matter. I do not say that my learned friend Mr. Trayner was wrong in not cross-examining him, but at any rate he goes to show that that which was in the earlier passages of the evidence, could not be taken to show that it was wrong to cast these columns horizontally: that thing required to be made, but that thing, it was proved, to be the most satisfactory way of making: that particular thing. Now I do not think I need call attention to the alleged defects about the shifting of the flakes in the moulding of the column. To what extent it is visible in the bridge, I should not be entitled to say, even if I had seen the ruins which I have not seen. I must leave that to the judgment of the Court, but this at any rate I do say that if any charge is to be made against the contractors for not having sufficiently fixed the top mould—if any suggestion of the kind is to be made, it should be made in evidence a little more satisfactorily and distinctly than that which has been laid before you. I do not complain that more evidence has not been laid before you, because I think it is not an issue freely: before you. Mr. Gilkes tells you that there were two flakes that were fastened down in a certain way, and he says he thinks the evidence of the ruin shows that he is correct upon that point; but one is justified in making this observation. This is not one piece that is going to be cast and nothing else like it. I was running it over in my mind just now—there are forty-two columns altogether in each pier. There are twenty-eight 15-inch columns in every one of those piers, and of course we have the fourteen of the 18-inch columns, therefore what was being cast at Wormit was a thing which would have been done many hundred times in the course of these works; therefore it is inconceivable that the proper appliances should not be used—it is inconceivable that Mr. Gilkes should not see that these were used, and that they whose duty it was to inspect this manufacture, should not have insisted upon their being used. I therefore venture to think that that is not a matter upon which you can at all condemn the contractors, because it is not a matter which it is alleged contributed to the falling of the bridge. Now, the next point referred to is that under ordinary circumstances, apart from anything extraordinary, it does not affect the question of downward, it may affect the question of lateral pressure, but I leave that with the observation that at most, it is something you must expect will occur; and I venture to think that the small number of instances in which I have seen Mr. Gilkes is right, in saying that they should be cast horizontally, because he says, and here again you have to judge how far that is within your province, my judgment is that the proper thing was to cast these columns horizontally said not to cast them vertically—and I do not say that my learned friend Mr. Trayner was wrong in not cross-examining him, but at any rate he goes to show that that which was in the earlier passages of the evidence, could not be taken to show that it was wrong to cast these columns horizontally: that thing required to be made, but that thing, it was proved, to be the most satisfactory way of making: that particular thing. 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this work had been scanned, and had been disgracefully performed by the contractors. I am sure if I did Mr. Law injustice in thinking him too much of a partisan in respect of the way in which he gave his evidence, and unreservedly apologised to him for it. But one or two things led me to that impression. For example, he called attention to two pieces of channel iron being fastened together, which he said was the most slovenly thing he ever saw. I saw I was being pitched into, and I put a question to him:- I asked him if it had anything to do with the fall of the bridge, and he said No it had not. Now I do not think Mr. Law felt that it affected the general building of the bridge, and if I perhaps put the question to Mr. Law in a way which he did not like, or in a way which I thought not to have done, I most unjustly apologised for it; but my desire was to distinguish between that which was the cause of the disaster, and those minute errors which must exist in every structure.

(The Commissioner.) I think to prevent any misapprehension I ought to say that the functions of Mr. Law and the Court are perfectly distinct. It was Mr. Law's duty to point out anything which occurred to him, whether it tended to the destruction of the bridge, or not and it was for the Court to consider that evidence.

(Mr. Webster.) Now, Sir, I am going to take that piece to the bottom, and ask you to let me call your attention shortly to the defects which attestation has been called. Now the first is the defect in the basement, to which Mr. Law has called attention, by showing that one of the stones has come away. Now here again I do not know whether it is going to be suggested that, after what has happened to this bridge, after the extraordinary strain it has been subjected to, that it is going to be suggested as a bad bit of workmanship for which you would cast blame upon the contractors. You, I suppose, Sir, know what the various duties of these relative pieces of work are—only subject to the relative position of the columns, and the stone that was torn up, nobody would have expected that that actual adherence of the cement, to the stone would be greater than the strain which it has been subject to in this accident— I think it would be a most false inference that because you find a piece of stone torn away from its bed that there is improper work in respect to it. I am not going into engineering details, but what you find is, that where the stone is embedded in cement, the particular point at which the structure has given way, the adhesion of the stone to the cement, has been less than the holding power in some other part of the cement work made under Mr. Noble's inspection. I say that to exonerate Messrs. Hopkins, Gilkes, and Company, for that cannot be said to have contributed to the falling of the bridge. I put it even stronger, subject to the criticism of my observations by Mr. Barlow and Colonel Yolland, that seeing what has happened to these foundations, it would be an extraordinary thing if anything had not happened to the stones. Whether it was caused by girders falling upon it or by some hundred tons coming and plunging down upon it with a leverage which ripped it up, nobody can possibly tell; but we know well that this work was inspected, and, as far as anybody could possibly tell, was holding its place well before the accident.

Now, Sir, the next thing I come to is the holding-down bolts of the base plates, and here I think I was misled to a certain extent by Mr. Law's own evidence. It will scarcely be suggested now that this was a matter in which Messrs. Hopkins, Gilkes, and Company were to blame; but you may remember that it was pointed out to you that the bolts had drawn up so much in the act of screwing that washers had to be put in upon the top, in order to make them good, because the thread did not extend long enough. If that had been the fact I dare say Mr. Gilkes would have admitted that it was an improper piece of workmanship in those on behalf of whom he was responsible; but the evidence is all one way that those bolts were set in cement for weeks and months before the bridge was erected. Mr. Grütte, I think, told you what Mr. Law suggested was impossible. There is another element in the matter; there is what Mr. Law said about one particular bolt where the hole was not probably deep enough, or the cement did not get to the bottom at the time, and the bolt stuck up; but even if it should come to the conclusion that those holding-down bolts were not perfectly level at the time, there is no blame to be attached to Messrs. Hopkins, Gilkes, and Company in the matter, and certainly it had nothing to do with the Board of Trade.

Now with regard to the spigots at the bottom of the columns, when this was pointed out by Mr. Law, I thought it was going to be seen that there was something the contractors had forgotten; but when we heard Sir Thomas Bouch's evidence, I say rightly or wrongly, because I do not wish that there should be any idea that I am approving the design, but rightly or wrongly, Sir Thomas Bouch determined to have no spigots at the bottom of that joint; that was put forward as being something for which Messrs. Hopkins, Gilkes, and Company were blameworthy, now turns out to be something with which they had nothing to do. Now, while I am upon that, let me remind you of a suggestion that in some instances—in fact, in several cases it was suggested that the spigot and fault was missing. Mr. Grütte told you that he had only got two. Mr. Gilkes told you that he did not believe a single plate was put into that column without a spigot and fault joint. I want to point out to you that unless you are satisfied in any case that that occurred in a place, in which it was important with respect to the fall of the bridge, there is no single point in which Messrs. Hopkins, Gilkes, and Company are to blame. I cannot help reminding you of Mr. Law's evidence, that, thinking it important, as he did, he could only tell you of two places in which he had observed the deficiency. Mr. Grütte has been over the bridge, and did not observe it at all. Upon the whole, therefore, I can only deny that that can be suggested as being in any way existing; and I respectfully submit that it is not to be contended as in any way a cause of blame with regard to the coming down of the bridge.

(The Commissioner.) At this point it will be convenient to intimate to you that I am given to understand, that Mr. Trayner has an engagement. I do not know at all whether or not you would wish that Mr. Trayner should remain.

(Mr. Webster.) Not at all. I shall certainly take no advantage of his absence.

(The Commissioner.) Before Mr. Trayner leaves I desire to say this, that we shall not certainly make our report until we have a distinct intimation from the parties as to the direction which the permanent way has taken at both those expansion joints. We consider that is a matter of very considerable importance, and we consider it absolutely necessary that we should have information as to its direction at both those expansion joints. I think you saw the importance of that, Mr. Trayner, sufficiently.

(Mr. Trayner.) I did, Sir. Perhaps you will allow me to make one further application, namely, whether the railway company may now proceed to repair the locomotive and tender, and whether they may now proceed also to deal with the débris of the carriages as being no longer useful for the purpose of this inquiry.

(The Commissioner.) Certainly.

(Mr. Trayner.) And whether they may also proceed to deal with the remainder of the girders which have been brought ashore at Broughsh Ferry, as old metal or otherwise.

(The Commissioner.) Yes, certainly; but we should be glad if they could raise the ends of those expansion girders untouched and have them photographed.

(Mr. Trayner.) That is those which the Court have not already seen; but as regards the ends and cotters which the Court have already seen or have had photo-
graphs of, those I understand the company may deal with.

(The Commissioner.) Quite so.

(Mr. Trayer.) Therefore we understand that whatever the Court has seen or has seen photographs of, the company may deal with; but with regard to what may be recovered from the Tay we will follow your directions.

(The Commissioner.) Before you leave, Mr. Trayer, we must thank you very much for your great attention and the great assistance you have given to the Court throughout the whole of these protracted proceedings.

(Mr. Webster.) Now, Sir, I was submitting that you may find that spigots and facets were wanting above the bottom; but if you should think so, it is not a matter which in any way can be made a matter of blame as between the contractors and the railway company. Mr. Cochrane told you that he could well conceive that there might be many reasons why the engineers would not like to have a spigot and faceting at the bottom of a joint. I do not know what Mr. Barlow's view may be, when he comes to report in the future, but it cannot be taken as a matter of blame to the contractors.

(The Commissioner.) It would not be the contractor's duty to do it.

(Mr. Webster.) No, not at all; I only wished it not to be, in any way suggested as being wrong on their part.

Now I come to the facing of the flanges inside and outside, and here again the course adopted by the engineer and contractor has been most amply justified. Mr. Law will pardon me when I say that he pointed out that spigots and facets were wanting above the bottom, but if you should think so, it is not a matter which in any way can be made a matter of blame as between the contractors and the railway company. Mr. Cochrane told you that he could well conceive that there might be many reasons why the engineers would not like to have a spigot and faceting at the bottom of a joint. I do not know what Mr. Barlow's view may be, when he comes to report in the future, but it cannot be taken as a matter of blame to the contractors.

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if it were thought better to drill the holes in these lugs that should not have been done. Sir Thomas Bouch and the inspectors saw the work as it was being erected from time to time, and saw that they were cast holes—that is not denied. It may be said, and I will take the burden upon myself for a moment, that it was not Sir Thomas Bouch's duty to see that each hole was exactly opposite the other, and that they were perfectly accurately cylindrical and not taper. I agree that that was not Sir Thomas Bouch's duty, but was a contractor's duty to see that accuracy existed, but they were being cast in the way which the engineer and which Mr. Law tells you is almost certain to involve a certain amount of taper, or at any rate a risk that the things will not be always cylindrical; therefore a practice was adopted, I am afraid, that the holes in these lugs should be cast holes and not holes drilled, because when you are dealing with a question of drilling, there could have been no difficulty in drilling them if it had been thought proper to do so. Now, it may be the destruction of the skin of the lug, yet if you find one of the cases of the lugs a little irregular you find it out and make a larger slot by an engineer's touch, and that renders a corresponding weakness of the cross section. Now, Mr. Grothe says, had I known that was the degree of taper, which existed in some of these holes, I certainly should not have let them go into the bridge, but just see what the opinion of Mr. Cochran is. Mr. Cochran says, I think it was a defect—the bolt must be bent, but when it took its bearing it would be as strong as it was before. It may have been that the lug would be injured by the bending; but apart from that, it is utterly impossible to say that the existence of the taper or want of cylinincreality could be pointed out as a thing for which the contractors are to blame. It was part of the result of a system which necessarily involved that risk, and although I agree with the suggestion that in a construction of this kind it is important to take steps to reduce the risk to a minimum, I respectfully protest against the contractors being charged with neglect because they allowed this system to exist. Here was the system adopted and carried out, and it was part of the engineer's design that it should be done. I hope there may be no reason for blaming the design, but certainly the contractors are not responsible for the adoption of that particular design if blame attaches to it. It may be that with extraordinary caution and extraordinary care those holes may be cast perfectly straight—it is possible that it may be done. It is possible that there is a risk that the thing may slightly taper.

Now, Sir, I have almost exhausted the little matter that I wished to refer to, but I must say a word about the gib and cotters. Here again you were told that the whole of the slots of the tie bars were roughly punched with a round punch, and were not fitted to the size of the cotters. Now, I believe, as a matter of instance every single slot in every tie bar was punched by a slitting machine.

(There are some sews which were made otherwise.)

Mr. Webster. Those were the slings. Nobody has produced a tie bar which was not punched, or I may say, slotted, but there may have been a sling or two. Now, you have, on the other hand, evidence that in by far the large majority of instances, if not in all, the slings were made in the same way. Mr. Law has discovered amongst the ruins one instance of a sling having rough edges, I ask, can it be suggested for a moment that this was the cause of the accident? So again with regard to the gib and cotters which Mr. Barlow has asked questions about, they were furnished from plans drawn by the engineers, and they were prepared by the contractors in a manner for which they cannot be blamed.

Now, with regard to the disappearance of the channels from the lugs, that is disposed of, because Mr. Grothe told you that he had never found all four of the holes in the channel iron disagreeing in position, and you have heard that unless all the four disagreed, so as to throw it off the centre, there would be no loss of strength. I was not sufficiently long to examine in any way whatever Messrs. Hopkins, Gilkes, and Company from any negligence, but I ask you, Sir, before you cast blame upon men to a greater extent than you are bound to do for the construction of the bridge, not to forget that there was this inspection.

Now with regard to the cause of the disaster, all I desire to say is this: Mr. Gilkes' opinion is, that looking to the fact that the cast iron broke, and looking to the fact of the way in which that bridge broke, in his judgment it must have been caused by a shock supervening upon an existing heavy strain. That there was an existing heavy strain we know, because a gale had been raging for a considerable time. Whether or not the fall of the bridge was the cutting of the ties I am careless to enquire; but this I should say for the purpose of correcting a slight error into which Mr. Trayner fell, it is not a 16-ton blow, but a mass of 15 or 17 tons moving at the rate of 26 miles an hour at the lowest, and I have enough to wonder how many days left, to know that you have got to get rid of that momentum in some way or other.

(The Commissioner.) Upon the principle that ex nihil nihil fit.

Mr. Webster. Quite so, and as you have got rid of that momentum, though a portion of it, as you have seen, has been superimposed upon the weight of the bridge, you have got rid of that momentum in some way or other. And this, as I said, is the heavy strain we know, because a gale had been raging for a considerable time. Whether or not the fall of the bridge was the cutting of the ties I am careless to enquire, but this I should say for the purpose of correcting a slight error into which Mr. Trayner fell, it is not a 16-ton blow, but a mass of 15 or 17 tons moving at the rate of 26 miles an hour at the lowest, and I have enough to wonder how many days left, to know that you have got to get rid of that momentum in some way or other.

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Correspondence between Mr. Harrison and Sir Thomas Bouch
relative to a portion of the Evidence given by the latter on the Inquiry.

Castle Hill Park, Ealing, W., London,

May 14, 1880.

Sir,

I beg to hand to you, as Chairman of the Tay Bridge Commissioners, copy of correspondence which has passed between Sir Thomas Bouch and myself, and I will feel obliged by your laying it before the Commissioners in order that the answer given by Sir Thomas Bouch to question No. 16,474 may be corrected, or explained in some way, in the Report about to be published.

I remain, &c.

(Signed) THOS. E. HARRISON.

(Copy.)

Castle Hill Park, Ealing, W., London,

May 1, 1880.

DEAR SIR,

In your evidence of yesterday before the Tay Bridge Accident Commission as reported in the "Standard" of to-day, I see the following statement:—

Q. You and your engineer (Mr. Stewart) went into details and calculations as to the strains which might be brought upon the bridge?—We did.

Q. You consulted with other engineers of eminence such as Mr. Harrison?—Yes.

Q. You had satisfied yourself that the design was sufficient?—I was perfectly satisfied with it, and if the foundations had turned out as expected the original design would have been sufficient for the purpose. A modification, however, was found to be necessary.

When the Tay Bridge Railway Bill was before Parliament, I gave evidence in Committee in support of it, the question of the practicability of constructing a bridge over the Tay Estuary being a minor one, the main objection being to the possible interference with the navigation and the probability of the deep water channel being diverted from its then course.

I should be quite prepared to repeat the evidence I then gave, but since the passing of the Bill I have never been consulted by you on the design of the bridge as executed, or have I seen any plans of it, excepting what has appeared in the illustrated papers, or have I seen the bridge itself, during its construction, when finished, or since its failure.

I must ask you therefore to correct your statement given above, so far as it refers to my having been consulted by you on the bridge you constructed.

I am obliged to go to the North by an early train on Monday morning, and do not return till late on Friday evening, or I should have attended to have given this explanation to the Commissioners.

Perhaps the simplest will be to hand this letter to the Commissioners.

I shall be at Newcastle on Wednesday.

Yours, &c.

(Signed) THOS. E. HARRISON.

(COPY LETTER FROM SIR THOMAS BOUCH.)

Chambers, 111, George Street, Edinburgh.

May 12, 1880.

MY DEAR SIR,

I am exceedingly sorry that my attention has only now been called by my assistant to your letter of the 1st instant.

I find it was handed to me just as I was entering the witness box on the second day of my examination, but in the excitement I was under at the time, I got mixed up with my other papers before I had read it, or even seen who it was from, and it has thus been unfortunately overlooked. I very much regret the delay which has occurred in replying to your letter, but I trust you will accept this explanation and apology.

On referring to the shorthandwriter's notes of my evidence it is apparent that the quotation you give from the "Standard," as calculated to give an erroneous impression, is very inaccurate and incomplete, and I did not in the slightest degree intend to convey any such impression.

The only passage in which your name is mentioned by me in the following:

16,474. I believe you also, whilst you were finally determining on the plan that you adopted, consulted other engineers of eminence?—Yes, Mr. Thos. Harrison; I talked it over with him as it was a novelty.

There was a good deal of talk about it, but the conversation with Mr. Thomas Harrison was not official.

My recollection, as well as that of Mr. Stewart, is that the drawings for the original contract, which was entered into before we went to Parliament, were shown to you, that we had a conversation at the time with reference to them, but this, as I stated in my evidence, was in no way official.

The design of the bridge as executed, i.e., with the substitution of iron piers for brick were never shown to you, nor were you ever consulted or spoken to on the subject, and I do not think my evidence can bear this construction.

I am most anxious that this matter should be cleared up to your entire satisfaction, and if you think it necessary I shall be glad to send a copy of this correspondence to the Commissioners, but will act entirely as you may wish in the matter. Will you therefore kindly let me hear from you as soon as convenient.

Yours, &c.

(Signed) THOMAS BOUCH.

Thos. E. Harrison, Esq., C.E.,
London.