

HM RAILWAY INSPECTORATE

INTERNAL REPORT

ON

A FIRE ON THE 18:30 PADDINGTON TO SWANSEA TRAIN

NEAR MAIDENHEAD ON FRIDAY 8 SEPT. 1995

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1 SEQUENCE OF EVENTS

1.1 General

On Friday 8 September, a High Speed Train (HST) set formed of a power car at each end and eight coaches departed Paddington Station on time at 18:30.

The train was crowded in the standard class coaches with all seats taken and some standing. The first class coaches however, were not completely full. In all there were around 500 passengers on board.

As it approached Taplow Station travelling at around 110mph., the fastenings on one of the fuel tanks came undone causing it to drop and drag along the track.

The tank became ruptured spilling the diesel fuel which then ignited. The ensuing fire engulfed the outside of the front three carriages and the fire entered toilet plumbing cupboards in the two leading (first class) carriages.

Substantial amounts of smoke entered several coaches at the front of the train and smoke could be smelt further down the train. There was general concern throughout the train, with increasing desperation towards the front where passengers had to crawl along the floor due to the intensity of the smoke and fumes. A number of windows were smashed by passengers anxious to get fresh air.

The train was fitted with centrally controlled secondary door locking. This is normally controlled by the guard but can also be operated by an emergency handle at each door location. The secondary door locking was not released centrally although a number of emergency releases were operated by passengers.

As the train came to a halt a number of passengers jumped from the train on the unsafe side and made their way across the tracks to the far side. One of them narrowly escaped being hit by a passing HST travelling at speed towards London on the adjacent track unfortunately however, another male passenger Mr Ian Jones, was struck and killed by this train.

The train had travelled approximately one and a quarter miles after the tank dropped and came to rest some half a mile before Maidenhead Station where the railway line passes over Oldfield Road.

Fortunately there was good access for the emergency services to reach the site and the Fire Service attended the scene within minutes and dealt with the small fire that remained. Both the Civil Police and the British Transport Police were on site together with the Ambulance Service.

Six passengers were taken to hospital suffering mainly from smoke inhalation and minor injuries. Passengers were eventually escorted along the tracks back to Maidenhead Station.

1.2 Events leading up to Mr Jones being struck

The precise location on the train that Mr Jones was travelling in or the actions that he took when he left the train have not been definitely established; however, a likely scenario is as follows.

It appears that Mr Jones had been travelling in the vestibule area between the front two coaches (G and H), it is in this area of the train that the intensity of smoke is thought to have been greatest. It is likely that he jumped from either a lowered drop-light door window or opened door on the right-hand side of the train as it came to a halt. At the same time, a high speed train was rapidly approaching the site, travelling towards London on the up main track onto which Mr Jones had jumped. As Mr Jones started to make his way across the up main track to the far (North) side, he was struck by the high speed train.

It should be noted that, given the circumstances of this incident where a number of passengers were leaving the train in an uncontrolled way on the 'unsafe' side, it was entirely a matter of chance as to anyone being struck by the passing train. Had the timing been slightly different, there may have been more fatalities.

1.3 Stopping of trains and blocking of adjacent lines

It was not until the train had come to rest that the driver contacted Swindon control centre on his in-cab telephone (NRN system) and due to his anxiety when speaking, there was confusion as to where his train was located. The first call to block all lines received at the local signalling centre at Slough was actually made by the driver of another train (travelling westwards on the down relief) who saw smoke coming from the train after it had gone past.

The local signalling centre might have received an earlier emergency call if the HST had been fitted with cab secure radio or if the driver had made himself understood. Given the short time between the tank first dropping and Mr Jones jumping from the train however, it is unlikely that anything more could have been done to stop the London-bound HST before it reached the point where it struck Mr Jones.

The driver of the HST (that caught alight) subsequently made another emergency call from a signal telephone and placed track protection. Further track protection was placed by the drivers of several other trains that had been stopped in the area.

2 THE INVESTIGATION

2.1 General

HMRI attended the scene of the incident on the evening it occurred in order to establish basic facts about what had happened and to ensure any perishable evidence was either collected or safeguarded.

The train was moved to a secure location at Old Oak Common Depot, to enable a subsequent detailed examination. The train was formally taken into possession the following day and placed under British Transport Police (BTP) guard to prevent any unauthorised access and preserve evidence for collection under HSE control.

A team of specialists from HSE's Health and Safety Laboratories (HSL) was assembled and visited Old Oak Common Depot on the morning of Tuesday 12th. The technical investigation work plan was discussed and agreed with HMRI's investigating Inspector and the collection of evidence was commenced.

Officers from the BTP also attended the pre-investigation meeting in order to co-ordinate the collection of evidence for HSE with the forensic and photographic work being undertaken for the Coroner.

Immediately following the incident, operators were asked to undertake a special check on the security of all fastenings on other HST fuel tanks. HMRI made visits to depots throughout the network to check if this had been done and to establish the general condition of fastenings.

2.2 Scope of the investigation

The main areas investigated were;

- the failure of the fuel tank support arrangements
- the system of checks and routine maintenance
- the ignition of the diesel fuel
- the spread of fire and entry of smoke into the carriages
- the operation of the PA and central door locking system
- the arrangements for the controlled de-training of passengers in emergencies

2.3 Collection of physical evidence

A detailed search of the track and surrounding area for any relevant objects was carried out by BTP prior to opening the lines back to traffic. Various objects were found but unfortunately, not the missing nuts and no others of particular relevance.

A survey of the track approaching Taplow Station revealed marks on the track made by the dropped fuel tank. Other evidence along the track included indications of diesel residue and heat radiation effects on vegetation. From this, it was possible to

establish, with reasonable certainty, the locations of the point of first impact through to the rupturing of the tank and the ignition of the fuel.

For two weeks following the incident, the train was kept in HSE's possession at Old Oak Common Depot to enable all the evidence to be collected in a controlled and systematic way. Specialists acting on behalf of industry assisted HSE with various aspects of the investigation, but were permitted accompanied, eyes-only access until all the required evidence had been collected and the train formally handed back.

A full photographic record was taken of the outside, inside and underside of the train. Further detailed photographs were taken as part of the controlled disassembly and testing of the removed components. A detailed fire survey of the train was completed and investigations into the fire dynamics, particularly the entry of smoke and flame into the train, were undertaken.

The fuel tank, complete with fixing assembly, was removed from the train and taken to HSL's Sheffield laboratories for detailed examination and testing. The testing included the controlled disassembly of several intact bolt fixings together with a simulation of vibration effects to try to reproduce the action of working loose of the fastenings.

In view of the crucial role played by the central door locking system, detailed investigations into the extent of the CDL control cable fire damage and likely failure modes was undertaken.

2.4 Witness evidence

On the day after the incident, the driver and guard on the train that caught fire were interviewed by BTP following discussions with HSE's Inspector. Detailed statements were subsequently taken by HSE after the preliminary findings from Railtrack's internal inquiry were available.

There was close co-operation with the BTP regarding the collection and release of passenger evidence, this was invaluable in view of the large numbers of passenger witnesses. The Police had taken contact details from passengers as they left the scene of the incident. They were later contacted and potentially useful witnesses selected for taking statements.

A summary of the evidence taken by BTP was prepared for HSE at an early stage, subsequently full copies of statements were passed on. In addition, a number of passengers contacted HSE direct and provided information.

In view of early indications of a weakness in the maintenance regime, HSE took statements from a fitter and supervisor at St. Philips Marsh Depot in Bristol where a routine maintenance check had been carried out the day preceding the incident. It became apparent later in the investigation that there were other, more fundamental weaknesses in the overall maintenance regime and that there was no negligence on the part of those checking the train the day before.

3 THE MAIN FINDINGS

3.1 Regarding The Fuel Tank Securing Arrangements

For a full description of the tank securing arrangements and the detailed findings of the technical investigation, readers should refer to the separate HSL report¹. The following sections are key selected extracts from that report.

3.1.1 General Description

HST power cars are fitted with two interconnected aluminium fuel tanks, one immediately behind the other. Each tank is held in place by a suspension arrangement comprising four suspension arms which are held to the underside of the power car by a clevis arrangement using a horizontal pin².

The lower end of each arm is fixed to the end of one of two cradle beams which run longitudinally underneath the tank. The fixing is by way of a vertically aligned M24 nut and bolt with head uppermost retained in the suspension arm³. The main nut is torqued up to a nominal amount to tighten the assembly and is held in place by a lock nut. Extra security is specified by fitting an M5 split pin inserted below the lock nut through a 5mm hole in the bolt.

The photograph⁴ shows the underside of the fuel tanks looking from the front of the incident power car no 43190. The 'arm suspensions' at the front of the front fuel tank can be seen nearest the camera, bolted to their cradles with M24 bolts. The cradles (left and right) are seen stretching rearwards to the rear of the tank. Beyond this, the front of the rear tank can be seen with the same arrangement.

The tanks are prevented from swinging in the longitudinal plane of the power car by four locating blocks on top of the tank which mate with others fitted to the frame of the power car.

3.1.2 Procedures for the installation of the fuel tank

Engineers from the Great Western Train Operating Company gave details of the arrangements for this work as follows.

British Rail lays down instructions relating to the periodic maintenance of HST power cars⁵. This requires the fuel tank to be changed as part of a "G examination" which is undertaken at 12-yearly intervals.

¹ Report by Health and Safety Laboratory entitled "Examination Of The Bolts"

² Appendix A1, HSL neg. no - 95 09-161/48

³ Appendix A2, diagram of arrangement

⁴ Appendix A3, HSL neg. no - 95 09-161/8

⁵ British Rail's "Vehicle Maintenance and Overhaul Instruction TI/VI0430"

A separate document ⁶ details the procedures to be followed by maintenance fitters when removing, overhauling and refitting the fuel tanks. There is a particular instruction relating to refitting the fuel tank ⁷ which specifies that the main nut must be tightened to a certain torque. This is significant for two reasons, firstly the specified torque of 4.14 kgf.m (30 lbf.ft) is a very low value for an M24 bolt and secondly, there is no mention of applying any tightening torque to the lock nut in order to prevent loosening.

Apart from the work carried out every 12 years, various other types of examinations and maintenance work are laid down ⁸, these specify that the power car exterior receives a general examination on a routine "A examination" which is normally carried out every 2 to 3 days. The scheduled work for this examination does not however, make mention of any form of checks on the fuel tank or its fixings and detection of any problems in these areas would appear to be a matter of chance.

3.1.3 Detailed Examination of the fixings following the incident

Rear Tank

Both the main securing nuts and the lock-nuts on the two rear suspension fixings on the rear tank were missing allowing the rear of the tank to drop. The two rear bolts were still held in the suspension arms and were removed for close examination at HSE's laboratories.

This examination revealed that there were short lengths of split pin retained within the drilled holes in both the rear bolts. The ends of the split pin had been cut by some process to the same profile as the bolt thread. There had been some plastic deformation of the pin and smearing of pin material which indicated it had been sheared off by a nut being unscrewed off the bolt.

The bolt from the rear right-hand (RR) position was in relatively poor condition. The lower half of the plain shank had suffered from significant pitting corrosion ⁹. The threaded portion had suffered from considerable mechanical damage. Threads in the upper part had been worn away by a combination of corrosion and abrasive wear, parts of the thread in the lower part had been broken off and the remainder had been plastically deformed around the full circumference. The plastic deformation was therefore consistent with the nut having been forced off the bolt under load.

The bolt from the rear left-hand (RL) position was in relatively good condition. It had suffered minor corrosion over the lower part of the plain shank and some minor thread crown damage over the upper half of the threaded part ¹⁰. This latter damage could have arisen as a result of abrasive contact between the bolt and the side of the bolt hole in the cradle.

⁶ British Rail's "Workshop Overhaul Standard Specification (WOSS) 160/2"

⁷ Section 5.11 of WOSS 160/2

⁸ British Rail's "Vehicle Maintenance Instruction GW/VI9430"

⁹ Appendix A4, HSL photograph 95 09-082/19

¹⁰ Appendix A5, HSL photograph 95 09-082/20

The two bolts at the front of the tank still had both lock nut and main nuts in place. One of the locknuts was within 1 mm of the thread at the end of the bolt¹¹. Although the main nut was in contact with the locknut, the locknut was loose enough to be removed by hand. When the main nut was removed, the remains of a split pin was found 15 mm from the end of the bolt¹². It appears that this joint was in imminent danger of failing, being loose with no intact split pin.

The locknut on the other front bolt was 11 mm above the end of the bolt¹³. Examination revealed a split pin hole with the remains of a split pin inside. This split pin was visible below the locknut before the nut was removed¹⁴. The ends of the split pins in the two front bolts appeared to have been sheared off in a similar way to those in the rear two bolts.

The remains of the split pins found in the holes of the bolts from the rear tank were M4's, designed for use in 4 mm holes. The holes in all the bolts from the two tanks were 5 mm diameter. The split pins recovered from the fixing of the front tank were also M4's contrary to WOSS 160/2 which specifies M5 split pins in the 5 mm holes.

Front Tank

All four bolts on the front tank were corroded to varying degrees. The least corroded was the bolt from the RL position. One possible explanation is that this bolt had not been on the tank for as long as the other bolts and may have been used to replace another damaged, or possibly missing, bolt at some time.

Three of the bolts exhibited similar patterns of thread damage, below and at one end of the split pin hole in each case. This damage suggested that in each case, some implement, for example a cold chisel, had been used at some time to shear off the ends of the split pins prior to removal. This damage was not present on the RL bolt indicating again that it had a different history to the other bolts. There was no other damage on the threads of any of the bolts from the front tank which would suggest that the split pins had been sheared at any time by an unscrewing action of any of the nuts.

3.1.4 Conclusions relating to the failure of the fuel tank fixings

The rear tank had not been correctly fitted when last re-fitted; in particular, new split pins had not been fitted beneath the locknuts which had been inadequately tightened relative to the main nut. Vibration had caused the nuts on one of the rear M24 bolts to loosen and fall off. The other rear M24 bolt assembly had failed due to a combination of vibration and overload (exacerbated by corrosion).

This work was most probably carried out at Plymouth in July 1993 following damage sustained during service. Due to the poor standard of written records however, this is not absolutely certain and it remains a possibility that a routine tank change carried

¹¹ Appendix A6, HSL photograph 95 09-077/7

¹² Appendix A7, HSL photograph 95 09-001/9

¹³ Appendix A8, HSL photograph 95 09-077/8

¹⁴ Appendix A9, HSL photograph 95 09-077/62

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out at Bristol in February 1993 was the last fitting prior to failure. Whilst the poor standard of records did not have any direct effect on the outcome on the incident investigated, in marginally different circumstances the existence of reliable records would be critical.

THE MAIN FINDINGS

3.2 Related To The Outbreak And Spread Of Fire

For a full description of the fire damage together with the detailed findings of the technical investigation, readers should refer to the HSL report¹⁵. The following sections are key selected extracts from that report, note that the Fig. references relate to those quoted in the detailed report.

3.2.1 Visual Impression of Fire Dynamics

The fire damage indicates a fire emanating from behind the rear fuel tank, which appeared to have been more severe on the LHS at the rear of the power car. It appears that flames swept out from just in front of the rear bogie before engulfing all of the LHs of the first coach, that of the second coach and most of the third one. The fire also seems to have swept under the interconnecting area between the power car and the first coach to travel at a shallow angle along the RHS of the train. However the fire was less intense on the RHS at positions corresponding with those on the LHS¹⁶.

The greater severity of the fire on the LHS may have been due initially to fuel first igniting near the LHS corner of the fuel tank and the flames subsequently stabilising on that side of the power car¹⁷. The pattern of wear observed on the fuel tank and its support straps¹⁸, supports the view that the tank probably leaked from the LHS first as also does the track damage East of and through Taplow Station.

3.2.2 Fire Damage Underneath The Vehicles

Underneath the first coach (coach H), the flexible pneumatic connections were all severely fire damaged, one connection on the RHS had parted. The electrical cables in this region were also burnt through, in places down to the bare wires¹⁹. There were a number of cables and fittings in this area underneath the coach that had also been burnt. Underneath the two wooden door steps there was considerable charring of the wood, more so on the LHS. There was also fire damage to the various fittings in this area and to the underfloor panels where what appeared to be a tar based protective material had melted and flowed. Underneath the front bogie of the lead coach were the remains of the plastic exit pipe from the toilet and a plastic vent pipe, which was from the overflow from the roof tank²⁰.

All of the hose cable connections to the second coach (coach G) showed varying degrees of fire damage. There was considerable charring to the underside of the

¹⁵ Report by Health and Safety Laboratory entitled "Ignition Source And Fire Dynamics"

¹⁶ Appendix A10, montage showing general pattern of external fire damage

¹⁷ Appendix A11, HSL photograph 95 10-001/132

¹⁸ Appendix A12, HSL photograph 95 09-076/13

¹⁹ Appendix A13, HSL photograph 95 09-078/25

²⁰ Appendix A14, HSL photograph 95 10-001/65

wooden door steps, more so on the LHS. There was also damage to cabling and fittings, some brake pipes, and the protective coating on the carriage floor. The two exit pipes from the toilet area were fire damaged, but the toilet waste pipe was fire damaged to a lesser degree than on the first coach²¹. At the back of coach G, the appearance of the fire damage was similar but of a lesser degree than at the front of the coach. The toilet outlet pipe on the LHS to the rear of the coach showed only minor fire damage.

Again, there was fire damage to all of the interconnecting pipes underneath the third coach (buffet coach F) but to a far lesser extent than at the previous set of interconnections.

3.2.3 General Description of Interior Damage

A general inspection of the condition of the interior of the coaches revealed little damage. In the compartments there was some evidence of very light sooting of horizontal surfaces and some traces of soot around the air conditioning grills in the ceilings of the first three coaches H, G and F. Beyond that there was little evidence of soot damage²². The sooting around the ceiling vents was probably due to ingress of smoke during the incident from the external fire and also from consumption of the air-conditioning paper filters in the forward coaches.

3.2.4 Internal Fire Penetration

Fire had penetrated to the interior of the coaches in two places. These were the service ducts adjacent to the forward toilets in carriages H and G; the latter being the more severe of the two fires.

The ducts themselves are triangular in shape and contain several pipes serving the adjacent toilet area, including the waste and supply pipes for the WC, the associated valve and control equipment and a plastic overflow pipe from the WC water tank. There are thus several fuels available for a fire, mainly comprising plastic items and insulation. The vertical orientation of the duct also provides a disposition of fuel able to promote rapid flame speed.

The duct is bordered by a further melamine faced panel dividing off the toilet area and a polycarbonate panel in an aluminium frame partially dividing off the compartment from the vestibule area. The ceiling area of the vestibule comprised a GRP panel with a recessed fluorescent light fitting.

In coach H the melamine panel had just been penetrated in two places²³ when it was extinguished by external action. The plastic items had been largely consumed and the plastic overflow pipe had disappeared completely. As a result the fire had spread to the access door. Such damage is indicative of a substantial fire within the duct²⁴. The adjacent toilet area showed significant soot deposition on horizontal

²¹ Appendix A15, HSL photograph 95 10-001/73

²² Appendix A16, HSL photograph 95 09-079/11

²³ Appendix A17, HSL photograph 95 09-079/5

²⁴ Appendix A18, HSL photograph 95 10-001/16

surfaces. This was particularly noticeable in the area around the WC and the floor, possibly due to low level penetration of smoke from the duct into the toilet. It is also indicative of the nature of the smoke produced from the duct fire.

In the forward vestibule area of coach G the damage was much more severe since the fire had grown to a significantly larger size before being extinguished as a greater proportion of the fuels inside the duct had been consumed in the fire. The plastic overflow pipe was again burnt completely away²⁵. There had been significantly greater consumption of the access door, in particular the melamine panel, allowing the fire to spread into the vestibule area.

The damage pattern indicates that it had grown to such an extent that flames played on the ceiling and ignited the GRP ceiling panel. As a result flames and hot gases had penetrated into the compartment and distorted a fluorescent light cover and a ceiling panel²⁶. The polycarbonate dividing panel had also been severely distorted indicating temperatures there in excess of 200°C. Flames had also extended along the ceiling into the door area of the vestibule. The upper parts of the melamine panels had been consumed and the metallic ceiling panels showed heat and smoke damage. Again the toilet area was severely coated with soot²⁷, but in this case, was not just confined to the horizontal surfaces and was more severe than in coach H.

The probable source of these fires was the external fire on the underside of the coaches which penetrated by way of the plastic overflow pipes. The latter had been totally consumed in both fires, and they would have been easily ignited in view of their compositions and vertical orientation, and thus would have provided a rapid route for penetration of the fires to the inside. With the fuels involved, these fires would have produced copious amounts of dense acrid black smoke. They were also growing rapidly at the time they were extinguished, particularly that in coach G, which had reached such a size that it would have rapidly spread into the compartment. This, given more time, would have resulted in an uncontrolled fire which could have propagated throughout the carriage.

However, they were unlikely to have been responsible for the rapid filling of the forward carriages with smoke while the train was still in motion, because at that stage the fires would not have had a chance to penetrate into the vestibule area. Also no passenger remarked on flaming in the vestibule area. It is likely that they became evident when the train was stationary and staff were checking for evacuation of the trains. Indeed one of the crew reports applying an extinguisher to such a fire.

The problem of fires involving flammable service pipes in plumbing cupboards had been known about on British Rail for a number of years. There had been reports and

²⁵ Appendix A19, HSL photograph 95 10-001/37

²⁶ Appendix A20, HSL photograph 95 10-001/35

²⁷ Appendix A21, HSL photograph 95 10-001/45

recommendations from BR Derby Research relating to fires in May²⁸ and June 1990²⁹ and again in Dec 1993³⁰.

3.2.5 Evidence from Observers

Several witnesses have related their observations of the incident from viewpoints adjacent to the track. One located in the old station yard east of Taplow station reported a large bang as a train passed followed by objects hitting his portacabin. These left small impact marks suggestive of ballast. Thus it would appear that the fuel tank was already at least partially detached at this point. Two other people in their house West of Taplow station reported a loud bang and stones showering down on their house. The former was accompanied by an intense flash. When they went outside the air was thick with smoke 'back to Taplow station'. Thus it would appear that there was already at least a small fire before the simultaneous occurrence of this loud bang and an intense flash adjacent to the location of these witnesses.

3.2.6 Evidence from On-board Staff

The staff on the train knew little of the incident and can add little to the experiences of the passengers. The driver responding to a loud bang, applied emergency braking and on alighting observed a small fire under the first power car.

The other staff provide similar observations to the passengers though none were further forward than the rear of coach G and coach F buffet area. One of the stewards reported applying an extinguisher to a smouldering area in the vestibule between coaches G and H after the train had stopped. This was probably the service duct carrying the water tank overflow pipe and indicates the later development of these fires.

3.2.7 Evidence from First Class Passengers

A number of the passengers in the first two coaches reported a loud bang. One passenger located this at the Old Station Yard, Taplow. Passengers heard ballast and debris being thrown up against the sides and underside of the coaches, possibly accompanied by sparks. Within a matter of seconds there appeared to be smoke and flames outside the carriages. Initially the flames were reported to be below the bottom of the windows and developed rapidly to engulf the sides of the carriages. The heat was sufficient for passengers to be well aware of it and for some to be aware of windows cracking.

Almost immediately after the flames were observed the level of smoke inside the carriages began to increase quickly. In coach H it appeared to build up rapidly from the front. The smoke was variously described as dark, dense, thick and grey in colour. It is clear that visibility was quickly reduced to virtually zero in the first class

²⁸ BR Research report into a fire at Stafford on 21 May 1990

²⁹ BR Research report into a fire at Darlington on 19 June 1990

³⁰ BR Research report into a fire in Dec 1993, investigated at Glasgow 20 January 1994

area and passengers dropped to the floor to obtain clean breathable air. Those that did found the floor hot. There was a suggestion of a light grey smoke early on in the incident. It was not accompanied by any internal flaming. A few passengers were of the opinion that the train was not slowing down until after the coaches began filling with smoke.

The forward door windows in the vestibule of coach G were both partially open at the time of the incident. Thus it is probable that some of the smoke from the external fire entered through these open door windows or from leakage between the coaches through the interconnecting corridors. Other door windows further back along the train may have also been open or partially open. Smoke appeared to propagate as far as coach F, the buffet area, where it was still necessary to drop to the floor to avoid it, but visibility was better than further forward. Smoke may have also entered via the air conditioning systems as these would not stop drawing in air until after the brakes had been applied.

3.2.8 Evidence from Standard Class Passengers

Passengers in coaches E to A undoubtedly faced considerably better conditions than those further forward. No passenger described the necessity to drop to the floor and visibility seems to have been sufficient to allow them to behave in a more or less physically normal manner. Smoke appeared to enter these carriages as some witnesses describe the smell of burning and the opacity of this smoke becoming worse as the train slowed. It appears that smoke entered coach E at a later time in the incident. It is possible that standing passengers closed windows in the vestibule areas at these points on the train and thus prevented significant smoke ingress.

Flames also appeared to stretch at least to coach E, since some passengers reported seeing flaming outside the windows of this coach. Further down the train there was no flaming outside the carriages but smoke was reported. Initially this was light grey but became thicker and darker as the incident developed.

3.2.9 Source Of Ignition

The evidence suggests that there were three possible ignition sources and that ignition occurred relatively soon after the fuel tank first made contact with the track, probably before the train entered Taplow Station.

The three possible sources were:

- frictional impact of the tank with the track,
- sparks from the brake system and
- electrical sparks from the traction motor immediately behind the fuel tank.

Of these the most likely was the first. The tank was constructed of aluminium, and any moving contact with the rusted metal clips holding the rails in place could cause a thermite reaction to occur in which the temperatures could be of the order of 3000°C.

The geometric layout of both the track and the base of the fuel tank was such that the first points of contact with the sleepers when the tank fell would be the two corner areas of the tank upon the metal clips holding the rails in place. This would be the case provided the stone ballast did not come above the top of the central portion of the sleepers as was the case East of Taplow, but not so over certain sections of the track West of Taplow especially after the three ATP ramps.

Thus repeated contact with the metal clips would be expected to erode and eventually puncture the corners of the tank, resulting in a slowly increasing rate of fuel flow into the vicinity of a potential source of ignition at a rate that would be unlikely to quench it. Alternatively, the tank falling initially may have resulted in the rupturing of its corner(s) sufficient to allow fuel to escape. At intermediate points a different design of rail clip had been used which projected higher above the base of the track sleepers than the usual ones. Contact with these would probably increase the extent of rupturing at the corners of the tank and increase the leakage rate of fuel from it.

Contact, with either the centre of a sleeper or both it and the rail clips simultaneously, probably indicated that the fuel tank was leaking, because of the degree of tank wear or distortion inferred. Such damage was observed East of Taplow³¹ and within the station. This is consistent with the witness statements suggesting that ignition occurred within seconds of the tank dropping.

An alternative or additional ignition source was frictional sparking from the cast iron shoes of the parking brake system which would be automatically applied under braking. However, their position on the power car wheels downstream of the first evidence of fire damage, the indeterminate delay in their application after the tank first dropped, and the longer than normal distance taken for the train to stop (due to either reduced efficiency of the braking system, delayed application or less than an emergency application), seems collectively to suggest that the brakes were not the primary ignition source. This accords with the opinion expressed by a number of the passengers; namely that the fire existed before they were aware of the train slowing down.

The third possible ignition source arose because the commutator cover plate on the first traction motor downstream of the fuel tank was missing when the train was first inspected at Old Oak Common. A comparison between this motor and that of the next traction motor indicated that there had been some heat damage to one of the internal electrical cables. There was no further evidence of fire damage nor of dirt egress. Therefore it seems likely that the cover plate came off during the incident, possibly as a result of impact from ballast thrown up by the dropped fuel tank. However, it seems improbable that this occurred immediately after the tank dropped and that a flammable mixture of fuel vapour had also penetrated to the commutator before the power was cut off, as would have had to occur if the evidence for rapid fire growth is to be believed.

³¹ Appendix A22, HSL photograph 95 09-081/26

3.2.10 Conclusions Relating To The Fire Investigation

1. The tank first contacted the track East of Taplow Station and a relatively small but increasing rate of fuel release occurred, which subsequently ignited probably as a result of sparks from the tank impacting upon the track. Ignition occurred prior to the train passing through Taplow Station.
2. The smoke inside the train was due mainly to the ingress of smoke from the external fire through the air conditioning unit, open door windows and gaps between the coaches.
3. The fire spread into the interior through burning the plastic overflow and toilet outlet pipes. The fires from these would have produced copious amounts of dense black acrid smoke. They broke through into the vestibule areas at a late stage in the incident, probably when the train was stationary. The fire in coach G was close to uncontrolled spread throughout the carriage when it was extinguished.
4. Impact with the first ATP ramp West of Taplow Station produced a step increase in the rate at which fuel escaped from the tank and a consequent increase in the size of the fire. The maximum rate at which fuel was released was probably about 20 kgs^{-1} and this was sustainable for a period of around 90 s.

THE MAIN FINDINGS

3.3 Related To The Central Door Locking And P/A Systems

For a description of the central door locking (cdl) and passenger announcement (pa) systems together with the detailed findings of the technical investigation, readers should refer to the separate HSL report ³². The following sections are key selected extracts from that report.

Overview of the systems

3.3.1 Public Announcement System

There are two largely independent voice communications systems available on HST sets ³³, the driver/guard system, allowing voice communication between the Trailing Guard Second (TGS) vehicle and driver's cab, and the public address system (also called the Tannoy system) allowing the guard to make announcements to passengers from the TGS vehicle and from the steward's compartment in the buffet car; we understand this system has a second installation in the buffet car for use primarily by buffet staff³⁴. There is a further handset in the baggage area adjacent to the power car, but for security reasons this is not directly available to the guard. The system has a fixed level of amplification, which is pre-set to be low enough to avoid feedback when the handset is operated when the door to the TGS (or steward's compartment) is open. The level normally set for the system thus represents a maximum for a given installation.

There is no provision for the driver to speak directly to passengers. To supplement the driver / guard intercom there is a buzzer code system. This can be accessed from all the vestibule control panels, but the code system would be of limited use in an emergency situation.

3.3.2 Central Door Locking System (CDL)

The CDL system provides a mechanism to ensure that a safety lock bolt is inserted, by pneumatic pressure, acting on piston surfaces with different areas and against a spring in compression, into the upper frame of each door in the passenger carriages before the train starts in motion. In normal use, the state of the system is controlled via the guard's CDL control panels which are mounted in diagonally opposing corners of the carriage in the vestibule areas. There are also three panels in the TGS carriage.

Certain doors in the HST set are not included in the CDL system, i.e. two doors in the buffet car, and two doors of the TGS car. The doors in the buffet car are marked for emergency use only, and a lock release handle is mounted above each door.

³² Report by Health and Safety Laboratory entitled "A Survey of the Tannoy and Central Locking Systems"

³³ Appendix A23, HSL photograph 95 09-114/2

³⁴ Appendix A24, Diagram showing communications points

3.3.3 Lock bolt state indication

In normal use, the state of each door's safety bolt is indicated within the vestibule by a lighted sign ('Door Unlocked') near to the bolt housing, externally, an orange light is illuminated alongside each door to indicate that it is unlocked. Additionally, the bolt's strike plate unit, attached to the top of the door at the hinge side, has a small circular view port showing the position of an indicator flag operated by a plunger displaced by the extended bolt³⁵. The visible area of the flag appears black when the bolt is fully extended, and yellow when the lock bolt is retracted. The black area of the flag carries a small yellow arrow, the position of which is used to indicate whether the lock bolt shims need attention to compensate for door displacement due to hinge wear.

3.3.4 Emergency egress

Provision is made above each door to release the air pressure holding the bolts in both doors of that vestibule, allowing the doors to be opened in the normal way. The mechanism is intended for use only in an emergency, and is operated by means of an egress handle, situated behind a frangible transparent plastic cover indicating its function and that a penalty is imposed for improper use. The only indication of a bolt's withdrawal under these circumstances is the appearance of the yellow surface in the view port.

The operation of the egress release handle causes pressure to be dumped from the brake circuit as well as that holding the two bolts in the doors to the vestibule. This loss of pressure is transmitted throughout the train, causing the brakes to be applied.

Use Of The Systems In The Incident

3.3.5 Public Announcement System

In the Railtrack Rail Rule Book the instructions to guards in the event of a fire³⁶ indicate that they 'should' use the PA system. When the incident first occurred, the guard was in coach B making his way forward through the train. It was not until after the train had stopped, and the guard had rejoined the train having attempted to clear passengers from the track that he eventually gave instructions over the PA. By this time a large number of passengers had already left the train.

3.3.6 Central Door Locking System

The guard states that he did not use the CDL system to unlock doors in the incident as he did not want passengers to leave the train until he knew what was wrong. Following the incident, and before the train had been moved, GWTC's Driver Standards Manager, Mr Watts, undertook a survey of the state of the train. His report

³⁵ Appendix A25, HSL photograph 95 09-114/5

³⁶ Railtrack Rule Book, section M 8.2.1

indicates that eleven egress handles had been pulled. He notes that all CDL control panels were locked (although no condition is noted for that in the Bristol end of carriage B). From witness statements, it appears that the bulk of passengers left by doors opened by the use of the emergency egress mechanism.

Discussion of CDL and PA systems

3.3.7 Public Announcement System

The most vulnerable part of the system in an incident of this nature is the 36-way jumper between pairs of vehicles³⁷. This link provides continuity for numerous control functions, and its loss would readily be apparent, and announcements over the PA would not be heard beyond the break.

According to the guard's statement, at the time the incident began he was in carriage B and moved to carriage C to try to assess the problem. At this point the guard had the maximum distance to travel (i.e. either back to his TGS vehicle, or forwards to the buffet car) to be able to make use of the PA system.

If extra access points were available, the guard may have been able to provide information to calm passengers. Even in a panic situation it is likely that a number of passengers would be disposed to listen to instructions and respond accordingly. In order to do this, the guard would require good access to the PA system.

3.3.8 Driver-guard communication

Although the guard and driver have rudimentary communication throughout the train by means of the buzzer code system, they can talk to each other only when the guard is in the TGS. Any information the guard has received from the driver should help him assess the situation and enable the guard to advise passengers of the safest course of action. His own observations may provide valuable information to the driver.

3.3.9 Emergency egress system

The mechanical nature of the egress provision provides a secure and reliable means for unlocking the doors in an emergency, but there may have been some momentary confusion about the operation of the mechanism. None of the instructions placed in the vestibule mention that the 'Door Unlocked' sign will not illuminate when the egress handle is pulled.

Since the striker plate view port effectively provides confirmation regarding the state of the lock bolt, it may be helpful if the casing carried a brief explanation of the significance of the surface seen in the view port (i.e. black when locked, yellow when unlocked).

³⁷ Appendix A26,HSL photograph 95 09-114/10

3.3.10 Fail-safe nature of CDL/Emergency egress systems

The system's design is such that it will fail to what may be considered a safe state, i.e all doors securely locked, in the event of a disruption to continuity (e.g. disconnected CDL jumper, loss of air pressure, failure of local electrical supply) whilst a train is at speed. When the train comes to rest, however, it is necessary to provide a reliable method for unlocking the doors although the nature of the loss of continuity may prevent operation via the guard's activities at a control panel. The egress release handles are intended to provide an unlocking mechanism under these circumstances.

It is evident that, before coming to rest, events associated with the effects of the fire on CDL jumpers at the front of the train gave rise to circumstances that compromised the fail-safe nature of the CDL system; lock bolts were stated to have retracted (albeit temporarily) whilst the train was under way, and 'Doors Unlocked' lights were stated to be lit (and hence bolts retracted), although no unlock command had been issued by the guard.

4 RECOMMENDATIONS

These recommendations relate directly to the circumstances of the incident but may have more general application. Unless otherwise indicated they are directed at operators of High Speed Trains. All are aimed at securing improvements which are 'reasonably practicable' in the context of the application of sections 2 and 3 of the Health and Safety at Work etc. Act 1974 and should be interpreted accordingly. Where reviews and further consideration are called for, these should include comparative risk and 'practicability' assessments of any emerging options.

Relating to the fuel tank securing arrangements

- 4.1 In the short term, the procedures relating to the fitting of fuel tanks should be reviewed. In particular, there should be a requirement to use new bolt assemblies and detailed instructions on how the locknuts should be tightened. Allied with this, there should be independent quality control inspections to ensure that the correct procedures have been followed.
- 4.2 The maintenance schedules should be reviewed to include regular checks on the tightness and integrity of the fuel tank securing arrangements.
- 4.3 In the longer term, consideration should be given to an improved method of securing the fuel tanks. Preferably this should not rely on a bolt in tension, or if it does, the bolt should be fully tightened.
- 4.4 Consideration should be given to introducing an improved system of reporting difficulties experienced in complying with laid down maintenance procedures to prevent non-specified 'custom and practice' methods being adopted.

Relating to the fire resistance of plumbing pipes and service ducts

- 4.5 In the vestibule area of coaches, consideration should be given to introducing measures to increase the fire resistance of the service ducts and the plastic pipes passing through them .

Relating to the Central Door Locking (CDL) System

- 4.6 Measures should be taken to improve passengers' understanding of the operation of the CDL system in an emergency. In particular, consideration should be given to an improved instruction layout which should also recognise the continuing need to minimise possible misuse.

Relating to on-board communications

4.7 A review of the on-board communications systems should be undertaken in order to identify further measures that could be taken to improve on-board communications in times of emergency. In particular, improved access to guard-driver and passenger announcement communications systems and the possible use of pre-recorded or automatic announcements should be considered.

Relating to training and instructions for on-board railway employees

4.8 Train operators should undertake a review of the training and instructions given to all on-board railway employees. Specific areas to be reviewed include communications concerning safety and the control of passengers in emergency situations.

Relating to the provision of emergency equipment and facilities for passengers

4.9 A review of emergency equipment and de-training facilities provided for passengers should be undertaken in the light of the various difficulties experienced during this incident. The review should include, inter alia;

- the role, accessibility and effectiveness of emergency window hammers;
- the accessibility of emergency egress handles; and
- the use of effective signs and instructions.

Relating to lessons for operators of other trains

4.10 The BR Board, as present operator of all passenger train services on the Railtrack network, should consider the wider implications of the foregoing recommendations for trains, and the operation of trains, other than HSTs.

5 ACTION TAKEN AS AT 1 JANUARY 1996

Discussions have variously taken place with Railtrack, British Railways Board HQ, the relevant train operators and train leasing companies regarding the issues raised in the above recommendations. HMRI has written to the relevant parties confirming the areas for attention and has already received proposals from industry on many of the issues raised on how they intend to comply. Progress towards complying with the recommendations is being, and will continue to be, monitored. The use of enforcement powers to secure appropriate action will be considered should the measures taken be considered insufficient to meet the requirements of relevant legislation.

6 BIBLIOGRAPHY

- Examination of the bolts used to secure the fuel tank to HST power car, number 43190, report by Health and Safety Laboratory.
- Ignition Source And Fire Dynamics, report by Health and Safety Laboratory.
- A Survey of the Tannoy and Central Locking Systems, report by Health and Safety Laboratory.
- British Rail's "Vehicle Maintenance Instruction GWVI9430".
- British Rail's "Vehicle Maintenance and Overhaul Instruction TIV10430".
- British Rail's "Workshop Overhaul Standard Specification (WOSS) 160/2".
- Railtrack Rule Book
- Report into a fire at Stafford on 21 May 1990....., report by BR Derby Research.
- Report into a fire at Darlington on 19 June 1990, report by BR Derby Research.
- Report into a fire in Dec 1993, investigated at Glasgow 20 January 1994, report by BR Derby Research.
- Passenger and other witness statements taken by British Transport Police.

Appendices A1 - A26 show selected photographs and diagrams from the three Health & Safety Laboratory reports. Note that the HSL references and descriptions have been retained for ease of cross-referencing.

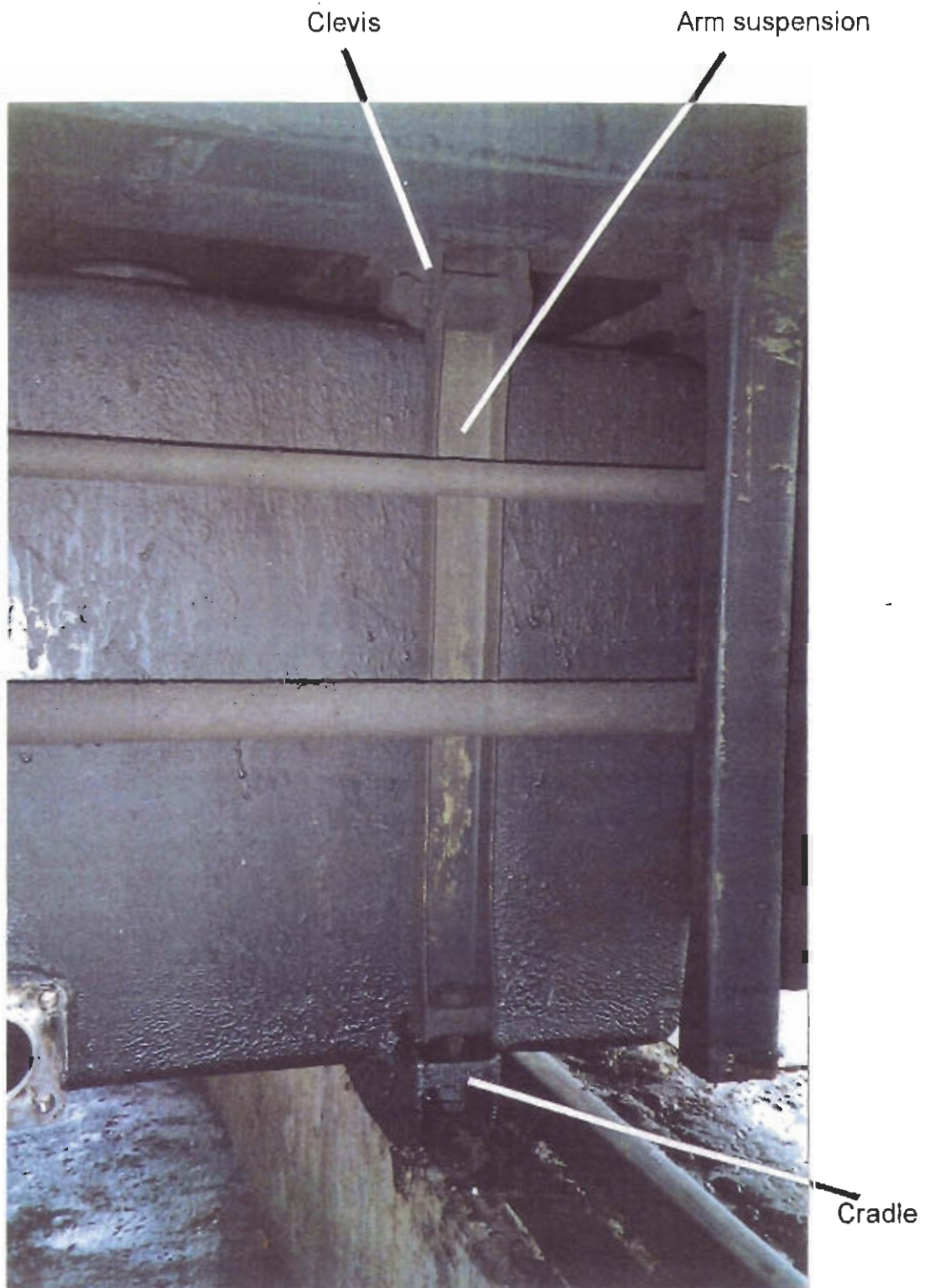


Fig 1 The fuel tank suspension arrangement of power car 43190 HSL neg no 95 09-161/48

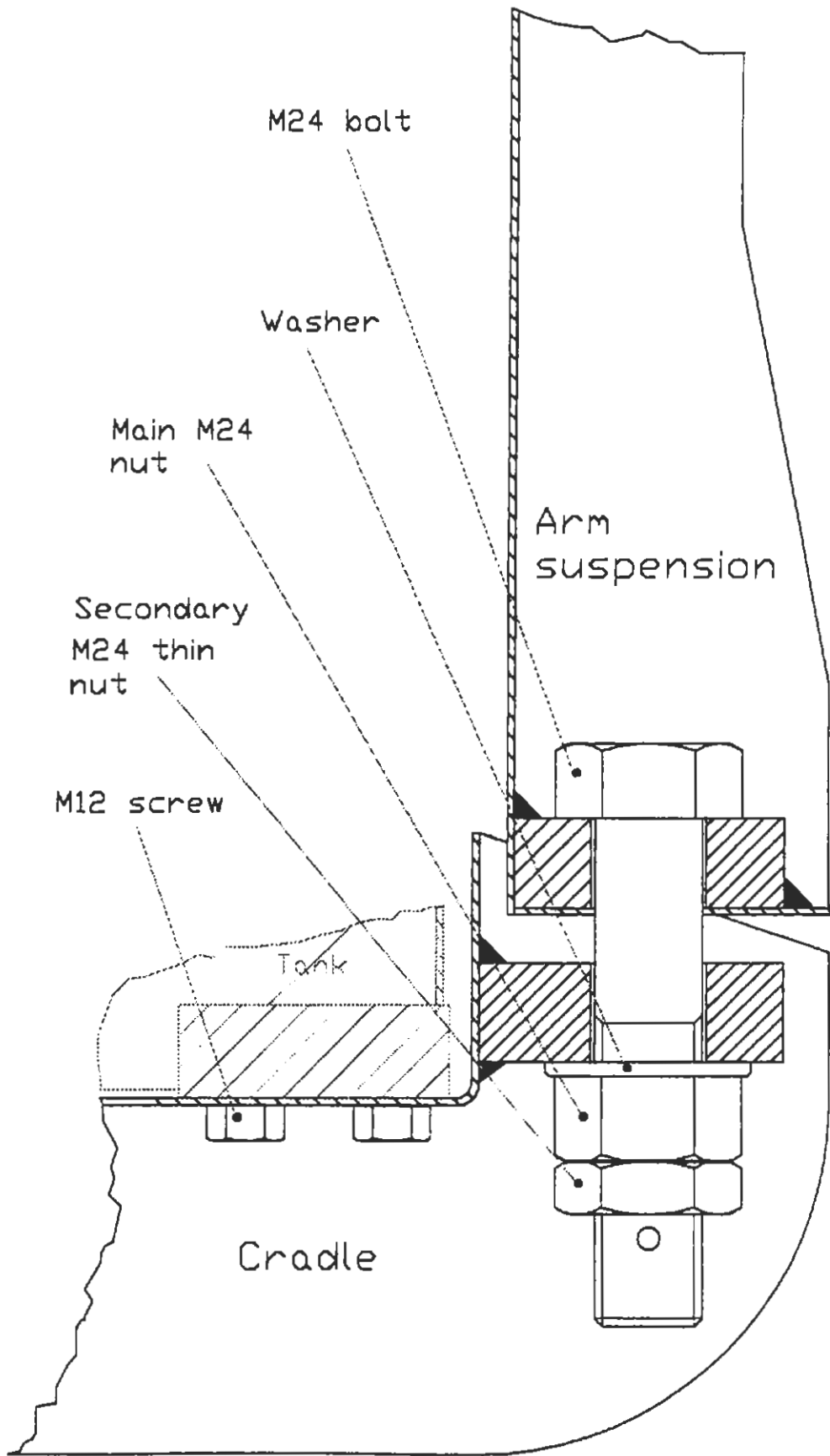


Fig 5 Assembly drawing of a tank suspension joint (not to scale)

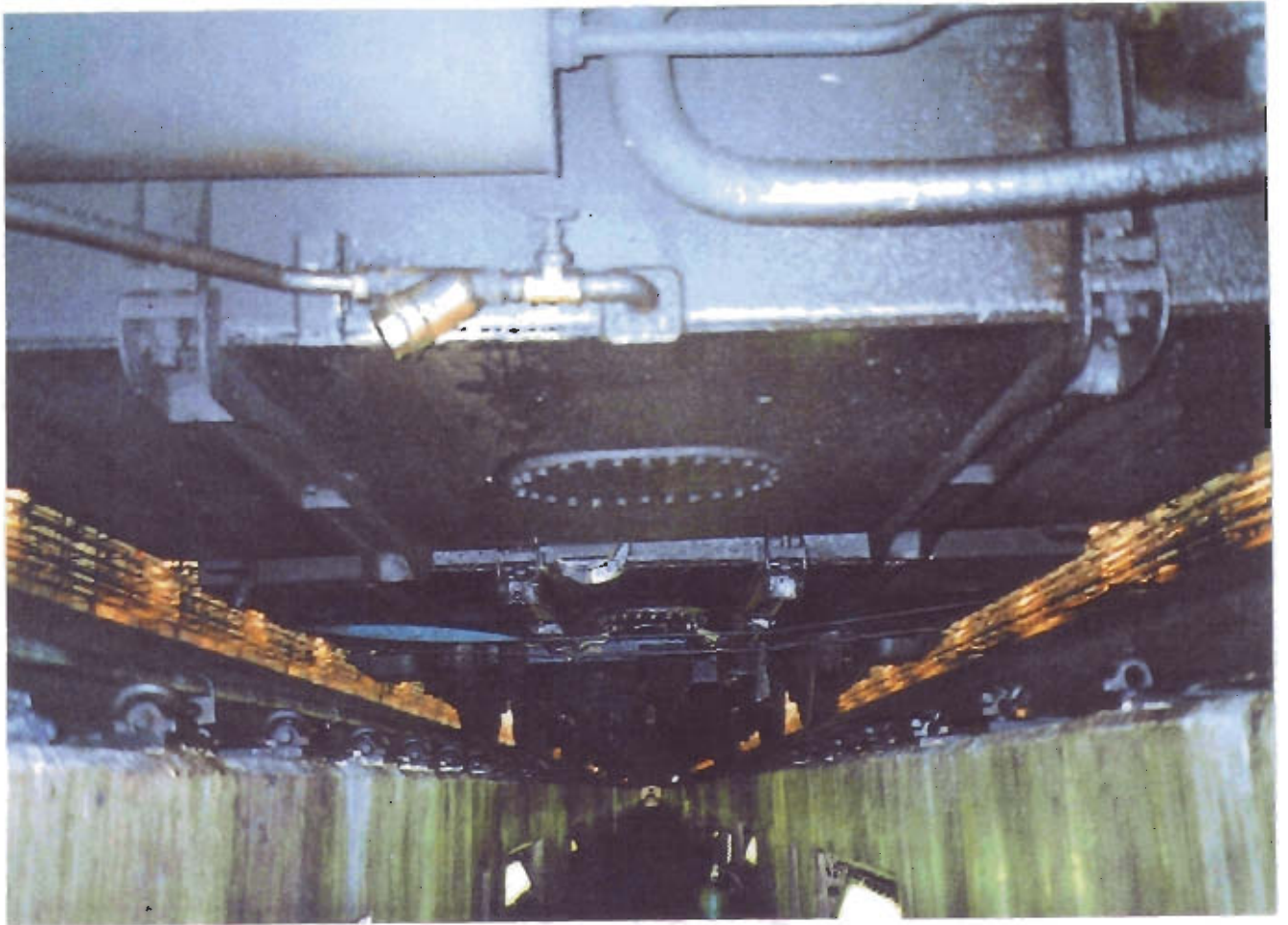
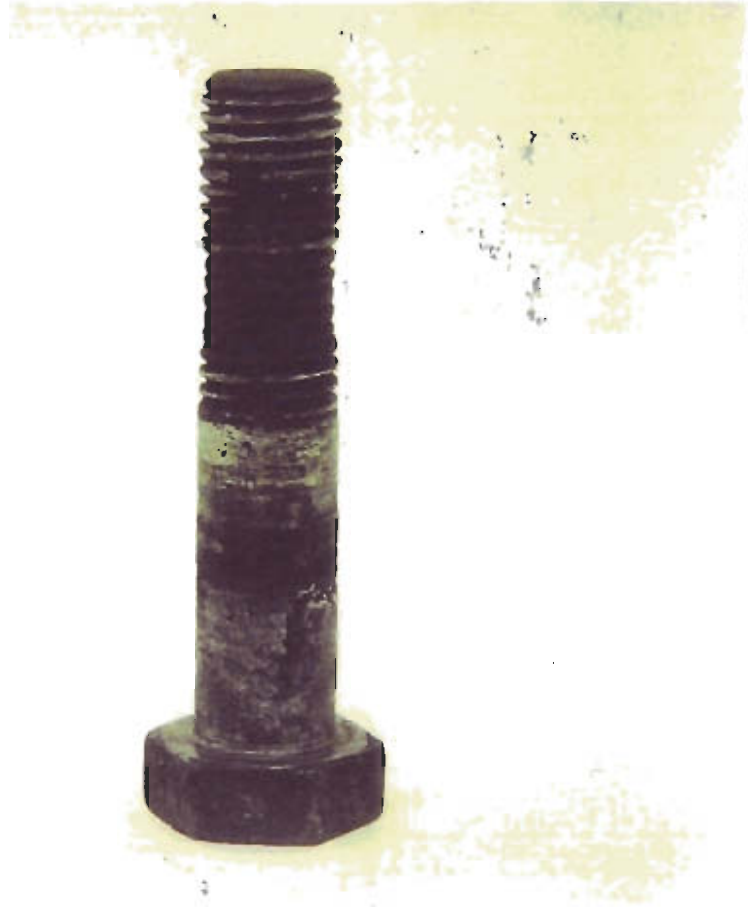


Fig 2 The fuel tanks under the power car, 43190

HSL neg no 95 09-161/8

APPENDIX A3



The rear right hand M24 bolt from the rear fuel tank

HSL neg no 95 09-082/19

APPENDIX A4



Fig 17 The rear left hand M24 bolt from the rear fuel tank

HSL neg no 95 09-082/20

APPENDIX A5



Fig 12 The front left hand M24 bolt on the rear fuel tank

HSL neg no 95 09-0777

APPENDIX A6



The thread profile in the end of the split pin in the front left hand M24 bolt

HSL neg no 95 11-001/9

APPENDIX A7

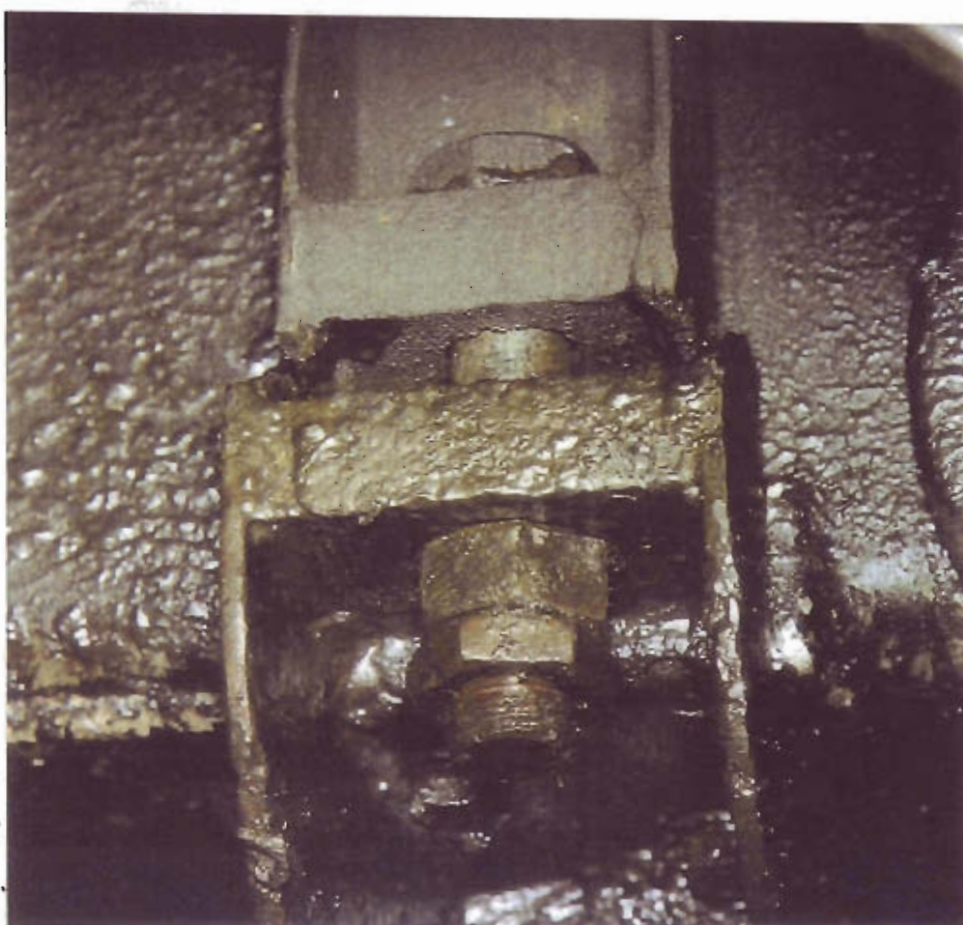


Fig 13 The front right hand M24 bolt on the rear fuel tank

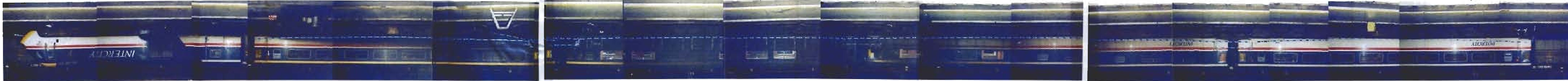
HSL neg no 95 09-077/8

APPENDIX A8



Fig 15 The end of the split pin and damage to the thread on the front right hand M24 bolt of the rear fuel tank

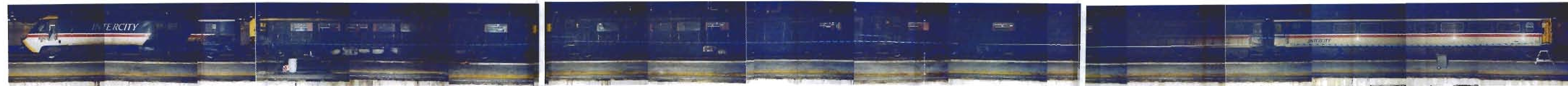
HSL neg no 95 09-098/62



HSL Negative Nos. 9510-001/01, 92, 93, 94, 95, 96, 97, 101, 102, 103, 104, 105, 106, 107

TOP OF
TRAIN →

Fig.1a - RHS of train showing overall fire damage



HSL Negative Nos. 9510-001/111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 87

Fig.1b - LHS of train showing overall fire damage



9510-001/132

**Fig.3a - Rear view of tractor unit
after separation
APPENDIX A11**

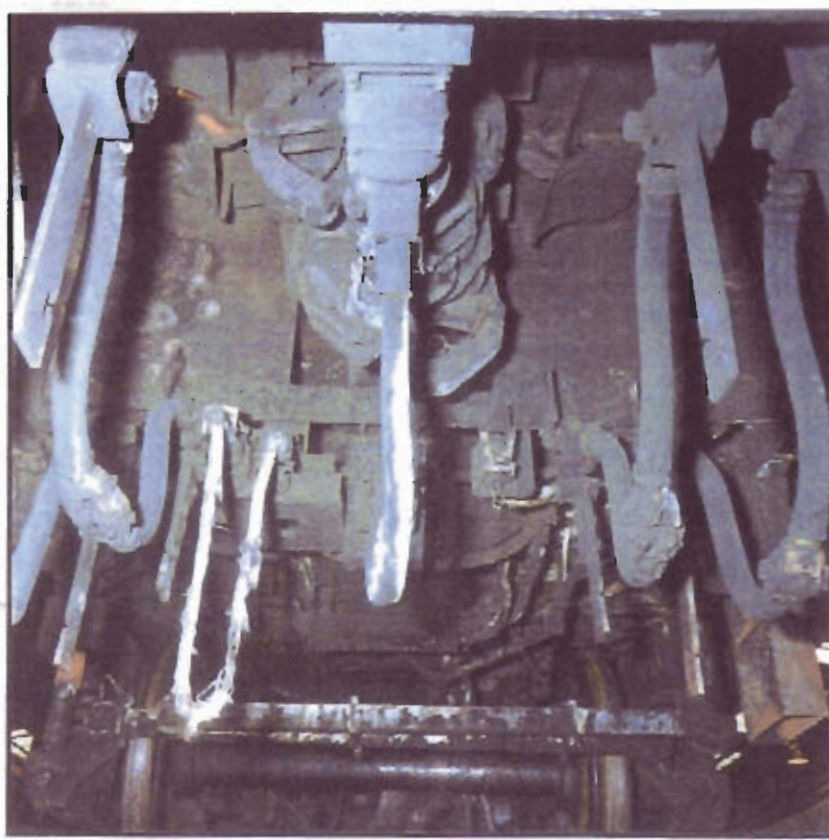


9509-076/13

Fig.6a - Damage to rear of fuel tank

APPENDIX A12

HEALTH AND SAFETY EXECUTIVE



9509-078/25

Fig.10a - Fire damage to connections between tractor unit and first coach

APPENDIX A13

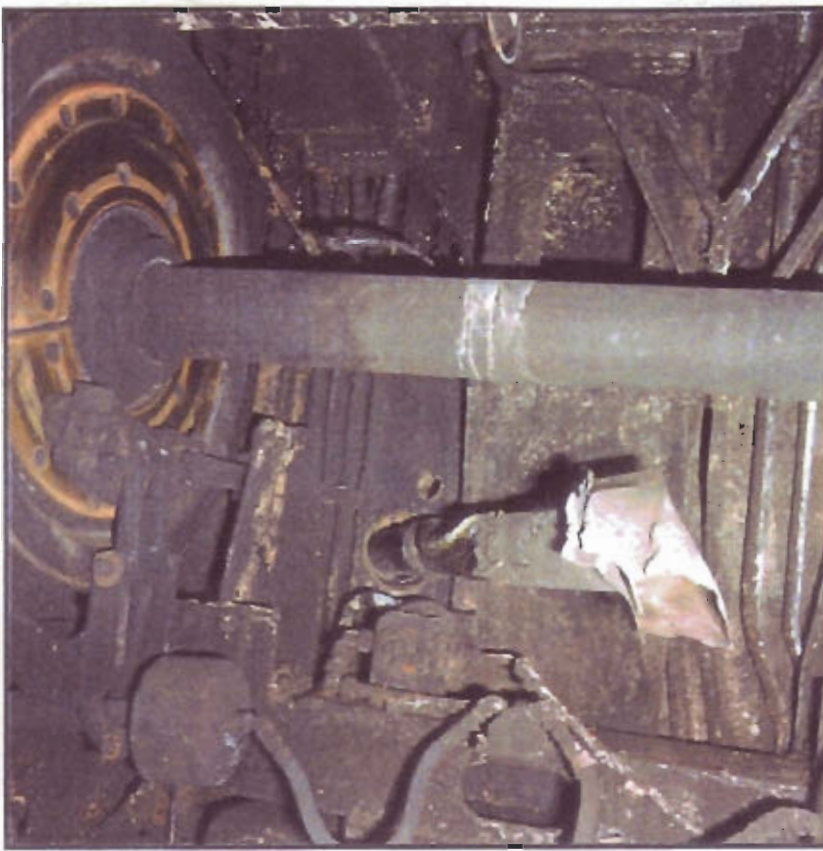


9510-001/65

Fig.11b - Close up of fire damage from behind wheel

APPENDIX A14

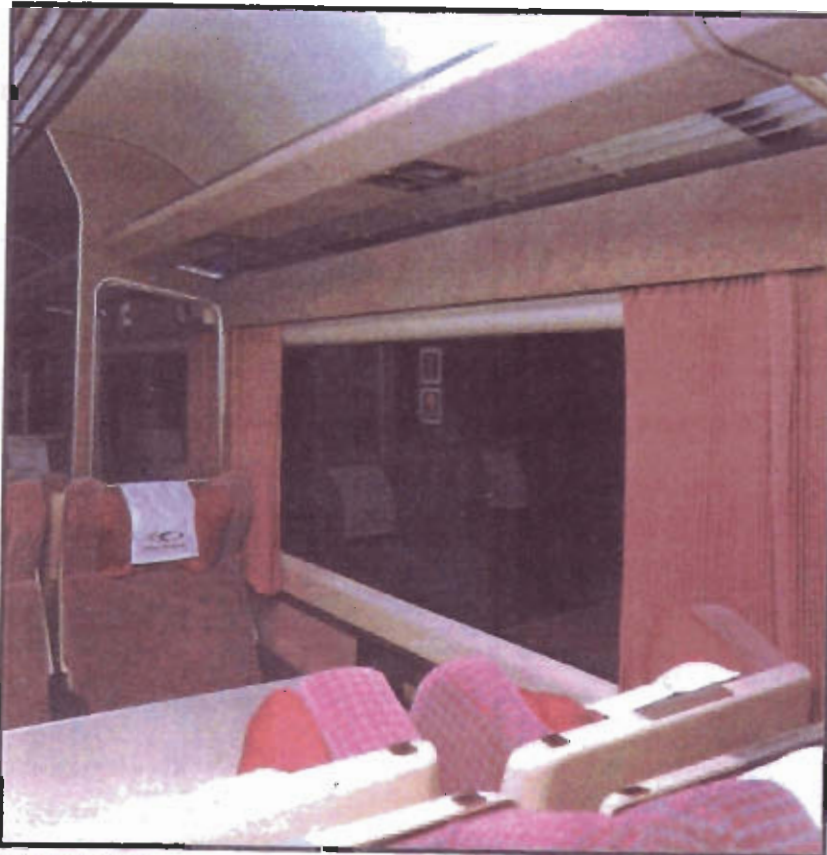
HEALTH AND SAFETY EXECUTIVE



9510-001/73

Fig.14 - Fire damage to WC outlet and overflow pipe towards front of coach G

APPENDIX A15



9509-079/11

Fig.21 - A general view of the post fire first class accommodation

APPENDIX A16

HEALTH AND SAFETY EXECUTIVE



9509-079/5

Fig.23 - The service duct access door adjacent to the toilet area of coach H

APPENDIX A17



9510-001/16

Fig.24b

Fig.24 - A view of the fire damage in the service duct at the front of coach H

APPENDIX A18

HEALTH AND SAFETY EXECUTIVE



9510-001/37

Fig.26a



9510-001/36

Fig.26b

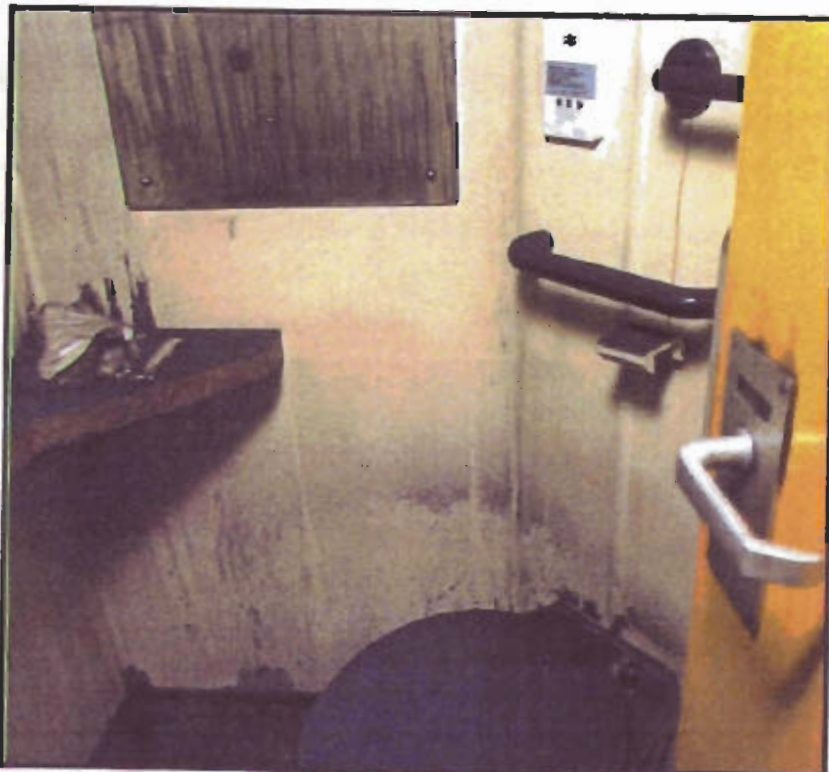
Fig.26 - The damage to the service duct due to the internal fire in coach G



9510-001/35

Fig.28 - A view from the front of the compartment of coach G showing damage in the compartment due to the fire in the vestibule

APPENDIX A20



9510-001/45

Fig.30 - Soot deposits in the forward toilet area of coach G

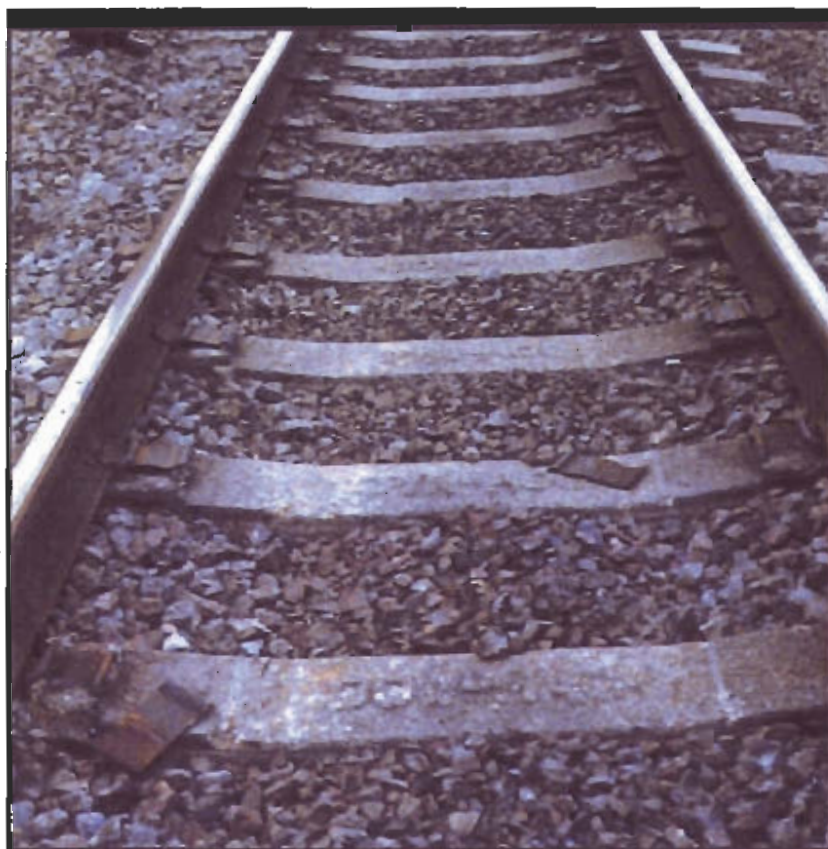
APPENDIX A21

HEALTH AND SAFETY EXECUTIVE



9509-081/32

Fig.33 - Further damaged sleeper observed east of Taplow Station



9509-081/26

Fig.35 - Disturbed rail fixing clips observed east of Taplow Station

APPENDIX A22

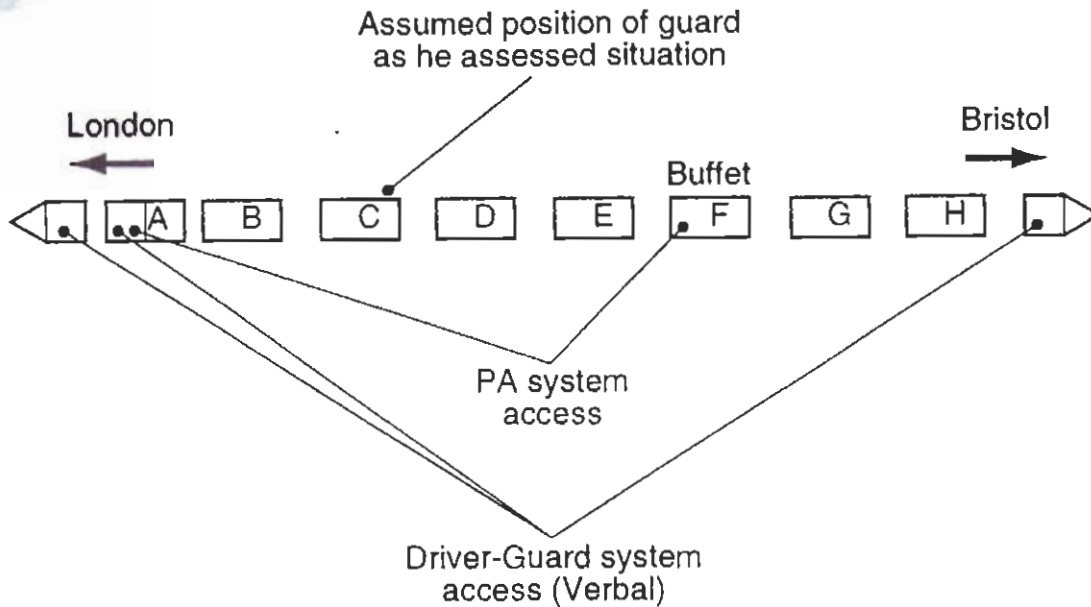


Fig. 3 - Location of verbal communications access points

APPENDIX A24



Fig.4 - CDL Systems, typical doorframe arrangement

APPENDIX A25

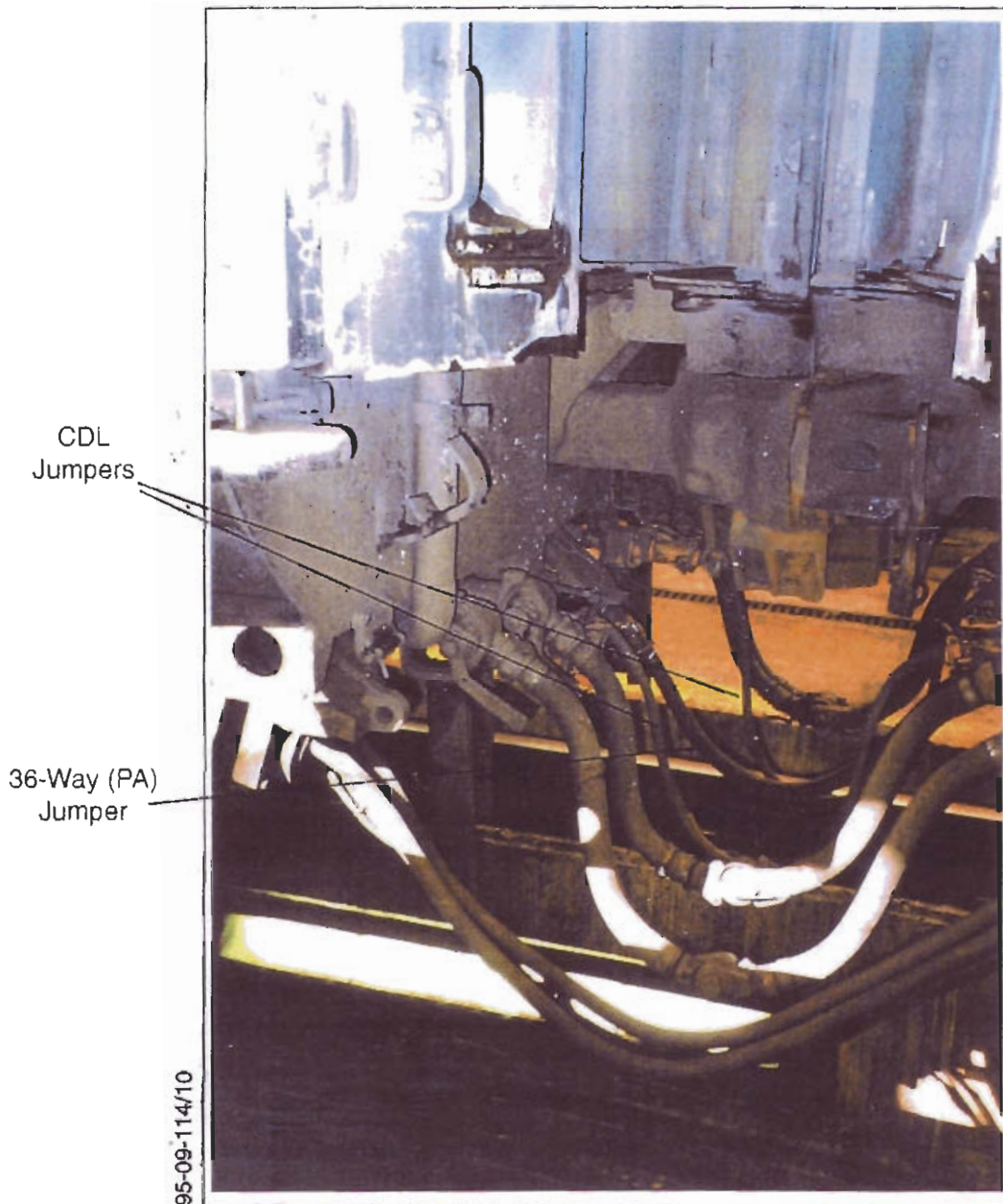


Fig.2 - Intercarriage Links for PA and CDL Systems

APPENDIX A26