HSE
Health & Safety Executive

HM Railway Inspectorate

RAILWAY ACCIDENT IN THE SEVERN TUNNEL

A report on a collision that occurred
on 7 December 1991

HM Railway Inspectorate

RAILWAY ACCIDENT IN THE SEVERN TUNNEL

A report on a collision that occurred
on 7 December 1991

HSE BOOKS

First published 1994

ISBN 0 7176 0729 1

The Permanent Under Secretary of State
Department of Transport

HM Railway Inspectorate
Health and Safety Executive
Baynards House
1 Chepstow Place
Westbourne Grove
London W2 4TF

3 November 1993

Sir

On Saturday 7 December 1991, at about 10.30 am, a diesel Sprinter train travelling from Portsmouth Harbour to Cardiff collided with the rear of a London-Cardiff High Speed Train towards the Welsh end of the Severn Tunnel. The driver of the Sprinter sustained serious injuries, including a fractured skull and loss of sight in one eye. Nearly 300 passengers were travelling on the two trains - 185 of them were injured, 5 seriously, and all experienced an unpleasant and lengthy delay in the Tunnel while the rescue operation was mounted.

I was appointed by the Secretary of State for Transport on 9 June 1992, under Section 7 of the Regulation of Railways Act 1871, to hold an Inquiry into the causes of the accident. Evidence was heard in public at the Hilton Hotel, Bristol, on 27 to 31 July 1992 and at the City Hall, Cardiff, on 26 to 28 October 1992. My report and recommendations are submitted herewith.

I was assisted at the Inquiry by Major John Poyntz, Roger Short and John Hopkinson, HM Inspecting Officers of Railways, and by other members of HM Railway Inspectorate. I wish to record my thanks to them and to the many officers of the railway, the police and emergency services and members of the public who rendered unstinting assistance with the rescue operation and the subsequent investigation of the accident.

R J Seymour
HM Chief Inspecting Officer of Railways (retired)

CONTENTS

GLOSSARY OF TERMS

ATP	Automatic train protection. A device that would prevent a train passing a signal at Danger or exceeding a safe speed.
AWS	Automatic warning system. A device which warns of the need to apply a train's brakes at a restrictive signal or speed restriction. Once the driver has responded, the system no longer monitors his actions.
B xxx	Signals on Bristol Power Signal Box Panel.
BTP	British Transport Police.
Concentrator	A device capable of terminating several telephone lines of different systems within one piece of equipment.
DMU	Diesel Multiple Unit train.
ES	Emergency services.
HST	High Speed Train.
Landline	A telephone line carried on land as distinct from submarine cable or a radio link.
MDF	Main distribution frame. Where S&T cables are terminated, normally in a lineside installation or 'interlocking'.
N xxx	Signals on Newport Power Signal Box Panel.
PSB	Power Signal Box.
PTO	Principal Technician Officer. Next grade of technician above TO.
QRA	Quantitative risk assessment: the identification of hazards and the evaluation of the extent of risk arising therefrom incorporating calculations based upon the frequency and magnitude of hazardous events.
S&T	Signal and Telecommunications Engineering Department.
SPAD	Signal passed at Danger
SPT	Signal post telephone.
STE	Severn Tunnel East.
STJ	Severn Tunnel Junction.
Tag block	S&T cable termination equipped with tag to facilitate description.
TC	Track circuit. An electric circuit established in the running rails of a section of track which, when short circuited, eg by the presence of a vehicle, may initiate the operation of various equipment such as indicators, signals and level crossing barriers.
TCB	Track Circuit Block. A method of working railway traffic, enabling spatial separation of trains travelling in the same direction on the same line, by signals operated by TC (qv), allowing trains to proceed only when the line ahead is clear. For reversible working over a single line, a directional - or acceptance switch or lever must be operated.

TDM	Time division multiplex. An electronic system, allowing multiple messages to be passed over a pair of wires, usually for the remote control of S&T (qv) equipment.
TO	Technician Officer. Junior supervisory technician grade.
Track circuit operating clips	Pairs of clips, joined by suitable wire, which, when attached to a pair of track circuited running rails, will cause a short circuit resembling the occupation of the track by a train. Usually applied to protect an obstruction.
Well wagon	A goods vehicle, normally of open construction, the deck of which is constructed as low as possible, between the wheels, to facilitate trackside loading and unloading.
WSF	Wrong-side signalling failure. Any failure in design, installation, testing or maintenance of vital signalling equipment which endangers or has the potential to endanger the safe passage of trains; the failure must be considered as potentially dangerous if it was not detected by other parts of the signalling system and had at least one of the following consequences: (a) it caused a signal to display an aspect less restrictive than the proper one; or (b) it prevented a signal from displaying a more restrictive aspect; or (c) it resulted in incorrect operation of the interlocking; or (d) it caused a train to pass without restriction over an automatic level crossing at which any road traffic crossing the railway was totally without protection; or (e) it caused all emergency telephones at an automatic half-barrier crossing or automatic barrier crossing locally monitored to be out of order.

Figure 1 Sighting of Signal N164. From 200 yards, on a misty morning. In the foreground is the Automatic Warning System magnet for the signal (photograph courtesy of BRB)

DESCRIPTION

The Tunnel

1 The Severn Tunnel is a double-track, brick-lined tunnel carrying the South Wales main line of British Railways InterCity Great Western under the Severn Estuary between Pilning, on the English side, and Severn Tunnel Junction (STJ). Its principal dimensions are:

Length: 4 miles $28^1/_2$ chains (4 miles 628 yards)
Width: 26 feet
Height: 20 feet from rail level to the crown of the Tunnel

In the Down direction (towards South Wales) the Tunnel begins at a point just over 11 miles from Bristol, descends at a gradient of 1 in 100 for two miles and rises at 1 in 90 to the Welsh side, emerging 15 miles 638 yards from Bristol. Again in the Down direction, the Tunnel runs straight for a distance of almost three miles, then takes a slight curve (1.5 miles radius) to the left before straightening again for the last mile or so. Shallow refuges for track maintenance workers are built into the wall on alternate sides of the Tunnel at intervals of one chain.

2 The Tunnel was built by the Great Western Railway to provide a direct link between London and South Wales, following GWR's acquisition of the South Wales Railway in 1861. Construction began in 1873; the first train ran through the Tunnel in 1885 and regular services began in 1886. In 1879 the Tunnel workings were inundated by an underground river, known as the Great Spring. This necessitated the construction of a pumping station at Sudbrook on the Welsh bank. Between 10 and 20 million gallons of water have to be extracted each day to prevent flooding. Two of the three pumping shafts contain a lift for access to the Tunnel by maintenance gangs and in emergencies. At Sudbrook there is also a ventilation shaft through which 80 000 cubic feet of fresh air can be forced into the Tunnel each minute by means of a 27-foot diameter fan at the top.

The signalling

3 The Up and Down lines through the Tunnel are operated by the Track Circuit Block system with multiple-aspect colour light lineside signals. In 1987 the track circuits used to detect the presence of a train in the Tunnel were replaced with electronic axle counters manufactured by Alcatel SEL AG (SEL) of Stuttgart, Germany. Conventional track circuits had been found impractical in the wet environment of the Tunnel and repeated failures had occurred, leading to serious disruption of services - though not to risk of accident, since the effect of failure is to put the protecting signal to Danger.

4 The axle counter operates through electronic detectors attached to the running rails. As a train enters the Tunnel the detectors register its presence and cause the protecting signal to remain at Danger until the appropriate number of axles has been counted out at the other end. Thus only one train in each direction should be in the Tunnel at any time. The Tunnel is under the control of the Signal Box at Newport. As with conventional track circuits the presence of a train is indicated by red lights on the panel diagram in the signal box. The counting and logic units, known as the 'evaluators', for both the Up and Down axle counters are located in the lineside Relay Room at STJ. Messages from the detector heads are transmitted to them by cable.

5 For the driver of a train travelling in the Down direction, the last lineside signal before the Tunnel is N164 at Ableton Lane, a distance of 1564 yards from the Tunnel entrance. N164 has only two aspects: red and green. It also has a junction indicator to let the driver know if the train is being diverted to the Up line under bi-directional working arrangements, but this has no relevance to events on the day of the accident, when the bi-directional working option had been suspended for reasons which will be explained later.

6 In the Tunnel itself there are permanent blue indicator lights (white lights at the time of the accident) to let drivers know when they have reached the change in gradient, and in each direction there is a single red emergency signal, normally unlit. In the Down direction the emergency signal is located at 12 miles 13 chains, just under a mile short of the bottom of the gradient on the English side. Under normal operating conditions drivers of Down trains do not see another signal after passing N164 until they reach N168R shortly before emerging from the Tunnel at the Welsh end - a distance of approximately five miles. The maximum permissible speed through the Tunnel is 75 mile/h.

The trains

7 The trains involved were:

1B10, the 08.30 InterCity High Speed Train (HST) from Paddington to Cardiff, which entered the Tunnel at approximately 10.20. This train consisted of front and rear power cars and eight passenger coaches, weighing approximately 413 tonnes. There were 129 passengers and three employees on the train.

1F08, the 07.00 Regional Railways Sprinter from Portsmouth Harbour to Cardiff, which followed the HST into the Tunnel at approximately 10.26. This was a Class 155 two-car Diesel Multiple Unit (DMU) weighing approximately 77 tonnes. There were 168 passengers and two employees on this train.

The emergency arrangements

8 At the time of the accident, on 7 December 1991, the physical provisions made by the railway operator (the operator) for responding to an emergency in the Tunnel were as follows:

Rescue equipment

(a) An emergency train was provided on the Welsh side. It was stabled at Sudbrook Pumping Station for security reasons, having been moved from STJ, close to the Tunnel entrance, in 1987 when the depot and sidings there became redundant. The train consisted of a carriage with accommodation for stretcher cases, two open four-wheel well wagons for emergency teams, a four-wheel van containing rescue and fire equipment and a 5000 gallon water tank wagon. Motive power was provided by a 350 hp diesel shunting locomotive marshalled at the Welsh end.

(b) On the English side there was no emergency train. Instead, arrangements were in place to make a service passenger DMU available for emergency use.

(c) A motorised rail trolley and two trailers were provided at Sudbrook Pumping Station. These could be taken down in sections by lift and assembled in the Tunnel to carry an emergency team to the site of an incident.

Fire-fighting

(d) Portable BCF (bromo-chloro-fluoroethane) fire extinguishers were provided: one in every other refuge on each side of the Tunnel. No fixed fire-fighting system is provided, nor is there a mains water supply although, as already noted, 5000 gallons of water can be made available from the Sudbrook emergency train. The train also carries weir-boards which could be used to dam water courses in the Tunnel so as to achieve a sufficient depth for fire fighting.

Communications

(e) A readily breakable 'tell-tale' wire ran along the Down side wall of the Tunnel. When broken it caused the Tunnel emergency signals to show red and started a visible and audible warning in the Newport Signal Box, and a warning light in the STJ Relay Room.

(f) Thirty-eight telephones, connected to the Newport Signal Box are located in refuges on alternate sides of the Tunnel at intervals of just over 200 yards. An indicator light is provided above each phone, and each is marked with the distance from Bristol in miles and chains. These phones are wired on eight separate circuits to a telephone concentrator in the Newport Signal Box which has provision for switching each circuit manually so as to transfer control of the system from Newport to Sudbrook.

(g) A landline with plug-in points for field telephones was installed in the Tunnel in 1980, but this could not be used because the emergency services (ES) did not have suitable handsets.

9 Apart from these physical provisions, a joint Emergency Plan for the Tunnel had been agreed in November 1991, after lengthy consultations between the operator and the ES on both the English and Welsh sides.

EVIDENCE

As to the operating background

10 *Mr Andrew Hancock*, Operations Manager, InterCity Great Western, gave a general description of the line and operating arrangements with the aid of a video film presentation. This showed the driver's view of the route through the Tunnel in the Down direction, starting from Patchway Station, five miles from the Tunnel entrance. He said that Signal N164 has excellent sighting from over 800 yards. Track circuit block signalling has been in operation since the late 1960s. It permits the signal to exhibit a proceed aspect when the line ahead is clear up to and including the 200-yard overlap beyond the next stop signal, N168, at the west end of the Tunnel. When N164 is showing a red aspect, the previous signal, B118, will display a single yellow.

11 While track circuits were in use, the humidity and temperature in the Tunnel had led to many right-side failures showing the line occupied when no train was there. In one year there were 18 track circuit failures lasting up to ten hours and causing considerable delay to trains. This led to the decision, approved by the Railway Inspectorate, to install axle counters. Mr Hancock described the operation of the counters: the number of axles is recorded as a train enters the Tunnel, and again as it leaves. Only if the two counts are the same will 'line clear' be indicated. On first installation the axle counters were operated alongside the track circuits for 12 months to prove their reliability.

12 Mr Hancock said the events leading up to the accident began with a failure of electronic remote control equipment on Thursday, 5 December. Because of this the signalling was switched into what is known as 'through routes' by means of a control in the signal box. The operation of this switch places all signals in the area at Danger for a short period while selected routes are set automatically. This done, the signals in the area will

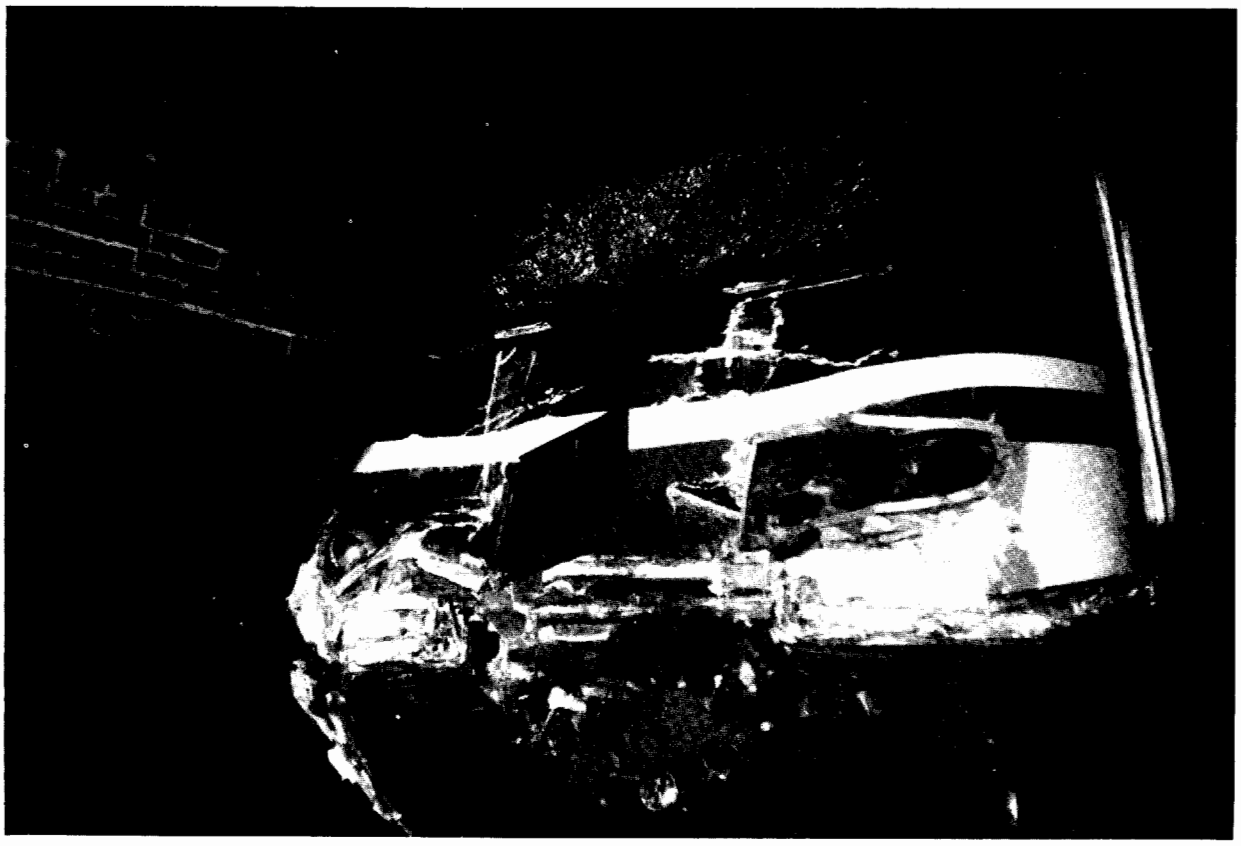


Figure 2 Rear power car of HST

Figure 3 Leading car of Sprinter train (photographs courtesy of BRB)

Figure 4 Sudbrook emergency train (photograph courtesy of J Harrison)

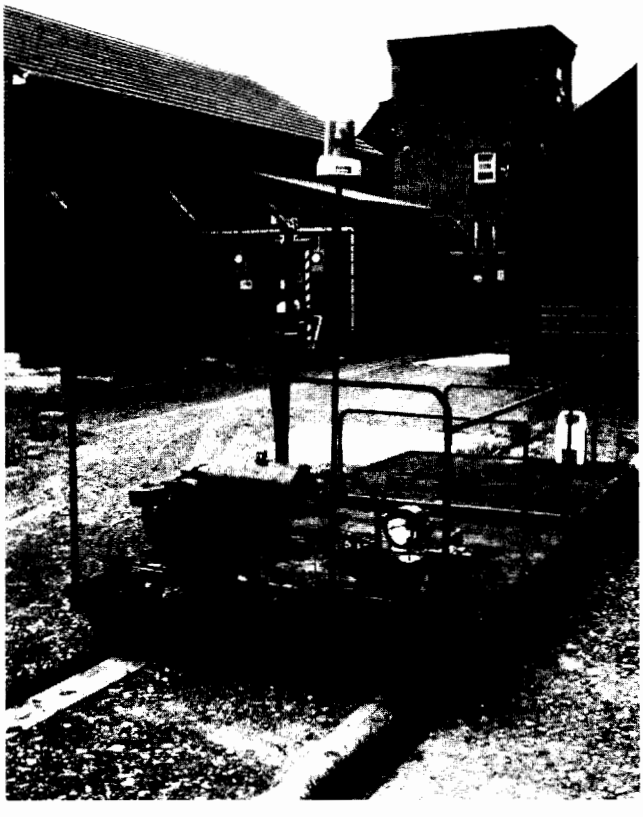


Figure 5 Sudbrook emergency trolley (photograph courtesy of J Harrison)

operate automatically, allowing trains to run normally over the selected routes. Through routes does not however permit the operation of points, so the use of loop lines is precluded, as well as bi-directional operation.

13 Mr Hancock showed a second film illustrating the control panel at Newport Signal Box. He demonstrated the indications that normally appear on the track diagram as a train passes and explained that when the through routes control is operated, flashing white lights appear on the diagram at each end of the area affected, which on the day in question was from Signal N164 to N168. The Signalman had no panel indications of the location of trains or the aspects of signals. The signals worked automatically, clearing for the passage of trains without the Signalman's intervention.

14 Mr Hancock went on to use the control panel film to illustrate the tell-tale wire operation indicator and the concentrator for the 38 Tunnel emergency telephones.

15 He said that through routes working continued until about 14.00 hours on Friday, 6 December when a driver used the signal-post telephone (SPT) at N164 to report to the Signalman that the signal was at red. Although the Signalman had no indication of the aspect of the signal he knew that the previous train had cleared the Tunnel and he would have expected Signal N164 to have cleared to green. On hearing that the signal was at red the Signalman made arrangements for handsignalling to be introduced in accordance with the rules. A stand-by signalman was appointed Handsignalman and sent from the Newport Signal Box to N164: his duties were to secure relevant points ahead of that signal and subsequently to allow trains to pass the signal at Danger and proceed at caution, on the authority of the signalman. A second person, known as a tail lamp man, was sent to Signal N168 to inform the Signalman as each train passed that signal, so that a further train could be authorised to pass N164. These arrangements continued until approximately 09.30 on Saturday 7 December, the morning of the accident.

16 Instructions for through routes working are to be found in the Signalman's Instructions for Track Circuit Block signalling and in the local instructions for the Newport Signal Box: the local instructions deal with the method of through routes working through the Tunnel. Rules for handsignalling are contained in the BR Rule Book (extracts are reproduced in Appendix 2.) Mr Hancock described the arrangements in force for the training of drivers and signalmen and for bringing to their notice changes in the signalling or in the instructions.

17 Mr Hancock confirmed that only one train at a time is allowed in the section between Signal N164 and the overlap of N168. The section is an exceptionally long one because of the need to avoid trains being stopped in the Tunnel, and it is therefore not unusual for trains to be kept waiting at N164.

18 Describing the Automatic Warning System (AWS), he explained that about 200 yards before each signal drivers receive an audible indication of the aspect being shown: a horn if the aspect is restricted (red or yellow) or a bell if it is green. A driver receiving a horn can cancel it by pressing the AWS button. If he does not do so the train will be brought to a stand. There is also a visual indicator in the cab which turns from all-black to yellow-and-black spokes when the driver cancels the warning horn. Mr Hancock agreed that the AWS is dependent on the aspects actually shown by signals: if a signal showed green when it should be red the AWS would not detect the error.

19 Mr Hancock described the Tunnel as a "black spot area" for radio communications and said that the Sprinter train involved in the accident was not fitted with cab radio.

20 He explained that the appointment of a handsignalman on the Friday afternoon was at the discretion of the Signalman. Had no appointment been made, a driver stopped at Signal N164 would have been expected to observe the provisions of the Rule Book: wait for a period of two minutes, then go to the SPT and ask the Signalman for instructions. The presence of the handsignalman avoided delay, not only for the two-minute waiting time but also the time taken by the driver having to return to his cab.

21 Mr Hancock agreed that reliance is placed on drivers obeying the signals. He had asked the BR Project Manager concerned with the prevention of signals passed at Danger (SPAD) to investigate the last three years' records: no SPAD incidents were recorded in which a driver had slowed down on approaching a red signal and then accelerated past it at Danger.

As to the circumstances

22 *Mr David Robertson* was the driver of train 1B10, the HST involved in the accident. He told the Inquiry that he had been a driver since 1960 and was very familiar with the route from Paddington to Cardiff. On 7 December 1991 he acted as assisting driver from London to Bristol Parkway: beyond this the line speed did not exceed 100 mile/h and Driver Robertson was able to take the train forward on his own. The day was sunny with fairly good visibility and he was feeling all right. The signal at Pilning Station was showing a yellow aspect. The signal for the Tunnel was at Danger and he brought the train to a stand. No handsignalman was posted at the signal. After waiting for about a minute he put on his yellow vest and went to speak to the Signalman on the SPT.

23 Mr Robertson said the Signalman told him there were some problems, and instructed him to pass the signal at Danger and obey all others. He got back into the cab, gave a long blast on the horn and proceeded at

caution, being prepared to stop short of any obstruction. The train entered the Tunnel and passed the gradient lights. As he was coming up to the left-hand turn and was about to apply power for the rising gradient, he felt an impact. The brakes started going on almost immediately. He applied emergency braking and brought the train to a stand.

24 He was satisfied the train had not run into an obstruction because at only 20 mile/h the train headlights would have picked up any obstruction ahead in time for him to stop. He did not think there would be another train behind him and his first thought was that his own train had derailed.

25 He got out of the cab, broke the emergency wire and walked forward about 100 yards or a bit more to a telephone. It was working: within a couple of minutes of the impact he was in touch with the Signalman. He reported the impact and said he was going back to check the train. He believed he had identified himself and reported the number of the telephone as 29.

26 He then started walking back alongside the train, between the two tracks, looking at the wheels with the assistance of another railway employee whose name he did not know. About halfway down the train they were met by the Senior Conductor who reported that they had lost the rear power car. It was standing about 20 or 30 feet from the rest of the train. Neither the train nor the separated power car were derailed.

27 The Senior Conductor then said that there was a Sprinter behind with a driver bleeding badly. They went back and found the Sprinter a short distance behind the separated power car. Together with another railwayman, whom Mr Robertson took to be the Sprinter Conductor, they tried to open the Sprinter's vestibule door, which was jammed. At Mr Robertson's suggestion one of the four went off to phone for the ES. Shortly after that they got the Sprinter door open.

28 Mr Robertson said he returned to his own train to let the passengers know what had happened, that the ES were on their way, and to try and put them at their ease. He remained in the Tunnel until he was asked to drive his train out at 5 mile/h, which he did. He was not hurt, although a bit shaken, and did not have to go to hospital. After reporting to the British Transport Police (BTP) he was relieved by another driver and got a lift back to Bristol by car to go off duty.

29 He agreed that the cab radio system does not work in the Tunnel. When the impact occurred he had passed the emergency signal, which was not lit at that time.

30 *Mr Stephen Carpenter* of Fratton Depot was the Driver of the Sprinter train 1F08. Mr Carpenter arrived at the Inquiry, intending to take part but on the advice of his lawyers, declined to give evidence in public.

31 *Mr Brian Nicholl* of Fratton Depot was the Conductor/Guard of the Sprinter. He told the Inquiry that at the time of the accident he had been working the Portsmouth-Cardiff service for about two and a half years and was very familiar with the route. He had ridden with Driver Carpenter on countless occasions and had one hundred per cent confidence in his driving ability. On the day of the accident there was nothing untoward about Mr Carpenter's driving. The train had to make two unscheduled station stops between Bath and Bristol and it was about 20 minutes late leaving Bristol. Between Bristol and the Tunnel the train stopped only once - at Patchway Station.

32 Mr Nicholl said that after leaving Patchway the train was travelling at less than line speed - possibly at 50 to 60 mile/h. Approaching Pilning it slowed down to a walking pace. He looked out of the window, saw the goods loop line to the left and concluded that the signal was red. That signal could be seen from a long way away.

33 Suddenly the engines "picked up". Mr Nicholl assumed that the signal had gone to green and the train would carry on as normal. He saw nothing alarming in this: it was a regular occurrence. He got on with his ticket checking duties and was in the leading coach, about three seats from the front, when there was a violent impact. He had not been aware of heavy braking, although he thought he would have noticed any emergency braking. However, he pointed out that he was busy with his revenue duties at the time.

34 The impact was sufficient to throw him into the air, and he landed on his back. He lost his shoes in the impact. He picked himself up, realising that the train had hit something and that people would be injured. He shouted to the driver to find out if he was all right. On receiving a response, albeit indistinct, from Mr Carpenter he decided his next responsibility must be to protect the train. To avoid passengers getting out onto the track he left the train by the rear connecting door which was kept locked.

35 His first act on getting down was to break the tell-tale emergency wire in several places, which he did not find difficult to do. He then put track-circuit operating clips across the track in accordance with normal procedure although he realised there was no track circuit in operation in the Tunnel. It was very dark, but with the aid of his handlamp he found a telephone about 200 yards away on the other side of the Tunnel. He estimated it was about five to seven minutes after the impact when he reached the phone. He told the signalman there had been a serious smash with a lot of injuries, and that all the ES were needed as quickly as possible. He used his lamp to read off to the Signalman

the location tally number on the phone, but he could not now remember what the number was.

36 Mr Nicholl then returned to the train and re-entered by the rear door, closing it behind him to conserve heat and to deter others from getting out. The lights in the rear coach were still on. When he got through to the front car he found the emergency lights on. He used the train's PA system to call for medical assistance. A doctor and several nurses came forward.

37 Mr Nicholl said that he is a trained first aider. However, the doctor (*Dr Oakley John*) took charge of the train's first-aid box and began attending to the more seriously injured passengers with the help of one of the nurses. Mr Nicholl himself had a very stiff neck and a sore back as a result of the impact, together with cuts sustained through walking along the track without his shoes. He made his way through the train looking at the less seriously injured and trying to reassure people. Two passengers volunteered to serve drinks from the trolley as the attendant on duty had been injured. He also got two passengers to note the particulars of all the passengers who were able to give them, and he kept the lists until the train crew manager visited him at home next day.

38 Mr Nicholl could not recall seeing anyone who had not been on the Sprinter at the time of the collision until about two and a half hours later when the train's sliding doors were opened, presumably from the outside. He explained that the emergency telephones are placed in recesses which are painted white around the outside but can easily be hidden due to the wet and dirty conditions in the Tunnel. He had to use his lamp to find one, but as he knew the phones were there he kept going until he did so. He agreed that lighting in the Tunnel would have made it easier to find a telephone but once he had returned to the train the lighting on board was adequate.

39 He said he had made himself familiar with the information in a sectional appendix to the Rule Book on emergency arrangements in the Tunnel. He confirmed his impression that the Sprinter had slowed down but not come to a complete halt at the signal. He believed the speed of the train through the Tunnel was about 50 mile/h.

40 *Mr Michael Anthony Carroll*, Quality Manager at BR InterCity HQ, was a passenger on the Sprinter. He told the Inquiry he had joined BR 12 years ago and spent his first five years on operational duties. He joined the train with his wife and two young children at Bristol Temple Meads. He was standing in the rear vestibule with the two children. He said that since the Sprinter windows could not be pulled down it was impossible to see anything of the lineside signals from where he was standing.

41 He described the journey from Bristol as "rather punctuated by a series of slowing downs and then accelerations". He thought the train had come to a stop for a matter of seconds on the approach to the Tunnel. After that it started to accelerate and he thought its speed through the Tunnel was 30 to 40 mile/h. There was a very sudden and violent bang and he fell backwards against a partition. He was carrying his 20-month old son who landed on his chest and winded him. He sustained bruised ribs and a twisted knee. His five-year old daughter who stood beside him was also thrown to the floor, but not injured. He did not think there was any braking before the impact.

42 Mr Carroll's wife, who had been sitting in the rearmost seat, came into the vestibule. After making sure they were all relatively unharmed, Mr Carroll made his way forward through the rear vehicle. He said some seats had become displaced and a number of passengers had sustained injuries, some of which seemed to be serious. There were indications of shock and panic so, to avoid any attempted evacuation, he asked people who were seated to stay where they were. When he reached the front vehicle it was in darkness and there was a fair amount of crying out and screaming. He again called out to ask people to stay where they were, and felt his way to the front of the train. He could not recall meeting the Conductor at this stage.

43 The sliding door leading to the Driver's cab was about half an inch open, but jammed due to buckling of the floor. Mr Carroll called to the Driver who replied in a quiet voice that he was all right. Mr Carroll enlisted the help of two passengers to force the door open about 18 inches. He squeezed into the cab and found the Driver bleeding badly from facial injuries. He located the Driver's bag and took out the high visibility vest, handlamp and small first-aid kit. He put on the vest and gave the first-aid kit to the two passengers who were helping him, asking them to treat the Driver. On looking through the cab window he could see the rear of the HST about 10 to 15 yards ahead.

44 Mr Carroll said he then went back through the train, using the handlamp to try and establish the severity of people's injuries and give them some comfort. As he reached the rear vehicle he heard the Conductor's announcement asking for anyone with medical experience to make themselves known. He spoke to Mr Nicholl and the doctor, briefing them about the passengers who seemed to be most seriously hurt, and then sought Mr Nicholl's advice on how to get off the train so that he could make a report to the Signal Box.

45 Mr Nicholl let him out of the front offside sliding door of the Sprinter. Outside he found the driver of the HST, who told him there was a phone about 50 yards in front of the HST, on the Down side. Mr Carroll said he

walked the length of the HST, noting that the rear power car had become detached but all vehicles appeared to have remained on the rails. The telephone had a light and was clearly recognisable. The Signalman who answered identified himself as Ken, at Newport. Mr Carroll reported the number of serious casualties on the Sprinter and the location in miles and chains which was painted clearly above the telephone. The Signalman confirmed that the ES were on their way. Mr Carroll felt he could time this call quite accurately at 10.50.

46 On his way back to the Sprinter Mr Carroll walked through the HST, reassuring the passengers and asking for medical assistance. Two passengers identified themselves and walked back with him to the rear of the HST. He helped one of them off the HST and on to the Sprinter where she began to render assistance. By this time the lights were on again in the leading car. Mr Carroll described the situation as "fairly controlled", with some people still distressed but no obvious panic.

47 Mr Carroll said he made two further calls to the Signalman before the ES arrived. The first was after he had got back on the Sprinter and checked that his family were all right. He got out of the rear door and walked back along the other track until he found another phone, about 200 yards to the rear of the Sprinter. He gave the location of this phone in miles and chains and the same Signalman confirmed that the ES had been called. Mr Carroll thought this call was made about 20 minutes after his first call, ie at about 11.10. Some time later he returned to the phone ahead of the HST and spoke to the same Signalman a third time to make sure he understood that the trains were not being evacuated.

48 Some time later, becoming concerned at the delay, Mr Carroll made a further attempt to phone the Signal Box. He said that he tried to use the phone to the rear of the Sprinter but could not get a ringing tone. Walking further back he encountered some fire officers who he believed had come down one of the shafts. He returned to the Sprinter. An emergency train arrived from the English side about two hours after the accident, travelling in the Down direction on the Up line.

49 Mr Carroll said the ES were well equipped with ladders to gain access to the trains. A controlled disembarkation of the Sprinter took place. First those who could walk were assisted off the Sprinter and on board the HST, then about 17 stretcher cases were taken off. The HST then moved slowly out of the Tunnel.

50 *Mr Roger Allan Keyse* was a passenger on the Sprinter, having joined the train at Westbury. He told the Inquiry that he sat about half-way down the leading coach, facing the direction of travel. The train was late leaving Bristol. He remembered stopping at Patchway. After that the train did not seem to be travelling as quickly as on previous occasions but he could not recall another stop before going into the Tunnel.

51 Mr Keyse said he was somewhat concerned because on looking out of the window to his left he had seen a red signal. However, BTP had subsequently shown him a video film from which it had become clear that the signal he saw controlled the exit from the loop and not the main line.

52 As the train entered the Tunnel the refreshment trolley came along and he bought coffee and sandwiches. He recalled thinking that the train was not travelling very fast as he could drink coffee without it shaking. He did not notice any braking. The impact occurred without warning. He was thrown forward against the table and winded. The lights went out and there was about 30 to 40 seconds of screaming and shouting, after which a calm settled over everyone except a woman whose baby was missing.

53 Mr Keyse recalled the Conductor going forward through the carriage. Some time afterwards, he and another passenger made their way on hands and knees to the back of the carriage, using cigarette lighters to light their way. The other person found the missing baby under a seat. In the vestibule they found a girl with a badly injured face and a man with a broken leg. They broke a glass panel to get at the first-aid kit in the vestibule.

54 Mr Keyse said he volunteered to assist with fetching hot drinks and warm clothing from the HST. On one of his trips he took the opportunity to look at the separated power car of the HST. The engine was not running and no lights were showing.

55 The first fire officers arrived about two hours after the impact. Mr Keyse said there was a lot of annoyance at the delay when they were only eight or nine miles from Newport and 15 from Bristol, which he regarded as a major emergency centre.

56 *Mr Andrew Roger Morgan*, lecturer in surgery at the Westminster and Charing Cross Medical School, was a passenger on the HST, having joined it at Paddington. He told the Inquiry the train was running 10 minutes late at Bristol Parkway. Outside the Tunnel it stopped for about five minutes and then proceeded at what he described as "a bit faster than walking pace".

57 Mr Morgan said he was travelling in the third carriage from the rear, sitting next to the window and facing the direction of travel. Through the window he could just see the edge of a signal gantry at the front of the train and he assumed, without being able to see the signal aspect, that the train had stopped at the signal. When the train entered the Tunnel it was travelling slowly enough to see the sleepers - about 15 mile/h he

thought. He had the impression it slowed down almost to a standstill several times. Shortly before the collision occurred it slowed right down and then started moving forward again.

58 There was an "almighty crash" and the train was shunted forwards violently, causing luggage to fall from the overhead racks. The lights went out and the train appeared to be in danger of tipping over, but then righted itself. He sustained a graze on the face and his shoulder was slightly bruised but he did not notice that at the time. Some passengers were crying and he went to see if they were all right. Then, on hearing a call for medical assistance over the public address system, he made his way to the back of the train where he was joined by two nurses and someone wearing a luminous jacket. They got down on to the track and walked back to the Sprinter.

59 Mr Morgan said it was bitterly cold in the Tunnel. As they approached the Sprinter they could hear "moaning, groaning and crying" from those inside. They boarded the Sprinter by the front door and the two nurses went towards the back to assist the injured passengers. Two men were in the process of breaking down the Driver's door and Mr Morgan squeezed through to see him. He estimated that at least five minutes, if not 10 had passed since the impact.

60 The Driver was sitting slumped, with a two-inch gash over his right eyebrow. Mr Morgan described him as "heavily concussed". He responded to Mr Morgan's questions, saying that he thought he was all right, but didn't know what had happened and hadn't seen the HST. Mr Morgan stopped the Driver drinking a cup of tea, since he was likely to need an anaesthetic later on. He then left the Driver in the care of a passenger and went back through the train to attend to the more seriously injured passengers.

61 Mr Morgan described the injuries sustained by the Sprinter passengers. He said that apart from the Driver, one person was critical - a passenger who had broken his leg and was shocked from loss of blood. Four people had spinal injuries, two or three had broken arms and he estimated about 75 facial injuries: broken jaws, noses and cheekbones and lacerations.

62 He asked some railway employees whether the ES had been called, and was told that a rescue train would be coming from Bristol but it was not known how soon. It was then 11.10. Mr Morgan asked if he could get through to the ES, to let them know the number and condition of the casualties and to find out how soon people could be rescued. He was taken along the Tunnel towards Bristol for about 200 yards until they found a telephone with a very dim light. He said it was only recognisable from within three feet. He got through to Newport and spoke to someone whom he believed to be a rescue co-ordinator. He described the injuries and asked for spinal stretchers to be brought with the Rescue Team.

63 On returning to the Sprinter Mr Morgan examined the Driver again. His condition was deteriorating and his level of consciousness gave Mr Morgan concern. By this time at least two hours had elapsed since the accident. He decided to try and get another message to the emergency services, but the telephone he had used earlier was not working: nor were other phones that he tried. As he was returning to the Sprinter he saw the lights of the emergency train coming from the Welsh side.

64 Mr Morgan advised the leading fireman on the location of the injured and who should be removed first, starting with Driver Carpenter. He asked for a message to be sent to warn the hospital to prepare for a serious head injury. Five to ten minutes later the rescue train from Bristol and a team of paramedics arrived. Mr Morgan supervised the removal of the more seriously injured.

65 Mr Morgan said that by the time those who were able to walk were being escorted from the Sprinter to the HST, a good three hours had elapsed since the accident. Over four hours had passed before the HST eventually arrived at STJ. In his view it is imperative to get help to the injured within an hour. He also observed that virtually all the injured on the Sprinter had either been standing or seated facing the direction of travel. The injuries were consistent with people's faces hitting the plastic seat-back in front of them.

66 *Dr Oakley John*, a Southampton GP, was a passenger on the Sprinter who assisted in treating the injured. Dr John was unable to attend the Inquiry to give evidence in person but he wrote to me expressing admiration for the courageous and cheerful behaviour of the passengers while awaiting rescue.

67 *Driver R H Forder*, based at Fratton, was the Driver of an early morning train, the 06.10 from Portsmouth to Cardiff, on the day of the accident. He told the Inquiry that Signal B118 was showing yellow and he stopped at N164, which was red. A Handsignalman approached the train from the direction of a building a few yards away. He told Driver Forder that the axle counter was not operative but the Tunnel was clear and it was all right to pass through.

68 Mr Forder was concerned because the Handsignalman was not posted by the signal, where he should have been, and had no flags or detonators as required by the Rule Book. He told the Handsignalman he had better get some quick - he didn't know where they might be obtained, and didn't consider this to be his responsibility. After moving off as directed he decided to stop at the next signal and use the SPT to report the

matter to the Signalman at Newport. The Signalman replied that he would get something done about it.

69 Mr Forder considered it acceptable to be controlled by handsignalling, provided everything is carried out satisfactorily. He confirmed that Signal N164 is clearly visible and easily identified. He said he had driven over the route a number of times. Due to the length of the section it was not uncommon in his experience for the signal to be red when first sighted and to change aspects on approach.

70 *Signalman Kyril Morgan* was in charge of the Severn Tunnel Panel at Newport Signal Box on the morning of the accident. He told the Inquiry he had been a signalman for 37 years and had been stationed at Newport continuously since 1981. He had worked the 6am to 2pm shift the day before the accident and had arrived a few minutes early for the same shift on the Saturday, when it was his turn to work the Severn Tunnel Panel.

71 During a short handover discussion, the Signalman he was relieving told Mr Morgan "that we were working in through routes over Severn Tunnel East, also that the axle counters are disconnected...". Mr Morgan said he was familiar with through routes working which was used during maintenance or testing as well as in cases of failure. Under through routes the panel is completely blank, but the signalman gets an indication on the describer, and a buzzer warning, of Down trains leaving the Bristol signalling area for Newport.

72 At about 06.00 Mr Morgan had a phone call from the Handsignalman who had been acting as Tail lamp or 'Train out of section' (TOS) man overnight at Signal N170, to report that he was going off duty. Mr Morgan explained that this is the signal protecting Severn Tunnel Junction. He attached great importance to having tail lamp reports, so he arranged for the level crossing keeper at Bishton, a mile or two further on towards Newport, to observe tail lamps temporarily until another TOS man could be stationed at N170.

73 Mr Morgan said that as there were no spare signalmen at Newport, he took the initiative of phoning the Bristol Panel, who offered him the services of a trainee signalman called Mark Ellott as a TOS man. Mr Morgan accepted the offer - he did not know Mr Ellott but he was described as "a bright lad".

74 While he was waiting for Mr Ellott to report his arrival at N170, it occurred to Mr Morgan that a qualified signalman from Newport, Terry Wood, had been put on hand signalling at N164 that morning. In order to save Mr Wood a journey over the Severn Bridge for what might prove to be only a short time until the fault was rectified, Mr Morgan decided, again on his own initiative, to arrange for him to change places with Mr Ellott. He explained to each of them by telephone what he wanted.

75 Mr Morgan said that Mr Ellott seemed "quite competent". As it was a cold morning he told him to shelter in the hut near Signal N164 rather than station himself at the signal. When Mr Morgan got an indication on the describer of a train approaching from Bristol he would call the hut and tell Mark to go out to the signal and speak to the driver on arrival. He shouid then call Mr Morgan for instructions over the SPT.

76 Mr Morgan said he didn't think it necessary to enquire whether Mr Ellott was properly equipped. As he was relieving a qualified signalman who had been on duty overnight, Mr Morgan assumed that flags and detonators would be in place. When the driver of 1F06 (Driver Forder) phoned at about 09.17 to report that the Handsignalman was not properly equipped, Mr Morgan passed the message on to Bristol, asking if they would send some flags down. Very shortly afterwards he received a call from Bristol telling him to withdraw Mr Ellott, on the panel supervisor's instructions. Mr Morgan said he thought it was safer to use a handsignalman and save drivers from having to get down from their cabs to use the telephone, although he agreed this is a perfectly normal procedure.

77 It was about 09.30 when he phoned to send Mr Ellott away. The next Down train was 1B08, Paddington-Swansea, which went through under caution, then 1B10, the Paddington-Cardiff train. Shortly after he instructed the Driver of 1B10 to proceed past N164 under caution, he got an indication on the describer of the approach of 1F08, the Sprinter, from Bristol. This he duly acknowledged.

78 Mr Morgan thought it was about 10 minutes later, at about 10.35, that he received the audible and visible indications of the breaking of the tell-tale wire. He understood the instruction was not to take immediate action on these indications - because the wire might have been broken unintentionally through the passage of a train - but to be prepared to act on receiving a call from the Tunnel. He was fully expecting a call as 1B10 had been in the Tunnel a long time.

79 He described the call from the Driver of 1B10, who told him he was calling from 14 miles 28 chains. When asked for the number of the phone, the Driver said he thought it was 29. Mr Morgan said this gave him a good idea where the train was, because No 1 was at the Bristol end and No 38 at the Welsh end. Almost immediately another call came through on the concentrator - he thought the two calls were on sections G and H. The second call was from the Guard of 1F08, calling for the ES. Mr Morgan again asked for the telephone number but didn't get a response. He called out to his colleagues on the panel and he understood they passed on the

emergency call while he was talking to the Guard. He later spoke to the Controller at Swindon, Mr Ian House, to pass on subsequent messages received from the Tunnel, but he could not clearly recall mentioning the location of the accident which he said he had passed on to his colleagues on the panel.

80 Mr Morgan could not recall receiving any calls from the Relay Room at STJ on the morning of the accident. Someone phoned to ask if there were any trains on the Up Main but he didn't know where the call came from. He was quite clear he had not given permission for the resetting of either the Up or the Down axle counter. He could not recall any occasion when the Signal & Telecommunications (S&T) technical staff had tried to reset an axle counter without first getting an assurance from the Signalman that the line was clear.

81 *Mr Kevin Michael Schofield*, S&T Engineer, Regional Railways South Wales and West, told the Inquiry that at the time of the accident he was the Area S&T Engineer for Newport, with responsibility for the whole of South Wales. He described his key responsibility as "the safety of the travelling public and the safety of the people who work for me". He gave a description of the Area S&T organisation, explaining that there is a signalling works team responsible for new installations, and a number of signalling section managers, formerly known as maintenance supervisors, responsible for maintenance and fault-finding on existing S&T equipment. A combined faulting and maintenance team, based at Newport, had to deal with the failures in the Tunnel area on 5 to 6 December.

82 All S&T equipment is subject to routine maintenance at intervals laid down in the instructions. The section manager is responsible for checking the maintenance records and site surveillance, and the maintenance support engineer for monitoring reliability and predicting major renewal requirements.

83 Faults are reported by the signalman to the Swindon Signalling Fault Control and passed for attention to the appropriate faulting team who carry out first-line faulting. Mr Schofield said that 80 to 90% of faults are dealt with at this level: 60% within an hour of failure and 80% within two hours. However, the first-line team has to deal with a very wide range of equipment. Faults requiring more detailed knowledge, or more complicated testing, are referred to the maintenance support assistant for second-line assistance. The maintenance support engineer provides third-line assistance and has a systems engineer specialising in electronic systems.

84 The technicians working at STJ on the morning of the accident were from the second-line assistance. Mr Schofield said he had every confidence in their competence and integrity. His complement of about 200 technical staff was "pretty well staffed up". The recruitment situation in South Wales was not difficult and he had recruited trainee technicians extensively in recent years: people with fairly good GCSEs or with experience in electronic firms.

85 Mr Schofield gave evidence as to the reliability of critical items of equipment. He said that the axle counters had been re-set or otherwise attended by technicians 18 times in 1991 prior to the accident, usually following civil engineering work affecting the counting heads but on three occasions the voltage drifted out of tolerance and once a head was cracked.

86 The tell-tale wire had failed 49 times in 1991. Mr Schofield explained that these were safe-side failures - he was not aware of any occasion when the breaking of the wire had failed to operate the alarm in the signal box and put the signals to Danger. However, to reduce the incidence of false alarms a duplicate wire had been installed, two to three inches above the first, in May 1992. In addition the system had been divided up into eight separate sections. The technicians would continue to be alerted to single breaks requiring repair, but only if both wires were broken simultaneously in the same section would the signalman's emergency alarm operate and the signals go to Danger.

87 The Tunnel telephones are tested to Newport Panel every Tuesday and Friday. Mr Schofield said that the Sudbrook concentrator had been tested and found to be working on 11 November. He understood the failure following the accident was due to a switch being in the wrong position which caused a lamp indicator at Sudbrook to fail. The system has some back-up protection in case of failure. There is an indication that power is available, an alarm which sounds if two circuits ring together and if the carrier circuit to Newport fails an alarm sounds and allows switching through to Sudbrook. If a handset is left off the hook, or removed altogether, the signalman gets a continuous indication.

88 The remote control system has a multi-station time division multiplex (TDM), which had failed twice in 1991 prior to 5 December. Mr Schofield said this was an improvement on the previous year. The first failure on 5 December occurred at 09.15 but this was put right by about 10.15. At 13.42 the system again failed. The technicians, with second-line assistance, worked on it until about 17.00 when they decided they would need further help. The maintenance support engineer received a call at about 19.00. Owing to the absence of one of his staff on leave and another on a training course, assistance was sought from Western Region S&T but by 09.00 on Friday 6 December it had become clear that the fault could not be put right that day. Arrangements were made to do the job on Sunday 8 December.

89 At 14.02 on 6 December a driver reported that Signal N164 was showing red. At that time it should

have been green. Signalling Fault Control passed the message on to the technicians and the Signalling Section Manager Mr Cantle was also informed. By 15.10 both he and the faulting team were at STJ Relay Room, where they found that the CG (Down) axle counter had failed. In consultation with the signalman they tried to reset it, without success.

90 Some time after 16.00 Mr Cantle phoned the Maintenance Support Engineer and described to him the state of the various indications on the counter. They concluded that the fault was probably in the trackside count-out heads. On this assumption it was decided to tackle the job on Saturday morning. The second-line team was alerted on Friday evening and the technical support assistant from Cardiff was asked to come and assist, bringing with him a spare counter-head which was kept there.

91 Mr Schofield said that instructions for the maintenance and testing of axle counters are contained in the national signalling testing handbook, which was being introduced at the time of the accident. The faults on the TDM and the axle counter were totally unrelated and the TDM failure did not necessitate the disconnection of the axle counter.

As to the faulting activities at STJ

92 *Mr Andrew Sperring*, an Engineering Technician in the Severn Tunnel faulting and maintenance team, told the Inquiry that on Thursday, 5 December he was on duty from 06.30 to 18.00. He assisted in the fault-finding process on the TDM by removing and replacing printed circuit cards as directed by David Croke, a Principal Technician Officer (PTO). He had no detailed knowledge of the effect of removing or replacing particular cards. He also removed a pair of cable links to disconnect the TDM. It was left disconnected at the end of the shift and he recorded this in the disconnections record kept in the Relay Room.

93 On Friday 6 December he spent the morning at Caldicot level crossing, carrying out routine maintenance and rectifying a telephone fault reported by the crossing keeper. He returned to STJ Relay Room for dinner. At about 13.15 he received a call from Sudbrook Pumping Station reporting that their 'box-to-box' phone was out of order. Mr Sperring said he associated this with the fault at Caldicot: he suspected a fault on the telecommunications carrier system to Newport. Referring to the information kept in the Relay Room he established that the Caldicot box-to-box phone was on cable 2354 PS 17. He removed the appropriate links from the main distribution frame (MDF) and tested the voltage with a meter. This gave an unexpectedly high voltage (60 V) but Mr Sperring thought this might have been due to someone trying to use the phone at the time. He concluded that the Caldicot phone was in order and so, without pursuing the matter any further, he put the links back in.

94 There were no identification marks on the links like the red paint marks used to identify vital circuits. He accepted that he might have mistakenly removed or wrongly replaced links for the axle counter, but said that to the best of his knowledge he had removed the links for the telephone circuit and replaced them in the position where they were before.

95 He left the Relay Room at about 13.45 and went to Chepstow to attend to some outstanding maintenance. While at Chepstow he received a call from the Technician Officer (TO) at Newport , who told him that there was difficulty in maintaining through routes at Severn Tunnel East (STE) and asked him to go over there. On arrival at STE he carried out some tests under the direction of the supervisor, Mr Cantle. On checking the relay for the Down axle counter, known as Z DN TPR, he found it was "down" (de-energised).

96 Mr Sperring explained that this relay is a repeater for the equivalent relay on the axle counter evaluator at STJ. He made no disconnections or alterations to equipment at STE: his function was simply to make observations as directed by Mr Cantle and the supervisor over the phone. He was then directed to make a visual examination of the out-counting heads at the Welsh end of the Tunnel, and found no obvious faults. He returned to STJ and went off duty between 17.30 and 18.00.

97 Mr Sperring said he was off duty but on call on Saturday. At about 10.30 he was called in to repair the tell-tale wire. On arrival at the Welsh end of the Tunnel he learned that there had been an incident. He and his assistant went on to STJ Relay Room where they were told that two trains were involved. They decided to report to Sudbrook Pumping Station as they were members of the Tunnel Rescue Team. Mr Sperring's subsequent evidence is reported at paragraphs 225 to 228.

98 *Mr Jonathan Napper*, an Engineering Assistant with BR Central Services, told the Inquiry that at the time of the accident he was a member of the Director, S&T's staff based at Reading. He said he had worked for BR since 1982, had a B Tech in electronics engineering, and had worked extensively on the electronics of axle counters.

99 Mr Napper gave a description of the Severn Tunnel axle counter functions and operations. He explained that the lineside equipment consists of detector heads bolted to the rails and connected to an electronic junction box about a metre-and-a-half away. Two differing frequencies are fed to the heads from the junction box. As a train passes the heads, each axle causes a phase reversal which is detected and

transmitted via the junction box to the evaluator frame in the STJ Relay Room. Mr Napper said that about five-and-a-half miles of cable link the evaluator with the junction boxes at each end of the Tunnel.

100 If the information from the count-out heads matches that stored in the memory of the evaluator from the count-in, the evaluator can reset and clear the section, but it will only do so after carrying out an automatic check to ensure that it is performing correctly. In case of any discrepancy, whether in the information received or in the operation of the equipment, the axle counter will go into the 'failed' state and the signalman will be unable to set a route into the Tunnel.

101 Mr Napper described the STJ evaluator which had been made available by BR for the Inquiry. He explained that the associated equipment had been added to enable the operation of the evaluator to be fully simulated. The evaluator has a series of removable electronic circuit cards, each having a specific function in relation to the passage of trains through the Tunnel. Mr Napper demonstrated with the simulation controls how the indicator lights on the count-in cards are lit in sequence as a train enters the section; a change of lights indicates that the section is occupied; and finally the count-out cards indicate the train leaving the section. He showed how the upper red light (G11) on the left-hand (FRM KTR) card indicates failure due to voltage out of tolerance and the lower one (G10) shows that the last count was 'in', and has not been cleared; and how the black button on this card (T1) can be used if necessary to clear a redundant in-count, but will not re-set the evaluator.

102 Card ZIANZG displays the number of axles counted. Below the numerical display are three indicator lights, the top one green (G3) and the others red (G2 & G1). G1 lights after a complete count-out, to show that the counter is clear. The middle light (G2) indicates satisfactory monitoring of the count with all the correct information received, and the top one (G3) lights if the track is clear and the system functioning correctly.

103 Mr Napper referred to the cards provided for testing voltages and other functions, and card WDH, which is mounted with relays for transmitting the output of the evaluator to the signal interlocking. Reading from the bottom they are:

AZT	- re-set push-button relay
GBP	- track occupied
GB	- track occupied
GS	- track clear

With the front cover of the evaluator removed the position of each relay is clearly visible. Mr Napper confirmed that only the top one (GS) will be 'picked' or closed if the track is clear.

104 Associated with the WDH relay card are the green re-set button and the adjacent green indicator light. When dealing with a fault the technician must be satisfied from the condition of the indicator lights that there has been an out-count before operating the re-set button (with the consent of the signalman). Mr Napper could not say what effect through-routes working has on the operation of the axle counter.

105 He demonstrated how with the front cover removed, the fuse can readily be removed from the WDH card to disconnect the evaluator from the signal interlocking. With the WDH fuse removed, Signal N164 will remain at Danger. He agreed that intermittent faults could occur without being explained or even identified, but said he had never come across an axle counter giving an inadvertent output allowing the signalman to set a route, nor any wrong-side failure of an axle counter, either intermittent or permanent.

106 He visited the STJ Relay Room on the morning after the accident to carry out tests on the Down axle counter. When he arrived the Relay Room was locked and sealed. On gaining access he found that the front cover was off the evaluator and the cover provided for the re-set button was undone. He could not recall whether the WDH fuse was in or out when he got there.

107 The fuse could not easily be confused with other fuses on the evaluator frame. The removal of the WDH fuse does not hinder the adjustment of the axle counter or the re-setting of the electronics and there is no benefit to the technician in having it in. The evaluator can also be isolated from the signalling by disconnection or by removing links.

108 *Mr Trevor Cantle*, Signal Section Manager/Signal Supervisor at Newport, told the Inquiry he had 38 years' experience on the railway and was responsible for the Severn Tunnel faulting and maintenance teams. He had attended an appreciation course on axle counters but not a technical training course. However, some of his staff had received detailed training and he was satisfied they had sufficient knowledge to undertake routine maintenance and first line fault finding. For very complicated faults a PTO or someone with greater expertise would be required.

109 Mr Cantle said he was not involved with the electronic failure on Thursday, 5 December, but at 14.30 on Friday he received a phone message from the signal box that Signal N164 was continuously at red, and this could not be explained due to the lack of panel indications under through routes working. Mr Cantle arranged for the faulting team to proceed to STE, where the controls for N164 are located, and he went to STJ Relay Room.

110 On checking the down axle counter evaluator Mr Cantle noted a count of 350 axles. This indicated to

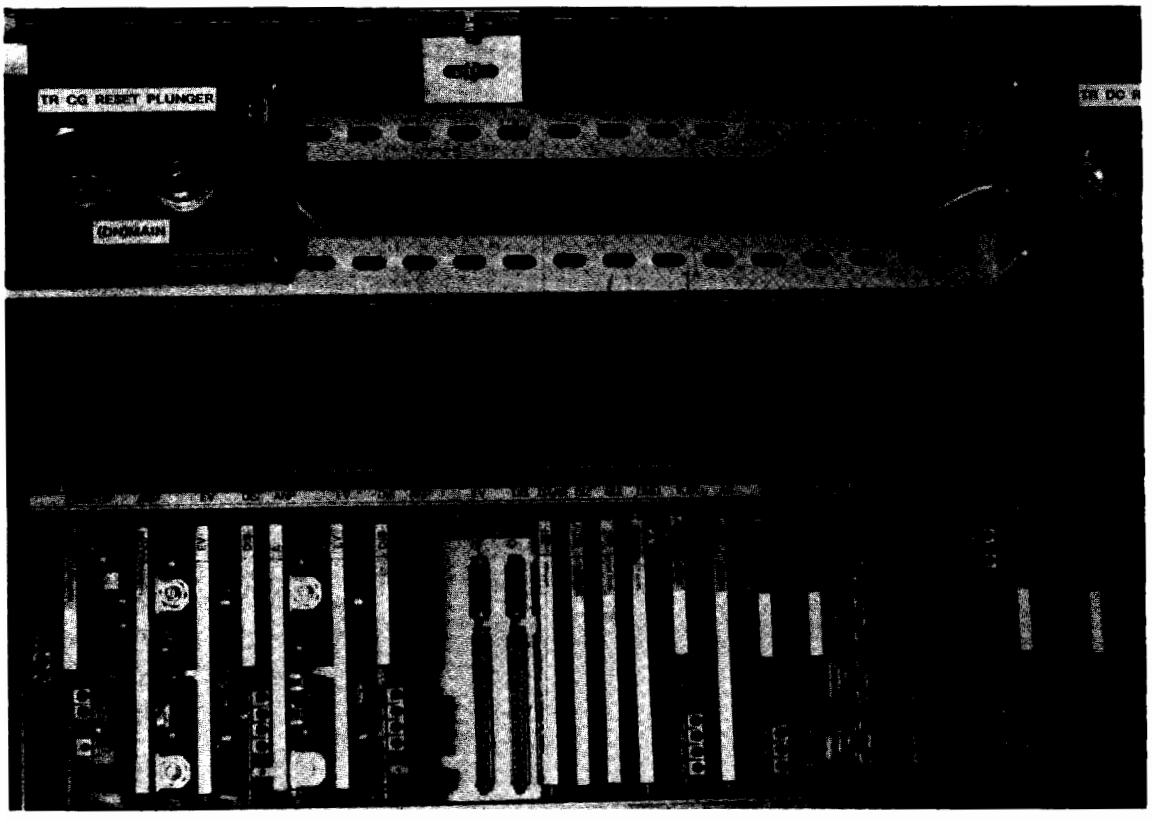


Figure 6 Axle counter evaluator and reset plunger. A photograph of the Down Main Line axle counter evaluator with its reset plunger above it, to the left (photograph courtesy of BTP)

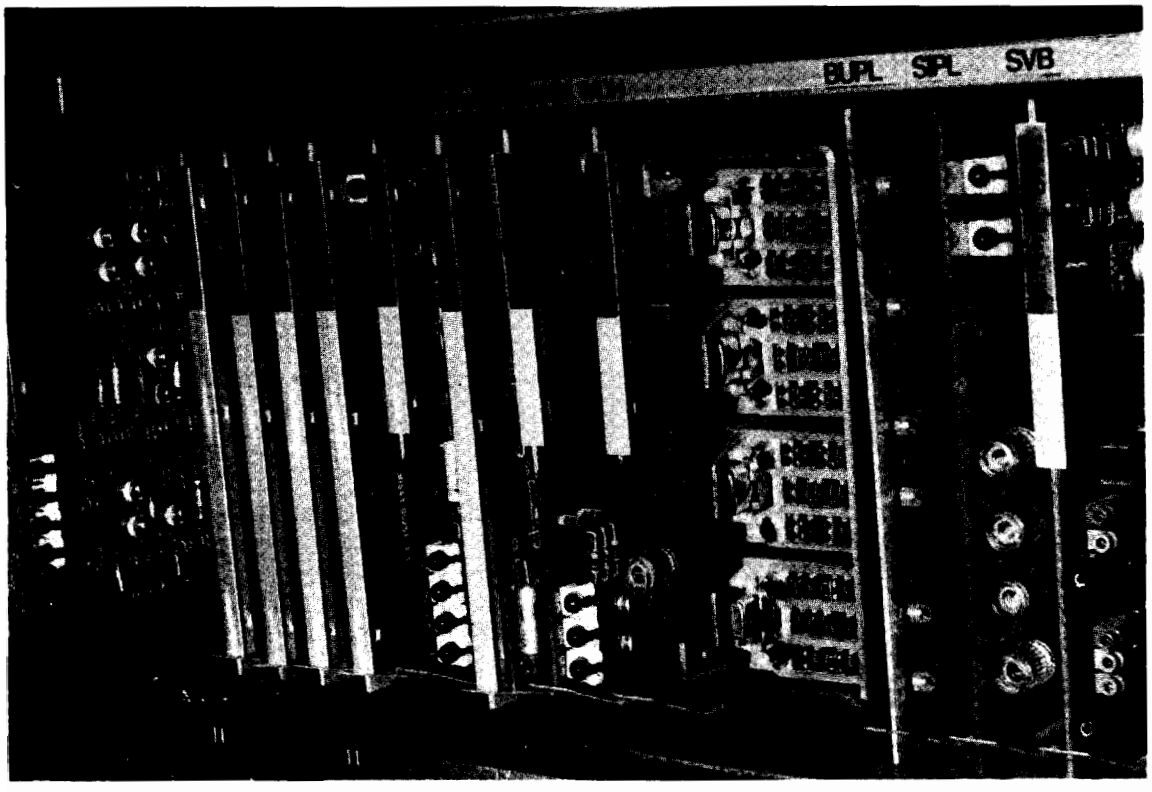


Figure 7 Axle counter evaluator. This photograph of the Down Main Line evaluator shows detail of the fuse location on the WDH card and the LED count-in/-out display on the ZIANZG card (photograph courtesy of BTP)

him that the axle counter had failed, since the count was too high for a single train. He asked the Signalman for permission to clear the counter and on receiving word that the Tunnel was clear, he took the cover off the green button and pressed it, but nothing happened. He then took the cover off the evaluator, pressed the black button and then the green button. The counter cleared but did not reset, so he replaced the covers and told the Signalman he would not touch the evaluator again without letting him know. He didn't look at the indicator lights and could not say what their condition was.

111 Mr Cantle said he pressed the black button first, and then the green, in the hope of getting the axle counter back into sequence and clearing the fault. He understood that on through routes, a successful re-set would have caused the signal to clear to green, but he was satisfied from the Signalman that both roads through the Tunnel were clear. Having tried without success to re-set the counter he didn't touch it again. He confirmed that the WDH fuse was in position at that time - had it been removed there would have been no need to contact the Signalman before attempting to re-set.

112 His next step was to consult Mr Button, the Maintenance Support Engineer, who advised that certain voltage tests should be undertaken. These disclosed a loss of voltage and it appeared that the lineside amplifier might be faulty. Mr Cantle decided that to avoid extending the faulting team's shift beyond 12 hours, and to enable a spare amplifier to be brought from Cardiff, work should be suspended until daylight on Saturday. He arranged for a PTO and other technical people to attend in the morning, and asked the Signalman to organise handsignalling until 14.00 on Saturday.

113 On Saturday he was off duty but he phoned STJ at 09.30 to find out how the technicians were progressing, and was told they were out on site. At 10.30 the PTO, Mr Croke, phoned to say they had found the fault: disconnected links on the MDF. Mr Daniel, the other Signal Supervisor, then took over the phone to inform him of the incident and Mr Cantle went straight to the STJ Relay Room, arriving there at 11.25. Apart from the faulting team already working there, he was the first manager to reach the Relay Room after the accident.

114 Mr Cantle said that on arrival he found everyone in a state of shock. He asked whether the axle counter had been reset and handed back to the Signalman, and was told it had not. He also understood that the fuse was still out although he didn't see it. Mr Inskip, the Assistant Area S&T Engineer, then arrived and ordered everyone out of the Relay Room so that those present at the time of the accident should have nothing to do with the independent post-accident testing. Mr Cantle said he remained in the messroom with the faulting team until he was taken home at about 20.30. None of the equipment in the Relay Room was touched while he was there.

115 He was aware of Special Instruction Notice No 35 (SIN 35) which called for ties to be removed from a certain type of cable, and agreed that the ties had not been removed from cables in location cabin Y27, about 200 yards inside the Welsh end of the Tunnel. The usual procedure for complying with such an instruction would be to form a team to go through the locations affected, dealing with as many as they could in a day. The team would report back on completing a section. SIN 35 involved looking at cables installed since 1987. Mr Cantle could not recall receiving a completion report and he thought Y27 might have been overlooked due to lack of time or staff shortage.

116 *Mr John Vivien Daniel*, Signal and Maintenance Supervisor, Newport, told the Inquiry he normally looked after Hereford and Ludlow but was on call for the whole area including the Severn Tunnel. On the evening of Friday 6 December he had a phone call from Mr Cantle, asking him to arrange for a spare line-side amplifier to be brought from Cardiff to STJ on the Saturday morning. Mr Daniel asked Stephen Andrews, the Cardiff PTO, to pick up the spare amplifier and Mr Andrews also came to STJ "because of his knowledge on axle counters". Mr Daniel described his own knowledge of them as "very limited". He also arranged for David Croke, the Newport PTO, to attend.

117 Mr Daniel said he arrived at STJ Relay Room at 09.00 on Saturday. Eight people were present: the Severn Tunnel maintenance team (Messrs Waters, Reed and Bunce), himself, the two PTOs and two look-out men to assist with any lineside work. Mr Daniel regarded himself as being in charge in a supervisory capacity, but he left it to the PTOs, as the technical support, to deal with the failure.

118 He recalled that when he reached the Relay Room the green light on the evaluator was out, indicating that it was in the failed state, but the other indicator lights meant nothing to him. He could not recall whether the cover of the green button was in place. He saw Mr Andrews remove the fuse from the WDH card and place it on top of the evaluator. He enquired the reason for this and Mr Andrews explained that it was to disable the axle counter from any outside signalling.

119 Mr Daniel took no active part in the work on the evaluator but he recalled that after taking voltage readings and making some adjustments the PTOs concluded that the fault was at the lineside. He and the two PTOs went to the Welsh end of the Tunnel, accompanied by the two look-out men who travelled in a second car. The PTOs checked the lineside junction box and he gathered that no supply was being received there, so it looked as if the fault was back at the interlocking.

120 They returned to the Relay Room and the PTOs went back to the evaluator. When Mr Daniels got there Mr Andrews was taking the back cover off. He took some measurements and said that it looked all right. They then went to the MDF where Mr Daniel discovered that two links were missing. He was "95% sure" that these links controlled the axle counter. He described the MDF as an interconnection point between internal and external cables and said he had dealt with it on previous failures. The MDF tag blocks were not listed but the axle counter wiring stood out from the rest because it was a thicker gauge wire.

121 It was concluded that the missing links were the cause of the axle counter failure. A search was made for replacement line links and Mr Waters eventually found some - he was also asked to find some labels, because Mr Daniel was concerned that a circuit as important as this should be properly marked. He felt it was possible for someone to put the links back in the wrong place.

122 Mr Croke went back to the evaluator and Mr Daniel, from his position by the stores cabinet some distance away, heard him remark that "it looks OK, an 8 count has just come in". Mr Daniel returned to the back of the evaluator and found Mr Andrews replacing the cover. Mr Daniel could not see the indications at the front of the evaluator but he understood the intention was to wait for the train to come through and see if the count went down.

123 While they were waiting the phone rang, and Mr Waters came over to tell him the Newport TO had reported a tell-tale failure. Mr Daniel asked him to call Andrew Sperring out to deal with the failure. The TO then phoned again. He told Mr Daniel there had been a collision in the Tunnel. Mr Daniel gave him permission to go to Sudbrook as a member of the Emergency Team, and he thought he had asked two of the ST maintenance team to go to Newport to assist the faulting team. He then received a call from the Signalling Fault Control, Swindon, reporting the collision. He couldn't recall the exact message but had the impression that it was about a mile in from the Bristol end of the Tunnel.

124 Meanwhile Mr Croke had phoned Mr Cantle, to let him know the fault had been remedied. On finishing his conversation with Fault Control Mr Daniel took over the other phone from Mr Croke to report the collision to Mr Cantle. While waiting for Mr Cantle to get to STJ, he and the PTOs went over what they had done that morning.

125 Mr Croke said "I have the fuse here" and produced it from his pocket. Mr Daniel didn't see him take it into his possession, but he recalled the PTOs having a discussion about fuses in the car on the way back from the lineside visit. They were concerned that there were no spare fuses. Mr Daniel took it that Mr Croke was simply keeping the fuse safe so that it didn't get lost.

126 When Mr Croke produced the fuse they were in the messroom, some distance away from the evaluator. Mr Daniel didn't think anyone could have returned to the axle counter in between receiving the news of the incident and his conversation with Mr Croke. He said they were all in a state of shock after hearing of the incident and he could not precisely recall the subsequent course of events. Nor could he remember how much time elapsed between Mr Croke's observation of the in-count and the phone message reporting the failure of the tell-tale.

127 Mr Daniel recalled that there was a failure of the Up axle counter on Saturday, 7 December, just after his arrival at STJ at 09.00. He thought it was Mr Waters who rang the Signalman to ascertain whether the line was clear, and that there was a further call to let the Signalman know that the axle counter had been re-set. These calls should be recorded on the Relay Room log books.

128 *Mr David Richard Croke*, PTO Technical Support, Newport area, told the Inquiry he is responsible for technical back-up on fault finding and testing of signalling systems, and for routine servicing of axle counters and TDM systems. He attended two one-day courses on axle counters in 1987, while still a TO, and had been a PTO for about two years. The courses covered basically how the system works, but not the electronics internal to the equipment. He used the notes provided on the course when servicing or doing any other work on axle counters. He had no special instructions about the ST axle counters but a manual is available in the Newport office and he thought there might be one at the STJ Relay Room.

129 On the morning of Thursday 5 December, with the assistance of the Severn Tunnel technicians, he located the TDM fault by testing and put it right by changing a card - it had nothing to do with the axle counter. At about 2 o'clock there was another fault, which he was unable to correct. At 5 o'clock he decided to disconnect STE interlocking: this meant that the other two interlockings could work correctly and through routes working would have to be implemented in the STE interlocking area which included the Tunnel. This should have no effect on the functioning of the axle counter which is completely divorced from the TDM.

130 Mr Croke said he was on leave on the Friday. He confirmed that Mr Daniel phoned him in the evening to say that Mr Andrews would be coming out with the spare amplifier on Saturday morning. As STJ is in his area, Mr Croke agreed to come and attend to the fault. Mr Daniel was there to direct the staff but correcting the fault was Croke's responsibility.

131 On arrival at 09.00 he went to the evaluator with Mr Daniel and Mr Andrews, who removed the fuse from the WDH card and placed it on top of the evaluator. Removal of the fuse was normal practice for servicing or for any job that looked like being a long one. The perspex cover was on the evaluator and the cover was closed on the reset plunger but not secured by a screw. Mr Croke used the evaluator to demonstrate that two indicator lights were lit, showing that the last count was in (G10) and that the voltage levels were out of tolerance (G11). There was a count-in reading of 81: this odd number was "a ridiculous amount", from which he took it that the problem was with the count out.

132 By using a meter on the count-out test points it was established that the required voltage (5 V) was not being received from the lineside amplifier and could not be achieved by adjustment at the evaluator. A test was also made at the lightning protector on the outgoing supply which confirmed that 60 V was being supplied at that point. Mr Croke agreed that this was not the last item of equipment on the Relay Room power supply system, but he pointed out that the voltage tests on both the evaluator and the lightning protector confirmed the previous day's assumption that that fault was at the lineside. Once he had 60 V on the lightning protector he assumed it was going on to site. He had never seen a manual laying down a fault-finding procedure and he relied on his knowledge and experience.

133 Mr Croke confirmed Mr Daniel's account of the visit to the Welsh end of the Tunnel. He said that Mr Andrews checked the amplifier and reported no voltage there, while he opened the location cupboard and checked the incoming supply, with the same result. On their way back to STJ in the car he remarked to Mr Andrews that he could have tested the wrong lightning protector, and there might be a blown fuse. Mr Andrews replied that he hoped not, because they had no replacements. Mr Croke said it was this that made him decide to put the evaluator fuse in his pocket for safe keeping. He didn't mention it to anyone else at the time, but as soon as they got back to the Relay Room he went to the evaluator and having checked that the other fuses were in order he picked up the WDH fuse and put it in the zip pocket of his trousers.

134 Mr Andrews went to check the voltage output at the rear of the evaluator while Mr Croke went to re-test the lightning protectors. While he was doing this Mr Daniel called from the MDF that there were some links out. They confirmed that the links were missing from the axle counter leads and used two spare fuse links as temporary replacements while a search was made for the correct line links.

135 Mr Croke said that having found the problem he asked Mr Andrews to replace the back cover on the evaluator. He himself went to the front and pressed the "T1" button with the intention of clearing the in-count of 81. The count cleared but he did not recall hearing any relays operating. A new in-count began almost immediately. His first thought was that this was a malfunction, but when the count stopped at eight he concluded that it must be a Sprinter entering the Tunnel, so he decided to wait and see if it counted out normally on leaving the Tunnel. He described the in-count as normal.

136 The next thing Mr Croke could recall was someone calling out that the tell-tale wire had broken. He assumed that this was another sporadic failure of the tell-tale and that the Sprinter would be held up at the Tunnel emergency signal until the fault could be put right. So he told Mr Waters, who by this time had found some spare line links, to put them in place at the MDF. He then decided to phone Mr Cantle and let him know that the job should be finished by 2 o'clock and no further handsignalling would be needed. While he was speaking to Mr Cantle on the messroom phone, Mr Daniel came in saying there had been an incident in the Tunnel, and took the phone from him to let Mr Cantle know.

137 Mr Andrews had also come into the messroom and on hearing Mr Daniel's report of the incident they began to consider whether it might have been caused by anything they had done. Mr Croke said that at this point he produced the WDH fuse from his pocket and showed it to the others, saying that there was nothing they could have done to cause it, because they had the fuse.

138 Mr Croke was unable to recall the precise timing of events on the Saturday morning but he accepted a suggestion that they could have got back to the Relay Room, after the lineside tests, some time between 10.10 and the time of the collision. He thought he waited in front of the evaluator for about four minutes at most for the train to go through before he became aware of the tell-tale failure.

139 After the phone conversation with Mr Cantle from the messroom Mr Croke did not go back into the Relay Room. He was asked to start some preliminary testing but declined to do so on the grounds that somebody independent should do it. He did however agree to have the information on the evaluator preserved and the covers screwed back in place to prevent interference, and he instructed Mr Waters to do this.

140 At the request of the Inquiry Mr Croke undertook two demonstrations of the way in which he cleared the count of 81 from the evaluator on the morning of the accident. He said he was under the impression that the black button (T1 on the FRM KTR card) would eliminate an unwanted count, but he could not reproduce this in demonstrations. On the first occasion, pressing T1 failed to remove a simulated in-count but it was cleared by subsequently pressing the green re-set button.

On the second, an in-count of 81 was simulated, the re-set button was pressed first with no effect, then T1, which left the count showing but converted it to an out-count as indicated by the count-in light (G10) going out and the count-out (G1) coming on; finally the re-set was pressed again, clearing the count and lighting the green track-clear (G3). The demonstration lineside signal remained at Danger and Mr Croke explained that this was because the fuse was out.

141 He was firm in his evidence on three points:

(a) that on the morning of the accident he succeeded in clearing the count of 81 by pressing the black button T1 only;

(b) that he had the WDH fuse in his pocket at the time;

(c) that he made no attempt to re-set the axle counter or to restore it to the Signalman.

He did however agree that the re-setting of the Up axle counter on the morning of the accident was not recorded in the Relay Room notebook, due to an oversight.

142 *Mr Stephen Andrews*, PTO stationed at Cardiff, told the Inquiry he had been involved in S&T work on the railway since 1975 and had been a PTO for about two years. His responsibilities included the maintenance of eight axle counters in the Cardiff area. He had attended two one-day courses on axle counters in 1986 or 1987 and had the course notes and other relevant instructions.

143 Mr Andrews confirmed that in response to a call from Mr Daniel on the Friday evening, he went to STJ with some spares on Saturday 7 December, arriving at the Relay Room with Mr Daniel and Mr Croke at about 09.00. He had not been involved with any of the work carried out there earlier in the week. He went straight to the evaluator and could see from the indications on the front that it had failed, although he couldn't remember precisely what they were. There was a number on the counter but again he couldn't recall it. The large green light was out; he couldn't remember where the cover for the re-set button was. He demonstrated how he had removed the WDH fuse and placed it on top of the evaluator, explaining that this was to isolate the axle counter from the signalling system so that they could do as they wished with it.

144 In all significant details Mr Andrews' account of subsequent events confirmed the evidence of Mr Daniel and Mr Croke. He could not be precise about timings but thought it probably took ten minutes by car from STJ to the Welsh end of the Tunnel. He confirmed having removed the cover from the lineside amplifier and that he established by testing that no voltage was present. He could not explain the working of the amplifier beyond saying that it is the equipment that feeds the detector heads and sends the information back to the evaluator. He agreed that on the way back to STJ they had discussed the need to look after the WDH fuse. He had spare fuses at Cardiff but did not think to bring any with him.

145 On returning to the Relay Room he removed the back cover from the evaluator and tested to find 60 V present. He didn't check that the WDH fuse was still safe where he had left it. On hearing about the missing line links he went to the MDF to see for himself - he thought it was a very unusual occurrence and possibly the cause of the fault. He took no part in the fitting of the temporary fuse links or the search for line links but not long afterwards he heard Mr Croke say that the temporary line fuses were in. He then returned to the back of the evaluator and started replacing the cover. He was virtually certain that he had not fouled any terminals at the back of the evaluator while removing or replacing the cover.

146 He heard Mr Croke say something about doing a re-set, and then that a count of eight had come straight in. Mr Andrews did not see what he was doing and didn't remember hearing any relays operating. He replied "Well, that's handy, we'll watch him". He went round to the front and they remarked on the time it seemed to be taking. Someone said that the tell-tale was down. He went to look at the tell-tale indicator in the Relay Room and saw that a break was indicated around the area of the Sudbrook shaft.

147 Mr Andrews said he heard something mentioned about there being two trains in the Tunnel. He confirmed that a discussion took place in the messroom during which Mr Croke produced the fuse from his pocket. He hadn't seen the fuse since he left it on top of the evaluator.

148 After the incident Mr Andrews was asked by the Assistant Area S&T Engineer, Mr Inskip, to go and test the Signal Post Telephone at N164. When he got there the signal was at red. Shortly after returning to STJ he was asked to accompany Mr Inskip into the Tunnel via the Sudbrook shaft. By the time they got there the first part of the HST had been taken away.

149 Mr Andrews confirmed that the Up axle counter had been re-set that morning, before they set out on the lineside visit. He recalled someone telephoning the Signalman but couldn't give precise details.

150 *Mr Raymond James Waters*, an Engineering Technician stationed at STJ, was leader of a gang of three technicians who were called out to give any assistance that might be required on Saturday 7 December. He had no special expertise on axle

counters but he was at the Relay Room from 06.30 until after the incident and his evidence as to the course of events confirmed that of Messrs Daniel, Croke and Andrews. He estimated that they were away at the lineside for 20 to 30 minutes but could not recall precisely what time they returned.

151 Some time after they came back he was returning from the messroom when he heard Mr Croke, who was at the MDF, say something about links being out. He was asked to find some links to put in and made a search in the store and messroom. During the search he went back into the Relay Room, where he noticed that the tell-tale indicator light was on in ZM section, in the area of the shaft. The phone rang and he took a message from Newport that the tell-tale was down. He asked one of his team to phone Mr Sperring, who was on call, to deal with the failure. Then someone found some links and he was asked by Mr Croke to put them in place of the fused links which had been put in earlier. Having done this he was asked to label up the leads on the MDF from which the links had been removed. He found some labels and was writing them out when he heard about the incident.

152 After he had done the labelling he was instructed to screw the cover in place on the re-set button of the evaluator, and did so. He played no further part in the activities in the Relay Room and went home towards 1 o'clock. Later in the day he and another technician were called out to repair the tell-tale wire in the presence of a policeman.

153 Mr Waters could not help the Inquiry as to the whereabouts of the WDH fuse during the morning but he confirmed having phoned the Signalman to seek permission to re-set the Up axle counter. He said that he frequently had to phone the Signal Box in the course of his duties and always began by giving his name and function. He was quite sure he had done so on this occasion. The Signalman gave the go-ahead to re-set - Mr Waters couldn't recall his exact words. He didn't do the re-set himself but had done so on other occasions. He demonstrated on the evaluator how he would do it, by unscrewing the cover and pressing the re-set button, with the consent of the Signalman.

154 *Mr Philip Inskip* was the Assistant Area S&T Engineer, Newport. He told the Inquiry that on Saturday, 7 December, while on leave at home, he heard about the accident on the mid-day radio news. He immediately tried to get in touch with colleagues, without success, but then received a call from Mr Schofield asking him to go to STJ Relay Room, make sure none of the equipment was interfered with and undertake any tests or interviews that might be required.

155 He arrived at STJ at 12.30 to find about eight people in the messroom and adjacent corridor. He went straight into the Relay Room, which as far as he could recall was unoccupied, to telephone Richard McCulloch, a Signal Maintenance Engineer who was acting as co-ordinating officer in the Area office. Mr McCulloch asked him to have the SPT at N164 tested and to ask Mr Croke about the speed of the in-count of eight axles that he had observed. Otherwise everything was to be left until independent testing had been organised.

156 Mr Inskip spoke to Mr Croke, who told him the speed of the in-count was normal. Mr Croke also gave him an account of what he had been doing and brought the fuse out of his pocket to show him. Mr Inskip got Mr Cantle to arrange for the SPT to be tested and to help him list the names of everyone present. Then he went back to the Relay Room to make a note of the lights displayed on the axle counter equipment. Mr Inskip explained that although he had no detailed technical knowledge of it, he was reasonably familiar with the system. He had attended the one-day appreciation course and was aware of the importance of recording what the individual lights showed.

157 The indications he noted were:

FRM KTR:	both lights lit (G10 & 11)
KTR:	lower two lit (G25 & 27)
ZIANZG:	count of 23, upper red lit (G2)

He didn't check the WDH fuse and didn't note at the time the condition of the relays, or whether the covers were in place. He was reasonably certain that the green light by the re-set button was out. He had been told that an emergency train had entered the Tunnel before he checked the axle counter at 13.13, and he assumed that this had caused 15 axles to be added to the count.

158 Mr Inskip said he next looked at the log book for the Down axle counter: there was no entry for that day and he signed to record that he had seen the book. Then he asked Messrs Cantle, Daniel and Croke to write down their recollections of what had taken place. He explained that they appeared to be in a state of shock - particularly Mr Croke. He felt they should be given something to do - it was "a fairly stressful situation just hanging about waiting for something to happen".

159 Following Mr Schofield's arrival Mr Inskip was asked to go into the Tunnel and check the damage to S&T equipment. Accompanied by Mr Andrews and a lookout man he descended the Sudbrook shaft and walked along the Down road towards Newport, examining the cables and other signalling equipment. The emergency signal was lit. They went as far as the ZM location cupboard where they found the tell-tale relay de-energised, signifying that the wire had been broken somewhere between where they were and the shaft. Then they walked back to the shaft. They found no damage to signalling equipment.

As to the testing of equipment after the accident

160 *Mr Robert Leslie Wilkinson*, S&T Engineer, InterCity Great Western, gave a description, with the aid of diagrams, of the S&T organisation at the time of the accident, the technical investigations undertaken thereafter and the signalling equipment and systems in the Tunnel area.

161 As to the organisation, Mr Wilkinson explained that he has three out-based area S&T organisations, one of which, at Newport, has responsibility for maintenance and rectifying faults ('faulting') in the Severn Tunnel area. To conduct independent tests following the accident he brought in Mr Peter Day from the Bristol area S&T organisation. Other independent experts were brought in from the BR Board and its Signalling Design Group and Technical Investigation Centre (TIC) at Reading.

162 Mr Wilkinson told the Inquiry that the Board's technical investigations revolved around the question of whether it was possible for Signal N164 to have falsely shown a green aspect. He agreed that wrong-side failures of signalling equipment (WSF) are known to occur, and he accepted that very occasionally the cause of an apparent wrong-side failure could not be determined even after exhaustive testing of the equipment, both on and off site. He accepted that one reason for this could be that the apparent failure was due to an intermittent fault which testing had failed to reproduce. Mr Wilkinson was only aware of one or two unexplained WSFs. He emphasised that in the absence of a satisfactory explanation, monitoring of the equipment would continue, and protective measures would be taken to ensure that if the failure occurred again, it could not impair safety. He said that monitoring was still going on as part of the BR inquiry into this accident.

163 Mr Wilkinson enlarged further on the description of the signalling system given by Mr Hancock. Referring to the AWS system he said it is possible to conceive of a WSF occurring somewhere between the controlling relays and the signal which would cause the signal to display a false aspect while the AWS continued to work correctly.

164 He explained the function of the signal interlocking: to check that any route called by the signalman is capable of being selected safely, and then to set the points and clear the signals accordingly. The interlocking in the Tunnel area is by electro-mechanical relays. It is not electronic but makes use of electronic equipment in the remote control equipment or TDM which enables a large number of signalling messages to be transmitted between the signal box and the Relay Rooms over two pairs of wires. As the TDM is not a fail-safe device and could corrupt the signalman's message, the interlocking equipment is located close to the equipment being controlled, and will check each message before acting upon it. There are cable connections between STJ and STE Relay Rooms (at opposite ends of the Tunnel) and between STE and Signal N164. These cables carry vital information for the control of the signal.

165 Each Relay Room can be independently isolated from the TDM. On Thursday, 5 December, STE was isolated from the TDM and put into through routes due to the failure of the TDM.

166 Mr Wilkinson confirmed that for Signal N164 to show green when called by the signalman (or automatically, during through routes working), the track ahead must be clear up to and including the overlap beyond the following signal, N168. This includes the axle counter section. Any points in the track ahead must be proved correctly set and locked, there must be no opposing or conflicting routes set, the signal ahead must be proved lit and the tell-tale wire must be intact. All these conditions can be checked by the STE interlocking, drawing information as required from STJ by the cable connection.

167 Referring to the 38 Tunnel emergency telephones, Mr Wilkinson explained that while normally connected to the Newport Signal Box, they can be switched through to the Control Room at Sudbrook Pumping Station in an emergency. Failure of the phones following the accident was due to the switch through to Sudbrook not working properly.

168 As to the panel indications at Newport Signal Box, Mr Wilkinson explained that if the signalman has set a route, the train's description will step forward to the next signal berth as the train moves and occupies the next track circuit. If the track circuit shows occupied but the train description does not step forward, it would suggest that the signal has been passed at danger, or possibly a WSF. Mr Wilkinson accepted that the provision of an automatic alarm in the signal box, to give prompt advice of such an irregularity to the signalman, might be helpful in avoiding an accident. At the time of the accident there were no indications on the panel of the positions of trains, and the train describer was inoperative.
Mr Wilkinson said this was not due to the adoption of through routes working but to the TDM failure which had led to the introduction of through routes.

169 Mr Wilkinson described the training arrangements for S&T technicians. He said that trainee technicians are required to have reasonable GCSE grades on recruitment. Having joined the railway they are given training both on and off the job. Off-the-job training takes place at regional training establishments (for intermediate technical training on S&T systems) and at the national technical school at Derby (for the more

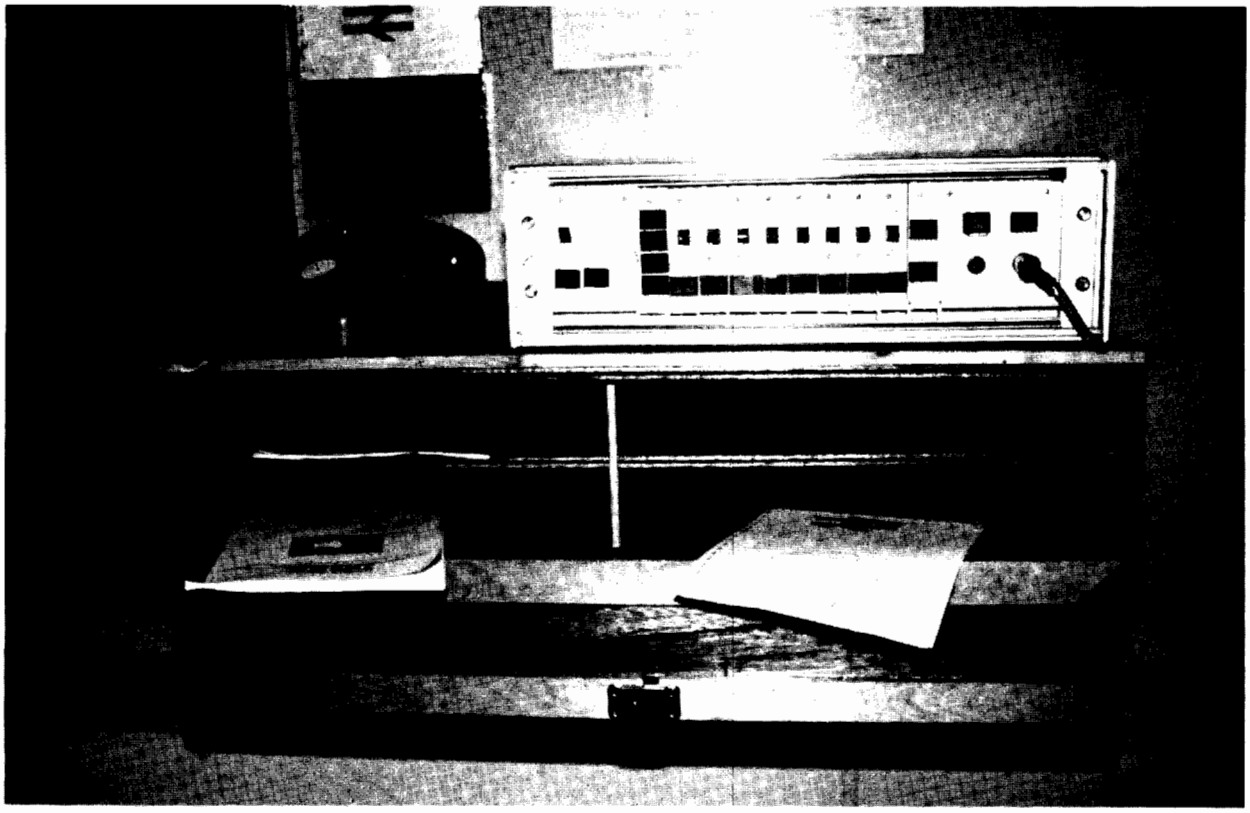


Figure 8 Sudbrook telephone concentrator - general view (photograph courtesy of J Harrison)

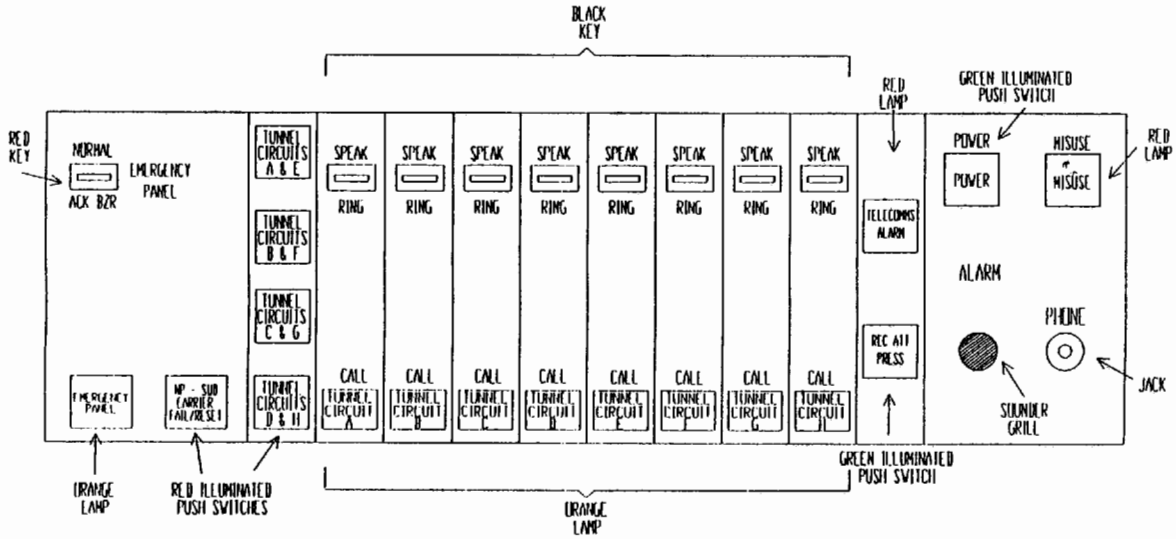


Figure 9 Sudbrook telephone concentrator - detailed diagram (courtesy of BRB)

sophisticated technical training). Area training schools have recently been established, concentrating mainly on lineside safety training. Mr Wilkinson thought that the average amount of off-the-job training for S&T technicians is about five days a year - a figure he would like to see increased.

170 *Mr Peter Day*, a Maintenance Support Engineer based at Bristol, told the Inquiry he had worked for the railway since 1973 and his present duties include testing, commissioning and maintenance of signalling. He had been involved in testing following signalling incidents. On the day of the accident he was asked to undertake independent testing of the signalling equipment concerned. He had worked on axle counters in the Bristol area since 1988 but had not been involved with those in the Tunnel.

171 Mr Day gave detailed evidence of the tests carried out under his direction, their results and the conclusions drawn. He explained that as the accident happened during a failure of the TDM linking Newport with the signalling on the ground, he did not consider it necessary to test equipment in the signal box. He was concerned with all the circuits affecting Signal N164, not only in the STJ and STE interlockings but also those enabling the signals in rear to display appropriate aspects in relation to N164. His principal conclusion was that in-situ testing disclosed "nothing whatsoever that would cause N164 to display anything other than red with a train in the Tunnel."

172 Testing was in two stages: first to note positions of relays and to note voltages without disturbing anything following the incident, then to recreate the circumstances at the time of the incident as accurately as possible and carry out specific tests.

173 Mr Day said he was informed of the incident at about 12.30 and having succeeded in assembling an initial technical support team he made his way to STJ Relay Room. Those who had been there at the time of the incident gave him some briefing about the events leading up to it, and he was able to produce a draft testing plan.

174 Mr Day himself observed the condition of the axle counter. The perspex cover was on, the green re-set button had its cover screwed on and relays TZR, TSR & TPR were all 'down' (de-energised). The other indications were as noted by Mr Inskip, with two exceptions:

(a) LED lights G10 & 11 were both out, indicating that the last train count had been 'out' and that the incoming signal voltage was within tolerance;

(b) the counter indicated 484, which tallied with the information subsequently supplied to Mr Day about train movements from the collision onwards.

175 Mr Day reminded the Inquiry that the absence of the WDH fuse has no bearing on the counting ability of the axle counter. The fuse is to do solely with the connection between the counter and the signalling.

176 A member of Mr Day's team, Mr Scarisbrick, was sent to STE and he was asked to check:

(a) relay 164DR which when energised controls Signal N164 to green - this was reported down;

(b) track repeat relay Z Down TPR, at the end of the through circuit from the axle counter - this was also down, indicating that 164DR could not be energised;

(c) the voltage leaving the Relay Room for the signal head - no voltage measured, indicating that the signal was at red, as subsequently confirmed by Mr Andrews' visual check.

177 Mr Scarisbrick was also asked to do a wire count of relay 164 and to check for any form of tampering with signalling equipment that might have occurred. He reported that the wiring was entirely correct to design diagrams and no additional wires had been provided. There were no signs of tampering.

178 Meanwhile at STJ Mr Day was endeavouring to find a complete set of wiring diagrams for the installation. Some time was wasted because there was more than one copy of some drawings on site, particularly appertaining to the circuit for Z DN TPR. He was concerned to find that the records on site were not accurate - there were two minor discrepancies which caused time to be lost, although they were of no consequence in relation to the accident. The outgoing feed for Z DN TPR from the axle counter was wire-counted and circuit tested and found in order.

179 Mr Day said that by the Saturday evening he had formed the perception that at the time of the incident the only thing that would have been holding N164 at Danger was the axle counter itself. When the counter was occupied they found there was zero voltage leaving on the cores allocated to Z DN TPR in the through circuit cable to STE. The cores were Nos 31 and 32 of a 37-core cable. The test was repeated several times, and no voltage found.

180 Mr Day arranged for the tell-tale wire to be repaired in readiness for the re-creation tests which he hoped to conduct early on Sunday morning. He also asked for the earth-free signalling power supplies to be checked, both at STE and STJ. This led to the discovery that the two unique supplies were not only out of tolerance but were effectively in contact. He reiterated that notwithstanding this, no background voltage was found at any time on the Z DN TPR circuit. Nevertheless

he decided to test the insulation of the through circuit cable. This was done by disconnecting the cable at each end and applying a voltage of 50: lower than the normal testing voltage in order to avoid disturbing or altering the condition of the cable. Mr Day confirmed that when the cable was re-connected after the test the faults found earlier had indeed not been disturbed.

181 Measuring the resistance of the insulation at 50 V confirmed that there were both core-to-earth and core-to-core faults within the cable through the Tunnel. However, both cores 31 and 32 were found to have a satisfactory insulation resistance of 20 megohms to earth and 20 megohms core-to-core. No fault was found which could have allowed a stray voltage to get into either of these cores and thereby falsely energise the Z DN TPR.

182 During the investigation it was found that one relay on the same circuit (AA TPR, a track circuit repeat relay) was of the type known as 'black base' which can suffer from silver migration: a condition which can create a conducting path between adjacent contacts or between contacts that are normally separated when the relay is de-energised. This was the only relay base of its kind in the entire circuitry for N164. There was no visible indication of silver migration on any of the surfaces of this relay, nor any evidence of background voltage on any of the many occasions when the actual voltage across Z DN TPR was measured.

183 Mr Day said that all the tests undertaken were recorded by BTP officers present, both at STJ and (once an officer was provided there) at STE. The Relay Rooms and Signal N164 were sealed overnight to prevent tampering, and on Sunday morning he had a team numbering about 20 people assembled to assist with the the re-creation tests. Some were deployed to watch the signal and the relays at STE, others were at STJ.

184 From its position after the collision it was assumed that the HST had reached the axle counter section by the time the Sprinter reached N164 and that, as already surmised, it was only the axle counter that was then holding the signal at Danger. With the tell-tale wire repaired and all relays in the condition they were believed to have been in at the time of the accident, Mr Day again checked the indications on the axle counter. The count had changed to 472, again correlating with train movements. The last count had been out of the section and voltage was within tolerance, so that the machine should be capable of re-setting. Mr Day said he carried out a specific sequence of actions:

(a) press black T1 button - no effect, N164 remained at Danger and count at 472;

(b) press green re-set button - count disappeared but signal remained at Danger, Relays TPR at STJ and Z DN TPR at STE remained de-energised and no voltage measured;

(c) replace WDH fuse and press T1 - no effect anywhere in the system;

(d) press green button - counter re-set, Relay TPR energised, followed by Z DN TPR, and signal showed green;

(e) remove WDH fuse - TPR dropped and signal replaced to red.

185 Following the re-creation tests, the axle counter was again isolated from the signalling and further tests carried out on individual components of the system. The TDM was brought back to its normal state. The aspect sequence of the signals in rear of N164 (B118 and DT7, including the AWS) was tested by Bristol staff and found to be in order. The tail cables between STE and the signal head were well within standards, a sighting test confirmed that the visibility of the signal was exceptionally good. A functional test of N164 was carried out by Mr Brookes (now testing engineer for InterCity Great Western) and no error found, all controls were present as required.

186 Routine tests on the axle counter were satisfactorily completed by Mr Napper who found that the counter could not clear when the conditions were not correct for it to do so. Mr Napper also dealt with a problem of voltage out-of-tolerance. Mr Day said he also took the opportunity to fit disconnection links in the signalling circuitry between the axle counter and the TPR - a standard feature on the later models of counter used in his own area. He was not aware of any axle counters in his area which could be re-set by the signalman.

187 On Sunday night an additional team tested the 37-core cable through the Tunnel. Mr Day explained that it is made up of several cables joined end-to-end. A fault had already been put right at location Y27, the first termination point between STJ and the Welsh end of the Tunnel. On testing, a further fault was found between locations Y27 and Y21, at the Welsh portal. After a section of cable had been removed and a new section jointed in, the cable was again tested throughout and found to be within standards.

188 Mr Day told the Inquiry that following completion of the re-creation tests and the restoration of the signalling to normal (which took place on Monday 9 December) the performance of the through circuit cable was monitored. On 10 January 1992 he learned that this had revealed inconsistencies which indicated a deterioration in the condition of the cable since 9 December. Voltages were appearing across the Z DN TPR circuit but not matched by events on the event recorder, and the recorder

showed one occasion when the relay was energised irregularly.

189 On investigation it was established that the irregular energisation was due to a fault investigation undertaken by S&T staff at a time when no trains were running: it was not a wrong-side signalling failure. The stray voltages were too small to be significant but had been magnified by incorrect setting of a voltage recorder. The cable was judged to be within acceptable standards. Nevertheless it was removed for further investigation, which confirmed that deterioration had occurred at the English end of the Tunnel, between location Y4 and STE interlocking.

190 Mr Day said that the Z DN TPR circuit was "double cut", so that a false energisation could only occur if a fault occurred simultaneously on both the negative and positive conductors. He accepted the possibility that an intermittent fault might have escaped detection but re-affirmed that he had found no reason for Signal N164 to have displayed anything other than red.

191 *Mr Philip James Fortey*, Technical Investigation Engineer in charge of the BR Technical Investigation Centre at Reading, told the Inquiry he had a degree in electrical engineering and had worked at the TIC since 1979 on the investigation of equipment and systems following failures. He said that the TIC is independent from regional or business engineers - at the time of the accident it was part of the Director of S&T Engineering's organisation, and now belonged to BR Central Services. In 1991 the TIC was asked to take part in some 250 investigations including the Severn Tunnel accident, which was the first incident in his experience specifically involving an axle counter.

192 Mr Fortey said he was first called in just before midnight on 7 December when he had a message to call Peter Day. Mr Day explained that testing of the 37-core cable between STJ and STE had indicated serious faults, and Mr Fortey agreed to visit the site as soon as possible. He reached STJ soon after noon on Sunday. Mr Day showed him the record charts prepared by his staff, which indicated a very serious fault: apparently a short circuit between cores 30 and 33 and a number of other cores in which the resistance to earth was lower than expected.

193 Mr Fortey described in detail the tests carried out on the cable in situ and subsequently on sections of the cable which had been removed to the TIC. He concluded that there was no fault in the various cables composing the entire 37-core link between STJ and STE that could cause the false energisation of the ZDN TPR relay "by external means". (A fuller account of Mr Fortey's evidence as to the cable tests appears in Appendix 1.)

194 He went on to describe the testing of a number of other items taken to the TIC: five individual relays; one black phenolic relay plug-board; the head of Signal N164 and the Down axle counter evaluator from STJ, some of which were produced as visual aids for the Inquiry.

195 The five relays were:

TCG TPR ex STJ
CGT ZR ex STJ
Z DN TPR ex STE
N164 DR ex STE
CD DN ULSJR ex STE

The most significant was Z DN TPR which had been manufactured in 1989 and was found to be in perfect working order. The contact pressures were slightly below the specified value but this was to be expected from use. All contacts had adequate wipe.

196 The black phenolic plug-board belonged to relay AA TPR and was the only one of its kind in the immediate circuitry controlling Signal N164. Mr Fortey explained the significance of this type of plug-board: under adverse circumstances silver can migrate from the silver-plated relay connectors, which in turn can lead to breakdown of the phenol formaldehyde resin, producing a path of carbon which can give a relatively low-resistance leakage path. This process leaves an unmistakeable track of white deposit on the plug-board which is easy to identify under laboratory lighting conditions with magnification. This plug-board showed no such evidence and when tested up to 1000 V produced no evidence of a leakage problem. Mr Fortey concluded that silver migration had no part to play in the apparatus immediately connected with the accident.

197 The head of Signal N164 was tested in the TIC. No fault was found which could have caused or contributed to an irregular display of a green aspect or to the extinguishment of any aspect. There was however an installation error: the 'hot strip' segments of the lenses, which are intended to improve short-range visibility, had not been adjusted to suit the position of the signal head immediately above the track to which it applied.

198 As to the axle counter evaluator, Mr Fortey said he undertook a visual examination of its condition in situ, in particular to determine whether the green reset plunger could have performed a reset, due to a breakdown of the electrical equipment lying behind it, without being manually operated. No fault was found which could have caused this to happen. There was no stickiness of the mechanism, and subsequent dismantling at the TIC produced no evidence of welding of the switch contacts that could have allowed an earlier reset to be retained.

199 The removal of the evaluator to the TIC was carried out under BTP supervision, and a video recording made. The recovery of the evaluator went without incident except that when the evaluator was lifted, a foreign body was heard to be loose within the apparatus. On arrival at the TIC it was removed from its sealed bag, and a 2BA plated brass nut was found inside the bag. Mr Fortey said that the axle counter manufacturers had been consulted as to whether such a nut - about a quarter of an inch in diameter - could have caused any malfunction inside the rack. They replied that as the TSR relay is double-cut, a false feed on one output will not operate the relay, and most of the equipment is protected from external 'devices' by covers.

200 At the TIC, the manufacturers' seals were broken to allow further investigation and several 'features' were noted and photographed: a slightly bent terminal pillar, a wire with insulation partly melted due to the subsequent soldering of another wire, and one of the retaining screws, which had penetrated the back plate, resting against the main wiring harness. Tests showed that none of these features could have caused an unsafe condition. No physical damage was found which could have accounted for the accident.

201 The manufacturers were also consulted as to whether a reset could be achieved with the WDH fuse removed. They replied that the WDH fuse "is not designed to disconnect the ... equipment from the external circuitry, but investigation shows that it is not possible to operate the TSR ... relay using the external reset button with the fuse out."

202 Mr Fortey summarised the outcome of the TIC tests and investigations, and of discussions with the SEL engineers and with Mr Wallis, a ScotRail S&T engineer with considerable experience of axle counters, by saying that they had found "no possible reason why the axle counter could falsely energise the track circuit relay CG while the fuse was removed from the WDH card".

203 A separate investigation was undertaken, again with the assistance of Mr Wallis and the manufacturers, into the behaviour of indicator light G11 on the evaluator, which lights when the voltage at the detector heads is out of tolerance. Mr Fortey said that the detector heads are of complex construction and because of their position close to the running rail they are vulnerable to impact damage. It was thought that at the time of the incident the heads had internal cracking which would have made them more susceptible to intermittent failure and also probably temperature-sensitive.

204 Mr Fortey reminded the Inquiry of the evidence about the condition of G11 after the incident:

(a) soon after 13.00 on the Saturday Mr Inskip found it lit;

(b) at about 15.00 when Mr Day arrived it was out;

(c) at about 10.30 on Sunday Mr Napper found it lit;

(d) later on Sunday when Mr Day checked the indications he reported voltage within tolerance, ie G11 out.

205 Using records obtained from the Bristol Weather Centre, some 15 km away, it was possible to hypothesise that the head voltage had drifted out of tolerance as the temperature fell and returned to tolerance as it rose. This would not lead to automatic re-setting of the counter. It would have been possible, had a rise in temperature brought the voltage back within tolerance, for the count indicator to have been cleared by a train leaving the Tunnel. But there was no possibility that temperature variations could have caused the signal to change from red to green.

206 Finally Mr Fortey described the "stored re-set" function of the axle counter, which had also been discussed with Mr Wallis and the SEL engineers. If a re-set has been attempted but prevented by the voltage supervisory circuit (G11 lit), the re-set is stored for a pre-arranged period (47 seconds on this counter, as proved by testing). Should the voltage return to tolerance within this time, the stored re-set will take place without further intervention provided every other condition necessary for re-setting is met - including the presence of the fuse.

207 Mr Fortey agreed that he could not exclude the possibility of a wrong-side signalling failure. He accepted that if an on-train data recorder had been fitted to the Sprinter, it should have recorded the condition of the Automatic Warning System (AWS) track equipment when passed by the train. However, there might be a lack of correspondence between the state of the signal when the train passed the AWS magnet and when the train reached the signal; or even between the state of the AWS and of the signal itself. The same limitations might apply with Automatic Train Protection (ATP) when fitted.

208 The train-borne AWS equipment from the Sprinter had been tested at the Crewe TIC. The AWS cab indicator or 'sunflower' was not designed as a data recorder and could not be relied on to withstand the impact of a collision.

As to the rolling stock

209 *Mr John Stephen Barlass*, Sprinter Engineer, Regional Railways, told the Inquiry that after the accident he examined the Sprinter at Canton Depot, Cardiff, identified the areas that needed to be tested and arranged for the relevant specialist engineers to undertake those tests. Mr Barlass' detailed report was made available to the Inquiry.

210 He said that two fire extinguishers in the driving cab of the leading car (vehicle No 57306) were dislodged by the impact. They had been mounted on brackets fixed to the bulkhead behind the driver at about head height. They were flat-bottomed halon extinguishers and did not fit the brackets provided, which were intended for round-bottomed 'Firesnow' extinguishers. Mr Barlass had ascertained that the difficulty in procuring the right type of extinguisher had been under discussion by the Fire Technical Sub-Committee, composed of the fire officers of the then BR Regions, since August 1988 but he was not aware of the problem until after the accident. He agreed that Driver Carpenter's head injury might have been caused by the dislodgement of the 1.5 kg halon extinguisher on the driver's side.

211 The Sprinter's AWS equipment was examined at Canton on 11 December when it was working perfectly well. No fault could be found with it. The cab indicator showed a yellow and black aspect. The manufacturers of the equipment had assured Mr Barlass that it would be extremely unlikely for the indication to have been changed by the impact. He agreed that it could be inferred that the driver had acknowledged and cancelled a warning at the last signal.

212 The clasp brakes of the Sprinter were also tested at Canton: no fault could be found with the braking system. No flats were found on the wheels but this did not exclude the possibility that there had been emergency braking. From the structural damage to the train it had been concluded that the collision occurred at a closing speed of between 12 and 15 mile/h.

213 Several areas of damage to the interior fittings gave rise to concern, notably the fact that several table tops became completely displaced, leaving table legs exposed. Damage to the seats suggested that passengers facing backwards were thrown into the seat backs which had bent in absorbing some of the energy, while those facing forwards had been thrown into the backs of the seats in front: quite a lot of cracks had formed on the seat shelves. There had also been a problem with retention in position of the seat cushions on these units and Mr Barlass accepted that this might have caused people to slide forward when the impact occurred, ending up underneath the table in front of them. He said there was no evidence of defects in the interior installation and suggested that design improvements would lie in the direction of controlled collapse on impact, not increased rigidity.

214 *Mr William Ogden*, Senior Brakes and Systems Engineer, Regional Railways, told the Inquiry he had carried out brake tests on the Sprinter two days after the accident. The tests showed that the unit was in good order at the time. It was fitted with electro-pneumatic clasp brakes: cast iron brake blocks acting on the wheel

Figure 10 Interior of Sprinter showing displaced table (photograph courtesy of BRB)

treads. The brake controller in the driver's cab had three positions or steps. There was also an emergency braking position, to which the controller could be moved directly, although this did not provide additional braking power beyond step 3: full service braking.

215 Mr Ogden said the braking system was designed to fail to safety. The electrical feed to the controller runs the length of the train and the brakes are applied automatically in the event of any interruption to the supply, which would occur if the pressure in the main reservoir fell below a set limit, if any of the passenger communication switches were operated or in the unlikely event of the train parting at any point. Each brake reservoir contains an ample supply of air to apply the brake, protected by a check valve so that it cannot be lost to any other system.

216 Emergency braking is not instantaneous: full application takes about 2.5 seconds, known as the 'filling time'. Mr Ogden thought that people on the train would have sensed an emergency brake application but it would not have caused any problem to someone standing holding a child or seated drinking a cup of coffee.

217 Detailed studies had been undertaken to estimate the speed of the Sprinter before the collision, taking account of the estimated closing speed, the evidence about the timing and speeds of the two trains from Signal N164 to the point of impact, the acceleration and braking capacity of the Sprinter as influenced by gradient and aerodynamics within the Tunnel, and the probability that Driver Carpenter did not see the tail lights of the HST until he entered the curve. At this point the distance between the two trains would have been as little as 200 m. Mr Ogden's conclusion was that the Sprinter's speed at sighting the HST was "in the region of 60 mile/h". He pointed out that this was well within the Tunnel line speed.

218 Timing calculations clearly showed that if the Sprinter had been travelling more slowly, it could only have caught up with the HST where it did if the distance between them had been shorter when the Sprinter entered the Tunnel: in which event Driver Carpenter ought to have been able to see the tail lights ahead of him, or at least their reflection on the rail heads, before the HST disappeared round the curve. However, Mr Ogden acknowledged that these calculations were largely based on hypothesis: in particular he referred to the need for the Sprinter driver's eyes to adjust to the darkness of the Tunnel and the possibility of other lights in the Tunnel having detracted from the comparatively poor light of the tail lights, which might have been affected by smoke from the HST.

219 Mr Ogden agreed that if the Sprinter had been fitted with a data recorder it might have been possible to pin-point some of the uncertainties about speeds and timings, and that the accident might have been prevented if there had been some means of alerting the signalman to the fact that the Sprinter had passed Signal N164, in time for the Tunnel emergency signal to be put on.

As to the emergency response

220 *Miss Miranda Green*, a passenger on the HST, gave the Inquiry a detailed account of her experiences from notes she had written on the day after the accident. She said she was travelling from Didcot to Cardiff in the third coach from the front, sitting in a single seat with her back to the direction of travel and the window to her right. She couldn't see the lineside signals or anything of what was going on outside. The train was about 10 minutes late leaving both Didcot and Bristol Parkway. It stopped for 5 to 10 minutes outside the Tunnel and then went on slowly.

221 Miss Green said the impact occurred without warning, throwing her forward in her seat, ie towards the rear of the train. She hit her head on the facing seat but was not seriously hurt. The lights went out but came on again within a few seconds. She noticed that some of the light diffusers had fallen off and some jackets and coats had fallen off the overhead racks. There did not seem to be any serious injuries in that part of the train.

222 Miss Green was able to give a detailed account of the sequence of events from the moment of the impact until she and her sister arrived at Cardiff Station by coach some eight-and-a-half hours later. She recalled the appeal for doctors and nurses, some five minutes after the lights came on; an offer of cold drinks from the buffet, about 45 minutes later, and hot drinks after another half hour or so; and how the train became quite cold during the first hour, after which it warmed up and became "airless and stuffy".

223 Her timing of subsequent events was:

12.30: ES arrived from Gwent - firemen seen walking through and alongside the train from the front.

14.30: HST began to move out of Tunnel.

15.30: Arrival at STJ, where paramedics boarded the train to check the minor injuries and police to take particulars of the uninjured.

16.00: Passengers off train, waiting to board mini-buses; one passenger volunteered the use of a portable phone for contacting relatives.

16.20: Arrival at Caldicot Leisure Centre where tea and sandwiches were available; also one public telephone and subsequently an office phone, shared by public and police.

17.00: Miss Green and her sister boarded a coach for Cardiff, having failed to reach a telephone.

17.45: Coach arrived at Newport Station where some relatives had arrived to meet passengers; some delay while station manager identified these passengers on the coach. Coach then left for Cardiff.

224 Miss Green praised the calm and patience displayed by her fellow passengers, which lasted, she said, until the arrival at Newport when those who had still not succeeded in contacting their relatives "were not being so patient any more". She said that the train crew were "very helpful and reassuring" but she was critical of the lack of information at later stages of the emergency, of the air quality in the Tunnel, of the inadequate provision for getting in touch with relatives, and of the detour to the Leisure Centre "where things just seemed to get held up". She suggested that time might have been saved if passengers' particulars had been collected (as on the Sprinter) during the long wait in the Tunnel, and that injuries might have been avoided if there had been seat belts on the train.

225 *Mr Andrew Sperring* (see paragraph 97) described the course of events following his arrival at Sudbrook at about 11.10. Four or five members of the Rescue Team had assembled, including the captain, who asked him to

phone Newport and gather as much information as possible about the collision. He spoke to Signalman Morgan and established that the incident was at 14 miles 28 chains. Mr Sperring said he chalked the location on the incident board in the rescue centre.

226 Some of the ES personnel had already gone down in the lift, taking the components of the rescue trolley. By the time Mr Sperring got to the bottom, the motorised trolley had been assembled and placed on the Down line, but pointing towards Bristol. Mr Sperring said that he mentioned to one of the firemen that the incident was at the Welsh end, but the conditions were windy and noisy (because of the ventilation fan) and he was not sure whether he had been heard. Another team of firemen arrived, saying they were going to walk towards Bristol. Mr Sperring said he assumed that his information had been updated and as he was working under the control of the fire service, he didn't feel in a position to press his point with them.

227 The trolley was loaded with breathing apparatus and other equipment and Mr Sperring travelled with it to the Bristol end of the Tunnel. On the way they met two fireman who said they had walked in from the Bristol end and there was no collision there. The fireman in charge of the trolley nevertheless decided to go on to the Bristol end to find out what was going on. Mr Sperring said that on arrival they were passed a written message confirming that the incident was at 14 miles 28 chains. A train that had been commandeered from Bristol for rescue purposes then entered the Tunnel on the Up line and the trolley reversed back on the Down line.

228 Mr Sperring said he rendered what assistance he could at the scene until the HST moved out of the Tunnel. The Rescue Team then cleared up all the equipment they had taken down, dismantled the trolley and got everything back up the shaft. He said that as a member of the Rescue Team he was provided with a pager for emergency calls. On the day of the accident his pager failed, but this didn't affect him as he was called out to deal with the tell-tale wire. He agreed that the Rescue Centre at Sudbrook was on the other side of the Pumping Station from the main Control Room, where the fire officer in charge would be located under the major incident procedure. The Rescue Team had not practised response times.

229 *Mr Philip Hill*, a Technician Officer at Newport Signal Box and a member of the Tunnel Rescue Team, told the Inquiry he was working in the Chepstow area at 08.00 on the morning of the accident. After calling at STJ Relay Room at 08.30 he went on to Newport Panel and was on the operating floor there when the tell-tale alarm went off, just after 10.30. From the operating floor it was not possible to determine whereabouts the wire had been severed, but this would have been shown on an indicator downstairs, which would continue to show the section concerned even if the tell-tale resumed its normal state.

230 Mr Hill said he was standing alongside Signalman Morgan when the first two calls came in from the Tunnel. He thought it was after the second call that he heard the Signalman say there had been an incident at 14 miles 28 chains, which to him meant about half-a-mile on the Newport side of the shaft. He made two calls to the Relay Room, first to warn the technicians that they should not attend the tell-tale failure yet, since there was a train in the Tunnel and it might be a genuine alarm, and secondly, 5 to 10 minutes after the incident, to let Mr Daniel know he was going to attend the Rescue Team at Sudbrook.

231 By the time he reached Sudbrook it was about 11.50. About six members of the Rescue Team were present and he heard that the first team had gone towards the Bristol end. After some discussion he went down the shaft with a fire officer. They tried to recall the first team with a loud-hailer and when this proved unsuccessful they set off walking towards the Bristol end. They were met by the Bristol emergency train coming in on the Up road. They boarded the train and guided it to the incident.

232 Mr Hill agreed that the correct location of the incident had been communicated to Sudbrook by the time he got there. He didn't know that the rescuers had been directed to the Bristol end but on hearing this he confirmed his own information to the ES.

233 *Mr Anthony John Cheeseman*, Duty Operations Manager at Swindon Control, said he was on duty on the morning of the accident, in charge of 12 staff including three Area Controllers. The accident happened in Area 2 which starts half way between Swindon and Bristol and extends to Swansea and Taunton.

234 The accident was reported to him at 10.39 by the Area 2 Controller, Mr Ian House, who had heard from Newport Panel that the tell-tale wire had been severed at 10.35, followed by calls from a driver reporting "a terrific bang" and from the guard of the Sprinter to say there had been a collision and people were injured. Mr House told him the accident was at the Bristol end of the Tunnel: there was no mention of mileage at that stage.

235 Mr Cheeseman proceeded to call out the ES as requested by the Panel. In view of his information about the location he started with Avon ambulance, police and fire service, then BTP and finally Gwent ambulance and fire services. At about 11.15 the Avon fire service phoned him to ask for the exact mileage. Mr House was asked to check with the Panel. It was between 11.15 and 11.30 that Mr Cheeseman got to know the correct location. He could not recall whether the emergency

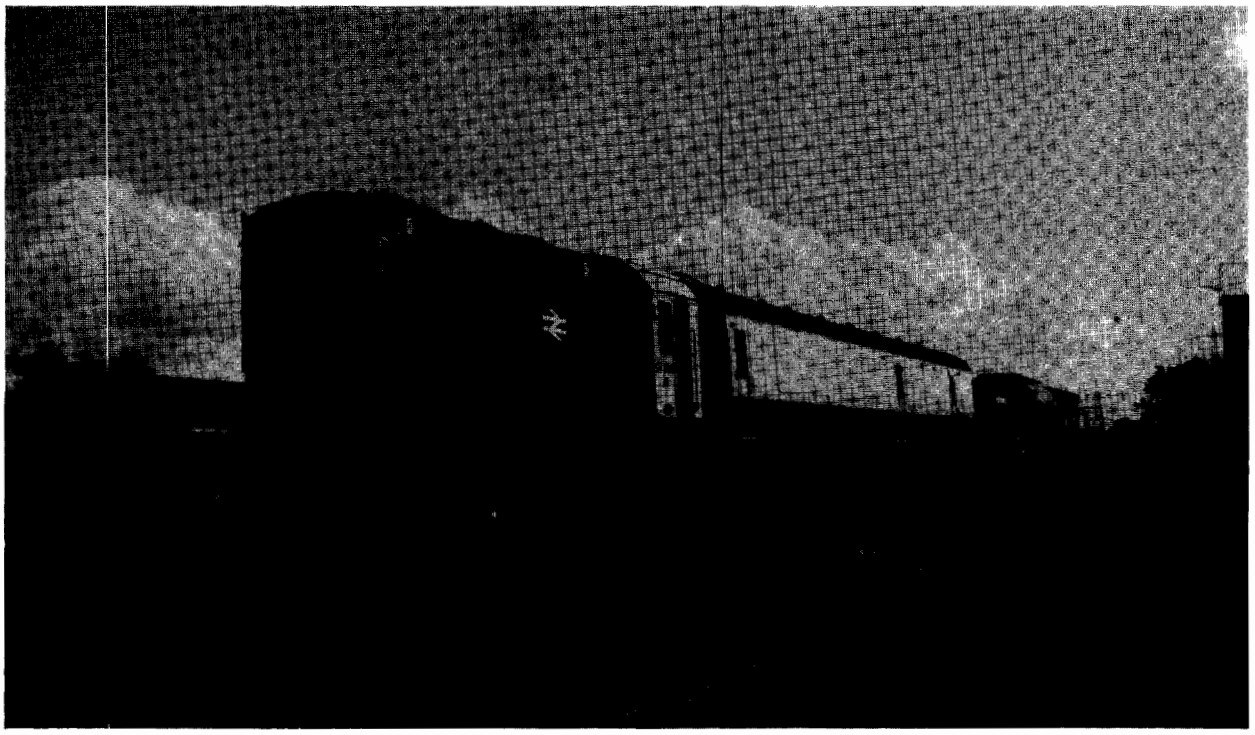


Figure 11 Sudbrook emergency train (photograph courtesy of Hansl Weichen)

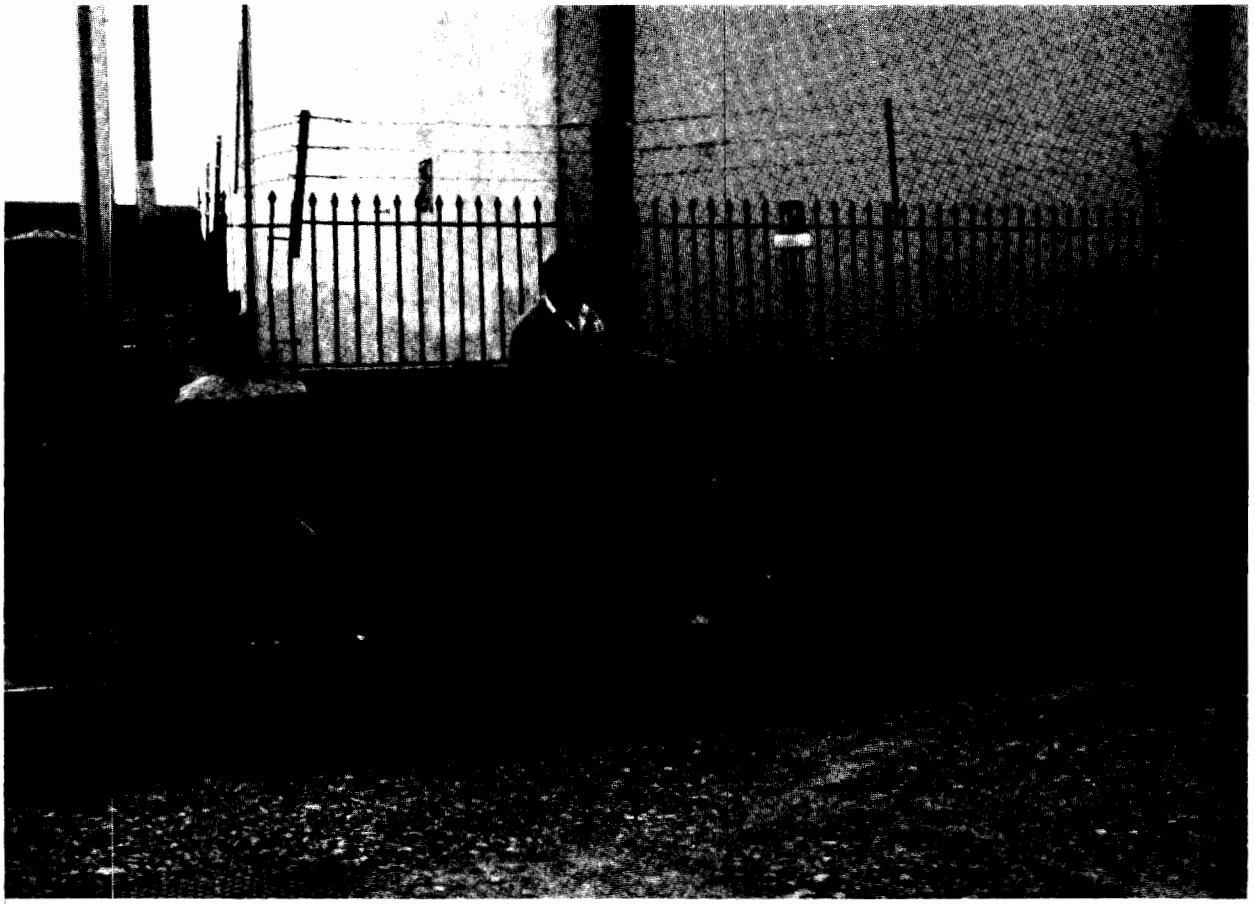


Figure 12 Sudbrook emergency trolley being test run in Sudbrook sidings (photograph courtesy of J Harrison)

instructions dealt with the importance of establishing the exact location.

236 *Mr John Dudley Buxton*, BR Project Director, Safety Planning, told the Inquiry he is a chartered civil engineer and in a previous post was responsible for the structural maintenance and safety of the Tunnel. He was appointed to his present post in December 1991, shortly after the accident.

237 With the aid of a video presentation Mr Buxton described the Severn Tunnel emergency trolley and train. The trolley is capable of speeds up to 30 mile/h and can tow two trailers. The emergency train was refurbished about five years ago to ES specifications. It has a dedicated locomotive and is manned by Sudbrook depot staff who take it down to the end of the Sudbrook branch line. A mainline crew then takes over: at STJ Station the ES load their equipment and the train is then propelled into the Tunnel. The loco and stretcher carriage can be detached so that casualties can be evacuated while the equipment vehicles and water tanker remain at the site of the incident.

238 On reaching STJ Station the casualties can be removed to a room on the ground floor of the Amenity Block, which also contains offices designated for ES use. Mr Buxton agreed that the reception room does not provide seats for survivors: under the Gwent County Council's Major Accident Procedure it is intended that survivors should be taken on to the Caldicot Leisure Centre, leaving the ground floor of the Amenity Block clear for stretcher cases. From the BR point of view it might be better to take survivors on by train to Newport Station where there is plenty of reception accommodation and numerous phone lines are available.

239 Mr Buxton said that the BR Incident Officer at STJ, Mr Robertson, had delegated his duties there on volunteering to act as Guard on the emergency train. The delay in leaving STJ was due to the need to locate the Sudbrook trolley before the Signalman could authorise the train to enter the Tunnel. There was a risk of collision between train and trolley. Mr Buxton accepted the need for a more flexible approach: BR was considering whether the emergency train could be got to the site of an incident more quickly, or whether other equipment might be used to speed up the system for getting to site.

240 Mr Buxton acknowledged that there was a misunderstanding about the exact location of the collision. He said the mileage was correctly established at an early stage and the delay in acting on the information was due to a failure to check the mileage figure against the Tunnel plan. BR had reviewed the initial communication system and the Tunnel emergency telephones would be provided with new markers to help prevent a similar problem arising in the future. Means of overcoming the problem of radio black-out in the Tunnel were being studied.

241 A new dedicated Command and Control Office (separate from the main Control Room) had been provided at Sudbrook for use by the ES, and over the next three years the pumping, ventilation and control systems would be renewed, and a larger lift provided. The provision of a recess for storing equipment at the bottom of the Sudbrook shaft, and of improved access to the track-side at both ends of the Tunnel was under consideration.

242 Acknowledging a recommendation by the Gwent Fire Brigade (GFB) that BR should prepare a Safety Case for the Tunnel, Mr Buxton said it had been concluded that the likelihood and consequences of potential major hazard needed to be reassessed, using predictive risk assessment techniques. This work was in hand: he expected it to assist greatly in prioritising expenditure on safety in the Tunnel. He pointed out that the safety record of the Tunnel is good, and though the consequences of an accident in the Tunnel can be serious, the risk has been reduced by special regulations which prevent the carriage of dangerous goods through the Tunnel at the same time as passenger trains. He acknowledged a distinction between taking preventive measures appropriate to the risk and providing for effective emergency response in the event that, notwithstanding the outcome of the risk assessment, something does go wrong.

243 Mr Buxton also acknowledged the value of emergency exercises. An exercise took place in September 1990 and another was planned for May 1991 but had to be cancelled due in part to the Gulf emergency and in part to the difficulty of closing the Tunnel to normal services at short notice. It had been agreed to update the procedures to reflect the actual experience gained from the accident, and further exercises were being planned for February 1993 and January 1994. BR intends to continue working with all the relevant agencies on both sides of the Tunnel on emergency planning and preparedness.

244 *Station Officer John Leslie Jenkins*, GFB, stationed at Caldicot, said that on 7 December while on duty in Chepstow he was informed about the accident by fire brigade control. He made his way straight to Sudbrook Pumping Station and arrived there at 10.56. A fire appliance from Caldicot was already there. Leading Firefighter Allmark was crossing the yard with Mr Isaac, the depot engineer, whom he introduced to Mr Jenkins. They did not know the location of the incident but having made a telephone call from the Control Room Mr Isaac said it was "50 yards inside the Tunnel, Avon end". Mr Jenkins asked him to confirm this: he thought Mr Isaac used a telephone on the wall, rather than one of the desk telephones, and was not

aware that the wall phone could only be used to communicate with the Tunnel.

245 Mr Isaac had also been told that the incident involved passenger trains and that there were casualties, numbers as yet unknown. Mr Allmark reported all this information by radio to brigade control. They made their way to the head of No 3 shaft, where Mr Jenkins asked the BR man in charge of the lift to get the trolley down into the Tunnel, with the assistance of the firemen and Rescue Team members then assembled. Mr Jenkins then led a reconnaissance team of four firemen down into the Tunnel, using the lift in No 1 shaft. They were all wearing breathing apparatus.

246 Mr Jenkins said he decided not to wait for the trolley to be assembled. He and his team set off on foot in the direction of the location 50 yards inside the Avon end. After walking for 15 to 20 minutes they met a reconnaissance team from the Avon Brigade who told them they hadn't passed the incident. Mr Jenkins said his prime concern then was to communicate with the surface at Sudbrook. Mr Allmark tried his radio, without success, so Mr Jenkins decided to go on to the Avon end on the trolley, which had now caught them up. On the way he made several attempts to use the Tunnel emergency telephones. At the first attempt he got a reply, evidently from the Newport Panel. He asked to be put through to Sudbrook and was told not to put the phone down, but no transfer took place. After waiting for "several minutes" he put the phone down and went on towards Bristol. He tried two other phones on either side of the Tunnel but found them defective or not working. The emergency train from Avon then reached them and he was told by a divisional officer of the Avon Brigade that the incident was in fact on the Gwent side.

247 Mr Jenkins estimated that since the message sent to brigade control from the surface at Sudbrook was timed at 11.08, it was probably about 11.40 by the time the trolley caught up with the reconnaissance party. Over an hour had elapsed since the incident and the role of the "first strike" reconnaissance team was becoming less important. Mr Jenkins said he judged Mr Isaac's information sufficient for him to act on. He did not see a blackboard at Sudbrook with the correct location chalked on it - he would have understood that "14 miles 28 chains" was inconsistent with 50 yards from the Avon end. Nor was he told that Mr Sperring had given the correct location to a fireman while the trolley was being assembled.

248 *Mr Neil Brynmor Isaac*, a Shift Supervisor at Sudbrook Pumping Station, told the Inquiry he was on shift on the morning of the accident. His responsibilities in an emergency are laid down in the depot instructions. At about 10.50 he was in his office when he received a phone call from the Control Room attendant who told him that there had been an incident in the Tunnel and Newport Panel would be contacting him. The call from the Panel came immediately afterwards, informing him that the incident was located at "14 miles 28 chains, 50 yards from the Bristol end".

249 Mr Isaac said he knew the shaft was at 14 miles but it didn't occur to him that there was some inconsistency in this message. It was given to him "in a definite, concise manner" and he took it to be the precise location, and relayed it to a fire officer who had arrived in his office. The fire officer immediately left and Mr Isaac said he didn't see him again, and could not identify him.

250 After making arrangements to despatch the emergency train in accordance with the depot procedure, Mr Isaac went to the Control Room, about 100 yards from his office and entered the location in miles and chains on the incident board, which he described as a blackboard on the Control Room wall. It had a permanent heading 'Incident' and a number of other indications in white, including 'miles and chains'. He did not refer to the Control Room plan of the Tunnel which showed markings of miles and chains from Bristol.

251 He then went to see if the train was ready. It left at about 11.03. After this he concerned himself with other duties, including arrangements for missing members of the Rescue Team, whose pagers were not working, to be telephoned at home. He was quite clear that he had passed on the location to a fire officer in his office, hadn't made a call from the Control Room and hadn't mentioned the location to any other fire officer until Divisional Officer Jarvis arrived to take control of the situation, "quite a while after 11 o'clock."

252 *Mr T L Glossop*, Chief Fire Officer (CFO), Gwent Fire Brigade, gave evidence about the Brigade's internal inquiry into the incident, the report of which had been submitted to the Inquiry. He explained that the Association of Chief Police Officers (ACPO) and the Association of Chief Fire Officers (ACFO), under the guidance of the Home Office, had produced national guidelines on their respective roles and how they could work together effectively in dealing with major emergencies. Other principal organisations including BR and the Society of Emergency Planning Officers had been consulted. The guidelines are not site-specific but they recognise the need to take the site of the incident into account, for example in locating the controls of the individual services as close together as possible without interference between their communication systems. Site-specific plans had been laid for dealing with an emergency in the Tunnel and BR had been represented on the co-ordinating committee to ensure complementary planning.

253 Every fire officer would be familiar with the brigade's operational procedure for major incidents within the Tunnel, and would carry an aide-memoire of the essential points for reference in the event of being called

to an incident. The officer's car radio would also provide up-to-date information on the situation which would be helpful in forming a view of the response needed.

254 The brigade's internal inquiry took a questionnaire from every firefighter who attended the incident and a statement from every fire officer. Every call had been logged by the central brigade control which had shared and confirmed its own information with the other services and with BR. Senior Divisional Officer (SDO) Jarvis, who had arrived at Sudbrook Pumping Station to take charge, first learned that the incident was located at 14 miles 28 chains from Bristol at 11.44, by message from Avon Brigade Control. He checked his plan to establish the correct location.

255 The fire brigade had timed the arrival of the Gwent emergency train at STJ at 11.34. Delay then occurred because the train driver required a third BR employee on the footplate, although the agreed plan called for only two. When the third person had been found and provided with breathing apparatus there was a further delay until 12.11 in obtaining consent for the train to enter the Tunnel past a signal at Danger.

256 Communications in the Tunnel had been the subject of tests for some years. Drawing on experience in other underground railways, CFO Glossop considered that a leaky-feeder aerial or similar system should be installed to permit the reliable use of radios. The availability of radio could have saved at least nine minutes in reporting the incident. He had received a report on a recent fire brigade inspection of the supplementary system of telephone plug-in points but did not find this an acceptable alternative: he understood it was not operational, no handsets were available and the system was defective in that any call could be cut off by someone plugging in another phone.

257 CFO Glossop said it would have been reasonable to expect the first Rescue Team to have reached the incident within 25 minutes of receiving the call, had the correct location been given at the outset. The internal inquiry had not found any weakness in the brigade's planning but on reflection Mr Glossop felt he should review its reliance on BR and "possibly strengthen our initial response". He said that the firefighters had been instructed to wear breathing apparatus, even though there was no report of fire or fumes, in the light of experience at the King's Cross fire. The breathing apparatus was not started up and was subsequently discarded.

258 The recommendations in the brigade's report had been endorsed by the CFO, Avon, with the addition of three recommendations on access to the Avon end of the Tunnel at Green Lane and the need to review BR's decision to withdraw the Avon emergency train formerly located at Pilning. CFO Glossop said the emergency planning service fully supported the recommendations. He accepted the need for risk assessment but said that after many years of consultation and experience, some of the recommendations were "so well understood and so clear and so well documented that I think action could be taken immediately".

259 Mr Glossop said such action should include some indication from the operator of a reasonable period of time in which a fire survey of the Tunnel structure would be undertaken, an assessment of the behaviour of spillages of hazardous materials, the provision of a fixed water drencher to contain a fire in the early stages, public address, lighting and monitoring equipment in the Tunnel and improvements to the road giving access to Sudbrook, where a vehicle had got stuck on a single-lane bridge some time before the accident. New arrangements for manning and turning out the emergency train were also recommended: earlier experiments with road-rail and rough-terrain vehicles had not been successful.

260 Superintendent Anthony Douglas Thompson, the BTP Area Commander for South-West England and South and West Wales, told the Inquiry that the role of the police in any major incident is one of control and co-ordination. Because the BTP has responsibility for the whole of the Tunnel it had played a part in co-ordinating the preparation of contingency plans by the emergency services on both sides - particularly in the three years before the accident.

261 Mr Thompson gave a summary of the BTP report on the incident, which had been made available to the Inquiry. He said that in February 1989 he had invited the ES and other agencies concerned to a meeting to review contingency planning in the light of recommendations in the Fennell Report on the King's Cross fire. This led to an emergency exercise in September 1990 and to agreement between the police forces to implement the "gold, silver and bronze" system of command and control recommended by ACPO. This is a three-level system, gold being strategic, silver tactical and bronze geographical. Mr Thompson explained how it was implemented on the day of the accident, with a chief superintendent in command of gold control at Gwent Police HQ, a BTP inspector as incident officer in charge of silver at Sudbrook and two bronze controls at STJ and Pilning Stations, both attended by BTP officers from 11.25 onwards

262 A casualty bureau was opened at Gwent Police HQ at 14.02 and dealt with 630 direct enquiries and 141 passed on from the Avon side. During the police investigation, lists provided by the bureau were used to seek information from the passengers, all of whom were traced except three uninjured passengers recorded as having travelled on the HST.

263 Arrangements for a second emergency exercise were still under discussion when the accident happened.

A planning meeting had been held on 29 November 1991, when it was agreed that the Chief Constable of Gwent should write to BR's Director of Safety expressing concern at the lack of progress.

264 In May 1992 the three police forces had produced the first joint police Severn Tunnel Permanent Operation Order, a copy of which had been provided for the Inquiry.

265 The BTP report raised a number of key issues including access to the Tunnel, the lack of a special emergency train and accommodation for the ES at Pilning, communications and lighting within the Tunnel, the arrangements for deploying the Sudbrook emergency train and the need for regular emergency training and exercises.

Evidence on other matters

266 *Mr John Jackson* BSc, the holder of a diploma in town and country planning, requested and was given permission to address the Inquiry on a memorandum which he had submitted. He was concerned about the effect that construction of the second Severn road crossing might have on the Tunnel, although work had not commenced at the time of the accident. He pointed out that the environment of the Tunnel is very hostile to signalling and other safety equipment and commented on the possibility of a wrong-side signalling failure and on the arrangements for handsignalling which he regarded as the weakest point in the system. He said that worst-case emergency planning in the Tunnel was "being rapidly degraded" and that poor communications had hindered the rescue attempts. He also mentioned a previous incident in 1961: "100 people were trapped for forty minutes when an engine caught fire but a well organised Emergency Plan prevented a potential disaster."

DISCUSSION

267 Concerning the cause of the accident, much of the evidence heard in public was directed to the question of why Driver Carpenter accelerated past Signal N164 and drove at normal speed into the Tunnel at a time when the HST ahead was travelling through the Tunnel at caution, as instructed. Did he pass the signal at Danger, or did he receive a clear signal? If the signal cleared, was this due to the action of the S&T technicians at work in the STJ Relay Room or was it due to a wrong-side failure in the signalling equipment?

Did Driver Carpenter pass Signal N164 at Danger?

268 It is regrettable that Driver Carpenter, having attended the Inquiry to give evidence, was advised against doing so by the lawyers who represented him and his trade union, and who later put obstructions in the way of a private interview with him. The purpose of the Inquiry - as was made very clear to each witness - was to ascertain the cause of the accident as far as possible, and not to ascribe blame. In view of the attitude of Mr Carpenter's legal advisers, and the continuing effects of his injuries (about which no medical evidence was forthcoming), it was clearly inappropriate to exercise the Inquiry's statutory power to compel him to appear.

269 In the absence of the best evidence, recourse was had to the report of what Mr Carpenter told BR's internal Inquiry, where he firmly stated that he saw Signal N164 change from red to green as the Sprinter approached the signal at walking pace. He said he accelerated past the signal and was travelling at "not far short of line speed" when he saw the HST's tail-lights ahead. He immediately applied the emergency brake and took his feet off the driver's safety device (DSD) - he assumed that he also closed the power handle as a normal reaction. Mr Carpenter also told the BR Inquiry that he had three to four years' experience of driving Class 155 Sprinters over this route. He confirmed that on the day of the accident he had to make two unscheduled station stops between Bath and Bristol and also that there is very good sighting of Signal N164 "from a long way back."

270 No other eye-witness was available as to the aspect displayed by Signal N164 when the Sprinter passed it. The Handsignalman had been withdrawn, Mr Carpenter was alone in the driving cab and the signal was not visible to anyone else on the train. Circumstantial evidence supports Mr Carpenter's account. There can be no reasonable doubt that the signal was at Danger as he approached, causing him to slow down to a walking pace; nor that on passing over the AWS magnet he heard and acknowledged the warning horn - had he not cancelled it the brakes would have been applied automatically.

271 In these circumstances, to have accelerated past the signal without waiting for it to clear would have been a mistake without precedent during the thorough investigation of reported SPAD incidents conducted by BR between 1986 and 1989. Such an unusual error would certainly have explained the accident, but in the absence of first-hand evidence the question must remain a matter for conjecture.

Was there an error by the S&T technicians?

272 The possibility that Signal N164 cleared at the critical moment due to the S&T technicians re-setting the axle counter was investigated exhaustively by BTP and at the BR inquiry, as well as being explored at length with witnesses at the Inquiry in public. Mr Croke was certainly working at the evaluator immediately before the accident. His description of the in-count of 81 clearing when he pressed the T1 button, to be followed almost immediately by a new in-count of 8, strongly suggests that this in-count was caused by the Sprinter passing over the detector heads at the entrance to the Tunnel.

273 Mr Day described how on the day after the accident he was able to clear the signal by re-setting the axle counter with the green re-set button. However, he could only do this after replacing the WDH fuse, which Mr Croke insisted he had in his pocket while he was working on the evaluator. The German manufacturers of the axle counter confirmed that the TSR relay could not be operated with the fuse out, while adding the comment that the fuse was not intended as a means of disconnecting the equipment from the external circuitry. The conclusion reached by Mr Fortey after thorough examination and testing was that with the WDH fuse removed, the axle counter could not have energised the relay falsely so as to clear Signal N164.

274 Mr Croke's immediate colleagues, Messrs Daniel and Andrews, confirmed having seen him produce the fuse from his pocket in the STJ messroom after news of the accident arrived there. Neither of them saw him take it off the top of the evaluator where Mr Andrews had left it when he removed it from the WDH card earlier that morning. Mr Croke's decision to put it in his pocket evidently arose from a discussion which took place in the car as the three of them were returning from their visit to the Tunnel to check the detector heads. Mr Andrews confirmed this conversation but it is not clear why they didn't take the precaution of securing the WDH fuse as soon as it was removed, bearing in mind that to their knowledge no spares were available at STJ.

275 Mr Daniel, who was driving the car, could not clearly recall the discussion which he evidently regarded as one between axle counter experts. The Signal Supervisor, Mr Cantle, although he had attended an axle counter appreciation course and knew how to re-set the evaluator, was content to leave fault-finding to the two PTOs, Messrs Croke and Andrews. Their expertise derived from a one-day technical training course and several years' day-to-day experience of maintenance and faulting. Mr Inskip, the Assistant Area S&T Engineer, who arrived to take charge of the Relay Room after the accident, had only a general familiarity with the equipment. Mr Croke himself was not entirely clear about the function of the T1 button although his use of it to clear an unwanted in-count was supported by other evidence.

276 The precise course and timing of events in the Relay Room remains unclear despite searching inquiry. There is some circumstantial evidence:

(a) the in-count detector heads on the Down track are located some 1500 yards from Signal N164. Assuming the in-count of 8 described by Mr Croke was generated by the Sprinter passing these detectors, it must have passed the signal at least a minute earlier. Mr Croke's recollection - that this in-count occurred immediately after he had cleared the outstanding in-count of 81 - implies that the Sprinter had already passed the signal when he pressed the T1 button;

(b) it seems clear that for much of the day of the accident the voltage at the detector heads was out of tolerance, evidently due to the combined effects of cracking and the low temperature. Taking the evidence at face value, it appears that the voltage on the Down counter was out of tolerance at 13.00 when Mr Inskip inspected the evaluator, and within tolerance on Mr Day's arrival at 15.00. If the voltage was temperature-dependent as suggested, it may well have been out of tolerance throughout the morning, which should have prevented the signal from being cleared by re-setting the evaluator, irrespective of whether the fuse was in place.

277 Although it was necessary to investigate thoroughly the possible association between the accident and the activities of the S&T technicians, no conclusive evidence has emerged. However, the possibility that S&T staff could re-set the evaluator and clear the signal, without the Signalman's knowledge, needs to be eliminated. A method of achieving this was demonstrated to me during a visit to the axle counter manufacturers and to Deutsche Bundesbahn (DB), the German Federal railway operator, in Stuttgart. At DB's Stuttgart Signal Control Centre over 100 axle counters are in use. Under DB regulations re-setting is performed not by maintenance personnel but by the Signalman, who is in a position to ensure that it is safe to do so.

Was there a wrong-side signalling failure?

278 All equipment associated with the operation of Signal N164 was thoroughly examined and exhaustively tested after the accident under the direction of Mr Day, the Tester in Charge. Subsequently Mr Fortey and his staff conducted tests of specific equipment in his laboratory. The signal head, the axle counter detectors and evaluator and all electrical connections from the signal to STJ and STE Relay Rooms, notably the 37-core cable running through the Tunnel, were checked. The tests were conducted by experienced signal engineers from other parts of the BR organisation who had not been involved in the design, installation or maintenance of the systems serving the Tunnel. They continued until June 1993 when the evaluator was finally subjected to potentially destructive testing at the TIC in the presence of a signalling expert from HMRI.

279 These tests were not independent in the full sense of the word, since they were carried out by the railway operator responsible for the Tunnel. However, all dismantling and removal of equipment for off-site testing was supervised by BTP and the conduct of the tests was monitored by HMRI, some of them being undertaken at the specific request of the Inspectorate. BR consulted

the manufacturers of the axle counter and also engaged consultants "to investigate possible circumstances that could enable Signal N164 ... ... to display a green aspect to the driver of the Sprinter train involved in the collision". A copy of the consultants' report was made available to the Inquiry.

280 I am satisfied that the technical investigation was thorough and impartial, drawing upon the best expertise available. Although no evidence of a WSF was found, such a possibility could not altogether be ruled out, as both Mr Day and Mr Fortey acknowledged. I accept that such a failure could have allowed the signal to show a green aspect momentarily, even though the axle counter was disabled; and that it might have corrected itself, leaving no trace to give a clue to the investigators.

281 Such a possibility must be regarded as extremely unlikely, yet it cannot be dismissed, given the extreme hostility of the Tunnel environment, the corrosive effect of water and the ever-present risk of mechanical damage to signalling and other electrical equipment. An analysis prepared by the BR consultants shows that in 1991 the combined total of recorded failures on the Up and Down axle counters at STJ was 64 (one every 5.7 days on average), of which 36 (56%) were unexplained. These were safe-side failures, not WSF, and it must be emphasised that, although the reliability of the axle counters was poor, wrong-side failures of the axle-counter itself can be eliminated as a cause of the accident. If the fuse was out, the axle counter could not have cleared the signal, regardless of any malfunction. If, on the other hand, the fuse had not been removed, the axle counter could have cleared the signal without any malfunction.

282 I believe the operator has made every reasonable effort to establish whether a WSF may have caused the accident. Had such a fault been momentary or intermittent, leaving no trace, it is self-evident that nothing would be gained by further prolonging an already protracted investigation. However, the performance of the signalling system in the Tunnel needs to be kept under close surveillance in case of any further untoward incidents which might be attributable to a WSF.

283 I was asked to extend the Inquiry beyond the circumstances and causes of the accident and to consider the effectiveness of the rescue operation conducted jointly by the operator and the ES: the BTP and the police, fire and ambulance services of the two Counties bordering the Tunnel: Gwent and Avon. A full day was devoted at the Inquiry in public to the questions pertinent to the emergency response:

(a) was there an adequate Emergency Plan?

(b) was the plan implemented effectively?

(c) what improvements should be made in light of the accident?

284 It is clear that for many years before the accident a great deal of effort was expended, jointly by the operator and the ES, on emergency planning. The report of the GFB inquiry describes in detail the discussions that went into the development of successive versions of an emergency procedure, and it refers to the series of emergency exercises held in 1984, 1986 and 1990. All this activity led to the issue in November 1991 of the 'Severn Tunnel Major Accident Procedure' which sets out the roles of the railway operator and each of the ES in responding to an emergency. Planning of a further exercise at which the Procedure would have been tested was overtaken by the accident. The Procedure was amended in 1992 and an exercise was held in February 1993 when I attended as an observer.

285 Local instructions to the staff at Sudbrook Pumping Station and the Tunnel Rescue Team for responding to an incident in the Tunnel had been issued by the operator. These also were amended following the accident.

286 It is impossible to devise a plan which anticipates precisely and in detail the unforeseeable characteristics of a real emergency. One of the principal objects of emergency exercises, in addition to providing practical training and experience for those involved, is to test the efficacy of the plan and to identify necessary improvements.

287 Within this obvious limitation I am satisfied that the current plans correctly identified the likely contingencies and were generally adequate in laying down the appropriate responses. The record of discussions shows that when the impending closure of the STJ Depot was discussed in 1987 the proposal to transfer the emergency train to Sudbrook was received with some misgivings about the time it might take to reach the Tunnel, but also with some support on the grounds that the Pumping Station would afford direct access to the Tunnel (via the lifts) and a good place to set up an incident control. A trial run of the train from Sudbrook to STJ, in December 1987, took 43 minutes but BR subsequently expressed confidence that this could be reduced to 30.

288 On the day of the accident the train travelled from Sudbrook to STJ in some 31 minutes but did not enter the Tunnel until almost two hours after the accident. Such a delay cannot be justified: if the train is to continue as a vital part of the Tunnel emergency procedure, means must be found to eliminate the causes of the delay, which appears to have been due in part to the insistence of the train crew that there should be three of them, and in part, to the difficulty in obtaining authority to pass a signal at Danger.

289 The operator is investigating the use of road-rail or rough-terrain vehicles instead of emergency trains in the Tunnel. Such vehicles are used by some fire brigades, although not for access to the railway, and their effectiveness on the permanent way has yet to be demonstrated. Until such time as the ES and HMRI are satisfied as to their performance and capabilities in comparison with the emergency train, no change should be made.

290 In this context it is relevant to mention that in Germany, DB has introduced a fleet of six new rescue trains for use in the tunnels of its new high-speed lines, at a cost of some £41 million. Should a train come to a stand in a tunnel, the two nearest rescue trains travel at high speed to the tunnel so that one can be deployed from each end. Halting of a train in a tunnel is regarded by DB as "extremely unlikely from a statistical point of view" but the view taken is that the rescue trains offer the reassurance that the "manageable risks" have been covered. The circumstances are not precisely comparable with the Severn Tunnel but any case for eliminating the Severn Tunnel emergency trains certainly needs to take the DB approach into account.

291 There was also concern about emergency communications in the Tunnel. The fire brigade's portable Storno radios were considered capable of covering the whole length of the Tunnel with the aid of a repeater unit located at the bottom of the Sudbrook shaft to boost the transmission of signals to the surface. Nevertheless, in the Spring of 1990 BR agreed to explore the feasibility of installing a 'leaky feeder' aerial to assist radio communications in the Tunnel, drawing on the successful adoption of this system in the London Underground tunnels. In October 1990 at a review of the emergency exercise Operation 'Black Hole', communications at Sudbrook were described as "abysmal". In November 1993, I was informed that a detailed specification for a leaky feeder aerial compatible with the ES radio equipment had received financial approval and would be installed during 1994.

292 One essential provision that does not seem to have emerged from the discussions or from the exercises (which were of course pre-planned) was a clear directive for unrestricted safe access for the emergency trains to and into the Tunnel to be secured as soon as the ES are called. I return to this in what follows.

293 Implementation of the Emergency Plan went seriously wrong in several ways:

(a) the breaking of the Tunnel tell-tale wire did not produce an immediate response at the Newport Panel because it was wrongly assumed to be due to a failure and not to an emergency;

(b) the precise location of the incident was not properly communicated in the early stages, basically because no one checked the location quoted against the Tunnel plan;

(c) most of the radio pagers issued to members of the BR Rescue Team failed, apparently due to lack of maintenance, or possibly through not being switched on;

(d) the attempt by someone at Newport Panel to transfer the Tunnel emergency phones to Sudbrook failed - an investigation by BR Telecommunications (BRT) concluded that the Sudbrook telephone concentrator was switched off, contrary to the major accident procedure which provides for the fire brigade to check with the Duty Engineer, on arrival at Sudbrook "that the circuits are switched to give access to the Tunnel telephones from the Control Room";

(e) there were delays in getting the Sudbrook emergency train into the Tunnel due to the need to obtain authority to pass a signal at Danger, and subsequently in moving the HST out with the survivors including many injured passengers on board;

(f) further delays occurred before the uninjured passengers were able to continue their journeys and there were understandable complaints of insufficient information and inadequate provision for them to get in touch with anxious families and friends.

294 Reference has already been made to the recommendations in the report of the GFB inquiry, some of which call for better physical equipment for emergency use and others for improved procedures. Before addressing the issue of improvements I must make clear my view that the problems that arose on the day could have been avoided and a much quicker response achieved had all the existing equipment been properly maintained and all the agreed procedures properly followed. Not only the ES, when they eventually managed to reach the site, but also the train crews, other railway staff travelling on the two trains and a great many of the passengers showed courage and determination in responding to the accident and in helping and comforting the injured. It is regrettable that their efforts were frustrated by a series of failures which could mostly have been prevented by a better state of preparedness.

295 This does not apply to the problem of moving trains past signals at Danger, which calls for a new approach. Any incident serious enough to require the attendance of the ES will also require the closure of the Tunnel to normal rail traffic in both directions. The

current procedure rightly emphasises that the ES must defer to the railway staff's expertise in matters of train operation. However, in the case of a serious incident it should be possible for 'possession' of the Tunnel and its rail approaches to be transferred, with due precautions, to the senior fire officer in charge of the emergency, who will assume responsibility for the movement of trains at caution within the possession. I understand that such a procedure is being discussed by the operator and the ES at the time of writing.

296 Some improvements have been made to the emergency equipment since the accident: notably the duplication of the tell-tale wire so that the alarm will only be raised when both wires are severed, thus greatly reducing the chance of a false alarm. This change had been approved, but not implemented before the accident.

297 Other improvements are in progress, including the introduction of a new lightweight rescue trolley and a new and larger lift at Sudbrook. It is necessary to address the question of what priority should be given to other improvements recommended in the GFB report, such as the provision of tunnel lighting and public address systems, fixed firefighting equipment and improved underfoot conditions.

298 Before the accident the operator commissioned an expert risk assessment to assist in decision making on expenditure to improve safety in the Tunnel. This is consistent with the now standard BR approach to safety-related investment, taking account of the likely reduction in risk and prioritising the application of limited resources accordingly. The GFB view is that such an approach is unacceptable where emergency planning is concerned, and that its recommendations should be implemented without regard to the outcome of the risk assessment.

299 In considering this issue I have borne in mind that quantitative risk assessment (QRA) is an accepted technique for providing management with guidance on the level of safety measures that may be regarded as 'reasonably practicable' and thus in conformity with the Health and Safety at Work etc Act 1974 (HSWA). I accept - to quote the railway operator's response to the GFB recommendations - that "investment in improved safety facilities ... must be judged against other safety schemes elsewhere on BR and a priority set, so that available expenditure is directed at the highest safety risk."

300 Yet QRA cannot provide cut-and-dried answers: only a guide to decision making. Not all the measures recommended by the GFB would materially have improved the rescue operation on the day, while proper use of those already available would certainly have done so. Nevertheless I believe that however remote the risk, the ES personnel who have to enter the Tunnel and deal with an emergency are entitled to rest on certain basic assumptions:

(a) that the location and nature of the emergency will be reported to them correctly, without delay;

(b) that safe and rapid access to the emergency site will be available;

(c) that those dealing with the emergency on site will have constant and reliable communication with the surface.

301 The outcome of the risk assessment, subject to review by the Health and Safety Executive, should be used to inform and guide future investment decisions. But the decision makers must also take account of these basic assumptions, which reflect the statutory duties of the ES to their own employees under the HSWA.

302 Those recommendations which relate to procedures rather than to investment in equipment should be carefully reviewed by the railway operator in consultation with the ES. A properly drawn up Emergency Plan for railway staff, setting out the foreseeable contingencies, the objectives and procedures for responding to them and the means of achieving and maintaining an acceptable state of preparedness, would go a long way towards avoiding the problems experienced on the day of the accident. It will be an essential component of the Safety Case for the Tunnel which was among the GFB's procedural recommendations and will be a statutory obligation under the Railways Act 1993.

CONCLUSIONS

303 Before setting out the conclusions of the Inquiry it seems necessary to draw attention to the number of errors which have come to light with a significant bearing both on the circumstances leading to the accident and on the effectiveness of the emergency response which followed. These errors included:

(a) the mistake in withdrawing and replacing disconnection links in STJ Relay Room, which appears to have initiated the failure of the Down axle counter: Mr Sperring, who seems to have been the last person to work on the MDF, believed he had only touched a telephone circuit, but the links were not clearly identified - and he was not a telephone engineer (paragraphs 93 and 94);

(b) the failure of the S&T technicians, lacking a properly laid-down procedure for faulting, to locate the fault at an early stage: even the two PTOs, who were senior technicians regarded as experts on the axle counters, did not discover it until after their unproductive journey to check the detector heads (paragraphs 119 to 121);

(c) the casual attitude towards re-setting revealed by the fact that neither the Signalman nor the

Technicians took the trouble to keep a record - as they should have done - of the re-setting of the Up axle counter on the morning of the accident (paragraphs 80, 127 and 158);

(d) the Signalman's well-intentioned but improper decision to change the postings of his Handsignalman and Tail-light man: although the use of a handsignalman was a convenience rather than a necessity, the decision once taken should have been observed to the letter of the Rule (reproduced in Appendix 2);

(e) the unsecured fire extinguishers in the cab of the Sprinter, one of which was almost certainly responsible for Driver Carpenter sustaining a fractured skull in the collision;

(f) the treatment of the tell-tale alarm as an indication of routine failure rather than a serious emergency (paragraphs 78, 86, 123, 136 and 146);

(g) the failure to see that the Rescue Team's pagers were in working order, which led to an unnecessary delay in assembling the team while a manager and a telephone were engaged in calling the team out individually (paragraphs 228 and 251);

(h) the failure to ensure that the Tunnel emergency phones were switched to Sudbrook as soon as the rescue operation started (paragraphs 87 and 293);

(i) the delay in moving trains in and out of the Tunnel during the rescue operation (paragraphs 226, 227, 231, 246, 251 and 255);

(j) the unsatisfactory state of the wiring diagrams kept at STJ Relay Room, which unnecessarily delayed the start of Mr Day's site investigation (paragraph 178).

304 To draw attention to these failings is necessary but it is also important to acknowledge the risk of human error and oversight in the difficult conditions of an emergency - hence the need for proper training and supervision and for dependable procedures. This has never been spelt out more clearly or in such detail as in Sir Anthony Hidden's report on the investigation into the Clapham Junction disaster. BR is committed to Total Quality Management and it is disturbing to find so little evidence of its effects in practice here, three years after Clapham and two years after publication of the Hidden report.

305 This is not to suggest that the railway managers and staff were negligent or lacking in concern for safety. However, it does seem that because of the Tunnel's excellent safety record, with only two minor train accidents recorded in over a century of operation, the possibility of an emergency received too little attention amidst other pressing priorities. A systematic approach to the identification, management and monitoring of hazards, which BR has adopted in principle, could have checked all these errors and prevented the accident.

306 The conclusions of the Inquiry are:

(1) The accident was caused either by an unaccountable error on the part of the Sprinter Driver or the S&T Technicians working in the STJ Relay Room; or possibly, although this seems most unlikely, by a momentary or intermittent wrong-side signalling failure which left no detectable trace, and has not recurred since the accident.

(2) Both the observance of the rules laid down for the operation and maintenance of the Tunnel signalling, and in certain respects the rules themselves, fell short of an acceptable safety standard.

(3) Although the agreed plan for dealing with major emergencies in the Tunnel had been drawn up with care and was broadly satisfactory, the state of preparedness of the emergency provisions made by the operator failed to meet the expectations of the professional ES and caused serious delay to the rescue operation.

307 It may be inferred from these conclusions that the operator failed to achieve a reasonably practicable standard of compliance with the statutory obligations laid down by sections 2 and 3 of the Health and Safety at Work etc Act, 1974, for the safety of those at work and others affected. However the Inquiry did not, in my opinion, bring out clear evidence of contravention of the Act by the operator or any individual. I do not consider it appropriate to pursue the matter any further.

RECOMMENDATIONS

308 My recommendations are:

(1) The operator should review the training of all concerned with maintenance and faulting work on the Severn Tunnel axle counters; there should be clear, comprehensive written instructions and effective monitoring to ensure that the instructions are at all times properly observed.

(2) Provision should be made, wherever axle counters are used, for re-setting to be placed under the over-riding control of the Signalman using a re-set button in the Signal Box .

(3) Improved means should be provided for positively isolating axle counters from the signalling system during maintenance and fault-finding work.

(4) BR's Track Circuit Block Regulations should be revised and extended where appropriate to take account of the differences between track circuit and axle counter sections, especially under fault conditions.

(5) The operator should ensure that all disconnection links on vital signalling circuits are clearly labelled to identify their purpose.

(6) The operator should review the railway emergency procedures for the Tunnel area, including the Newport Panel and the shorter tunnels on the English approach, to ensure that both the objectives and the means of achieving them are clearly laid down and that the state of preparedness is regularly monitored and recorded.

(7) The operator should proceed as quickly as possible to implement those improvements to the emergency equipment and procedures that have been agreed with the ES. Other procedural recommendations should also be implemented as soon as possible in consultation with the ES concerned. Recommendations for additional emergency equipment or facilities should be implemented to the extent that they are justified by the QRA, when finalised.

(8) The QRA should be an integral part of the Safety Case for the Tunnel under the Railways Act 1993.

(9) The operator should review the arrangements for 'through routes' operation in the Tunnel in order to find a means of providing the Signalman with panel indications of the presence of trains in the Tunnel during through routes working, irrespective of the nature of the failure for which through routes working is initiated.

(10) The operator should ensure that all fire extinguishers carried on rolling stock are firmly secured in place and are located in such a position that accidental dislodgment will not endanger train crew or passengers.

(11) Finally, although it is by no means certain that the accident would have been prevented by a system of automatic train protection (ATP), the operator should ensure that its plans for the installation of ATP (which automatically brings a train to rest in the event of the Driver passing a signal at Danger) extend to the Severn Tunnel at the earliest possible date.

APPENDIX 1 Mr Fortey's evidence as to cable testing (see paragraph 193)

1 Mr Fortey described the cable from STJ to STE, a total length of nearly six miles laid in a series of seven independent lengths connected at location cupboards. The first (NP3785) ran several hundred yards from STJ interlocking to location cupboard Y27, the next (NP3786) to Y21 at the Welsh portal. The longest (NP3789) ran from the foot of the Sudbrook shaft to Y4 at the English portal, and the last one from Y4 to STE interlocking. The cable used was manufactured to BR specification 872 (1986 edition) which called for a high performance elastomeric rubber-insulated cable. This was a newer type of insulation with superior electrical properties but installation experience had shown that pinch damage could be caused because of its mechanical properties. This led to the issue of two instructions, the first prohibiting the use of PVC string ties which could put very high pressure on cable 'trees', and the second (SIN 35) requiring the removal of such ties where they had been used.

2 Testing confirmed that the short circuit between cores 30 and 33 was in a cable tree, which had been laced with PVC string. The lacing had not been removed in accordance with SIN 35. The cable tree was carefully removed and taken by BTP to Reading TIC for further investigation. The two cables were 'treed' within the cupboard: Mr Fortey explained that this involved stripping off the the outer insulation, leading the two sets of cores vertically upwards and branching off the individual cores to the appropriate links. It was found that the tree had been laced up with PVC string which had not been removed in accordance with SIN 35.

3 Initial testing of the cable tree took place on Tuesday 10 December in the presence of HMRI and BTP. It was confirmed that core 33 of one cable was in contact with core 30 of the other at the point where it had been threaded through the cable to branch off to its terminal. The short circuit could be reproduced by fitting a clip and tightening it around the cable at this point. Mr Fortey said that because of its elastomeric property, the insulation could restore itself to proper electrical performance after inadvertent damage by pinching or shearing. As a result such damage might only be detectable under a microscope. At the bottom of the tree the cables were wrapped with PVC tape. Some of this was removed and a number of knife cuts found in the insulation. Mr Fortey suggested that these had been made during the original installation, but he said none of them appeared to be adjacent to any other conductor.

4 Further knife cut damage was found in the course of dismantling the tree, and appeared to have taken place when the cable was originally prepared for termination. Mr Fortey did not think the damage had any bearing on the accident although he was critical of the "careless workmanship" to which he attributed it. He was satisfied that the cable tree had not been tampered with between the time of the accident and the TIC examination.

5 Microscopic examination of cores 30 and 33 clearly showed where they had been damaged. A test rig was used to determine the force needed to re-establish a short circuit: with the two cores lying perpendicular to one another, about 1.1 Kg (11 newtons) was sufficient. Mr Fortey said that a PVC tie could exert such a force and since testing on installation had not disclosed a fault, he considered the short circuit had developed later, due to pinch damage caused by the use of PVC ties. Contraction of the ties due to the cold weather could have been the immediate cause of the fault. A fault which was temperature-dependent might well have been intermittent. Mr Fortey was "completely satisfied" that cores 31 and 32 were not involved in a similar failure.

6 A length of damaged cable from NP 3786 was also removed to the TIC where visual inspection showed obvious external physical damage and one core was physically damaged, with a green corrosive deposit which suggested that the damage had occurred some time before the accident. Mr Fortey said the cable was subsequently examined by electron microscopy at the BR Research Centre at Derby, where it was concluded that the core had actually been corroded through. However, the significant cores, 31 and 32 were "well clear of the general area of damage".

7 Mr Fortey went on to refer to Mr Day's evidence about the information that came to light on 10 January as a result of monitoring the performance of the through-circuit cable. In the interest of safety, and to facilitate further testing, it was decided to replace the cable between Y4 and STE. This left the original cable free. To minimise physical disturbance, additional termination blocks were installed for the replacement cable.

8 The original cable was tested thoroughly and found to be within acceptable standards - the perturbations recorded during monitoring were not present. However, near Ableton Lane Tunnel on the English side a 'sensitive' cable joint was discovered: disturbing it affected the monitor readings. Further testing disclosed earth leakages on several cores: core 20 was particularly unstable.

9 After discussion with HMRI and BTP the joint was cut out and removed to the TIC. Mr Fortey said it had been made by the resin injection method and had external physical damage in three places, probably caused by a heavy impact which had shattered the resin, allowing the absorption of moisture. When the joint was taken apart at the TIC, only one of the three sites of damage was found to have penetrated the inner

structure of the joint. A strong smell from the cloth tape around the joint was indicative of mildew, suggesting that the damage had been present for several weeks at least. Tests showed that the damaged joint would absorb more water - the damage was thus progressive, leading to deterioration of the insulation. Mr Fortey could not speculate as to the cause of the damage but he said that even when taken out of service the cable remained within tolerance. From an engineering point of view it could have continued in use, although progressive deterioration would eventually have reached the point at which departmental standards required its replacement.

10 During monitoring the voltage recorder had logged a full-scale deflection, indicating a value in excess of 500 mv. However, the event recorder showed no evidence of the Z DN TPR having operated. This would normally occur at 50 V and could not have occurred below 20 V, so the voltage recorded could not have exceeded 20 V.

11 When the substitute cable was fully operational, further monitoring of the original one was instituted. On 17 July 1992 there was a momentary leakage of between 100 and 150 kilohms between cores, and 300 to 400 kilohms to earth. Mr Fortey said the cause had not been established but with effect from 31 July, cores 31 and 32 were individually monitored. Between that date and 1 October numerous minor leakages, both core/core and core/earth, had been recorded. However, cores 31 and 32 had shown "no trace whatsoever of simultaneous perturbations". For the Z DN TPR relay to be falsely energised the insulation resistance of these cores would have had to be reduced to the order of 3400 ohms: the earth leakage or resistance to earth as recorded never fell below 1 megohm - a value 300 times greater.

12 All the faults found on the cable tree from Y27, the length of damaged cable between Y4 and STE and the cable joint from Ableton Lane, had successfully been reproduced on an electrical model of the through circuit cable which was produced as a visual aid for the Inquiry. Mr Fortey said that this model had been used to amplify each recorded fault by a factor of 10, and this clearly showed that no combination of the faults identified could produce any significant voltage on cores 31 and 32, the circuits controlling the Z DN TPR relay. He concluded that there was no fault in the various cables composing the entire 37-core link between STJ and STE that could cause the false energisation of the Z DN TPR "by external means".

APPENDIX 2 Extracts from Track Circuit Block Regulations on failures and from BR Rule Book on handsignalling

Appendix 'H' **Extract from Track Circuit Block Regulations**

2. DESCRIPTION OF SYSTEM

2.1 Track Circuit Block signalling permits a signal to exhibit a Proceed aspect when all track circuits in the line ahead are clear up to and including the overlap beyond the next stop signal and all necessary points within that distance are detected in the correct position for the safe passage of the train. An overlap is not normally provided at signals on goods lines.

9.3 Procedure for track circuit failures

9.3.1 If a track circuit fails to clear after the passage of a train, or otherwise shows occupied, the Signalman must ensure that the previous train has passed clear of it. Unless it has been established that the line is clear, the Signalman must arrange for the line to be examined in accordance with clauses 9.1 and 9.2 except that:-

(a) In all weathers any class of train may be used except as shown in clause (e);

(b) the Driver need not be accompanied;

(c) the Driver must be instructed to pass the signal held at Danger;

(d) when a train will pass over an adjacent line before one passes over the affected line, the train must be signalled normally. The Signalman must stop the train, advise the Driver of the circumstances and instruct him that he must proceed cautiously and report the state of the affected line;

(e) where any portion of the track circuit is within a tunnel, any class of train may be allowed to enter the tunnel on the unaffected line, in accordance with clause (d), provided the Signalman is satisfied that the previous train on that line has passed clear of the tunnel. If the Driver of this train reports that the affected portion of line appears to be clear, the first train required to proceed over the affected line may be allowed to enter the tunnel. If, however, the first train required to proceed over the affected line is not waiting to enter the tunnel, normal working may be resumed on the unaffected line until that train is ready to proceed;

The Driver of the first train over the affected line must be instructed to pass the signal held at Danger, proceed with extreme caution at not more than 10 m.p.h. over the affected portion of line, and to report the state of the line to the Signalman. If, however, a train has to pass over the affected line before the section can be examined by a train on the unaffected line, a passenger train must not be used unless it can be established that the tunnel is clear, if necessary by a member of the traincrew walking through.

9.3.2 If it is established that the line is clear, the track circuit concerned must be considered as having failed and the provisions of Regulation 11, clause 11.4 or 11.5, as appropriate, must e applied for following trains.

11.4 Failure of track circuits - double lines

11.4.1 If a track circuit fails to clear after the passage of a train or otherwise shows occupied, the provisions of Regulation 9, clause 9.3 must be observed.

11.4.2 If it is reported that the affected line is clear, the Driver of each train requiring to pass over the affected line during the failure may be authorised to pass the signal concerned at Danger, provided one of the following arrangements has been introduced:-

(a) the signalman is able to ascertain that the portion of line concerned is clear after the passage of each train or a competent person has been appointed to report the state of the line in accordance with the Rule Book, Section E, clause 4.7.

SECTION B. PART II
DUTIES OF EMPLOYEES APPOINTED TO ACT AS HANDSIGNALMEN OR POINTS OPERATORS

8. DUTIES OF HANDSIGNALMEN

8.1 Competence

An employee appointed to act as a Handsignalman must have been passed as competent by the Operations or Civil Engineering Departments.

8.2 Equipment

The Handsignalman must have with him:

(*a*) a red, a yellow and a green flag

(*b*) a handlamp capable of showing a red light, a yellow light and a green light

(*c*) sufficient detonators

(*d*) clips and scotches } if necessary

(*e*) a signal post replacement key }

8.3 Positioning of Handsignalman

8.3.1 The Handsignalman must position himself as directed by the person shown below:

Circumstances of appointment	Person positioning Handsignalman
Defective or disconnected signal	Signalman
Single Line Working	Pilotman
Protection of hand trolley	Person in charge
Protection of engineering work on line not under Absolute Possession	
Emergency speed restriction	
Protection of line blocked by an Absolute Possession	Person in Charge of Possession (PICOP)
Protection of line which may be fouled by a crane or other mechanical equipment	Operations Dept. Supervisor

8.3.2 The Handsignalman must remain in position until withdrawn by the person shown above (or his relief) or until the Handsignalman is himself relieved.

8.3.3 When at a signal or signal box, the Handsignalman must report his arrival to the Signalman.

8.4 Positioning of detonators

Detonators must be placed (in accordance with this clause 8) sufficiently far from the Handsignalman to ensure that the Driver has time to observe the handsignal after they explode. Where the Handsignalman is positioned at a signal **which is being maintained at Danger**, the detonators must be placed at the signal.

8.5 Duties when appointed in connection with a defective or disconnected signal

8.5.1 The Handsignalman must position himself at the signal at which he is appointed or at the place it normally occupies.

8.5.2 When appointed at a stop signal, the Handsignalman must exhibit a hand Danger signal to the Driver of each approaching train until the train has stopped and maintain one detonator on the line to which the signal applies. He must ensure that the route over which a train is to pass is correctly set and that the points specified by the Signalman are secured. He must give an assurance to the Signalman when this has been done.

After the Signalman's permission has been obtained for the train to proceed, the Handsignalman must:

(*a*) give the Driver the necessary instructions

(*b*) remove the detonator from the rail

(*c*) exhibit a yellow handsignal

If, however, the Signalman gives permission for the train to proceed before it approaches the Handsignalman **and** the Signalman confirms that the necessary instructions have **already** been given to the Driver, the train need not be stopped. The Handsignalman must remove the detonator from the rail and exhibit a yellow handsignal.

8.5.3 When appointed at a signal which cannot normally display a Danger aspect/indication, the Handsignalman must maintain one detonator on the line concerned and exhibit a yellow handsignal to each approaching train.

8.5.4 When employees are appointed to assist the Handsignalman with the clipping of points, he must instruct them to act only on his instructions. The Handsignalman remains responsible for carrying out the Signalman's instructions and for all communication with him.

8.6 Duties when appointed in connection with Single Line Working

8.6.1 When positioned opposite a signal where trains may be required to stop, the Handsignalman must maintain one detonator on the line which is being used for Single Line Working and exhibit a hand Danger signal to each train approaching on that line in the direction concerned until the train has stopped.

After the Signalman's permission has been obtained for the train to proceed, the Handsignalman must:

(*a*) give the Driver the necessary instructions

(*b*) remove the detonator from the rail

(*c*) exhibit a yellow handsignal

If, however, the Signalman gives permission for the train to proceed before it approaches the Handsignalman **and** the Signalman confirms that the necessary instructions have **already** been given to the Driver, the train need not be stopped. The Handsignalman must remove the detonator from the rail and exhibit a yellow handsignal. This does not apply where trains are required to draw forward and then set back through a crossover in order to return to the right line. In such circumstances, trains must always be stopped and the Driver reminded as to what is required before permission is given to draw forward.

8.6.2 If he can safely do so, the Handsignalman must withdraw the protection if a train approaches in the opposite direction. He must reinstate the protection immediately after the train has passed clear.

8.6.3 Where there are more than two Track Circuit Block running lines and all lines in one direction are blocked, Single Line Working may be introduced over one of the unobstructed lines. In such circumstances, the Handsignalman must position himself as directed by the Pilotman and observe the provisions of this clause 8.6 except that a detonator must be maintained on the line in **each** direction on the approach to the portion of line over which conflicting movements may take place. After the Signalman's permission has been obtained for the train to proceed, the **appropriate** detonator must be removed from the rail.

8.7 Duties when appointed in connection with the protection of a hand trolley, or engineering work, or a line which may be fouled by cranes or other mechanical equipment

8.7.1 When in the signal box or at a signal which can be controlled to Danger from the signal box, the Handsignalman must obtain the Signalman's assurance that the signal(s) will be maintained at Danger until the line is safe for trains to pass. When in the signal box, he must countersign the Signalman's entries in the Train Register and remain there as a reminder to the Signalman.

8.7.2 When at a signal equipped with a signal post replacement switch, the Handsignalman must, after obtaining the Signalman's permission, operate the signal to Danger and tell the Signalman when he has done so. The signal must be maintained at Danger until the line is safe for trains to pass. The Signalman's permission must then be obtained before the signal is restored to automatic working.

8.7.3 Except when positioned in a signal box, each Handsignalman must maintain three detonators, 20 yards (or 20 metres) apart, on the line(s) concerned and exhibit a hand Danger signal to any train approaching on that line. This protection must be maintained until the line is safe for trains to pass. If the detonators are exploded for any reason, the protection must be reinstated immediately. If he can safely do so, the Handsignalman must withdraw the protection when a junction signal is cleared for an unaffected route. He must reinstate the protection immediately the signal is replaced to Danger.

8.8 Duties when appointed in connection with an Engineer's Absolute Possession of the line

The Handsignalman must maintain three detonators, 20 yards (or 20 metres) apart, on the line concerned and exhibit a hand Danger signal to any train approaching the detonators from either direction. He must not allow any train to pass the detonators without authority from the PICOP and must reinstate the protection as soon as a train has passed.

8.9 Duties when appointed in connection with an emergency speed restriction

8.9.1 The Handsignalman at the warning point must place two detonators, 1 yard (or 1 metre) apart, on the line concerned and exhibit a yellow handsignal waved slowly from side to side to each train approaching the restriction.

If he can safely do so, the Handsignalman must withdraw the detonators when:

(*a*) a junction signal is cleared for an unaffected route **or**

(*b*) a train approaches from the direction of the restriction

The detonators must be replaced immediately the junction signal is replaced to Danger or after the train has passed clear, as appropriate.

8.9.2 The Handsignalman at the beginning of the restriction must exhibit a yellow handsignal. The Handsignalman at the end must exhibit a green handsignal waved slowly from side to side.

Where the restriction is so short in length that only one Handsignalman is appointed, he must stand where the restriction ends and exhibit a yellow handsignal until the train is close to him and then exhibit a green handsignal waved slowly from side to side.

8.9.3 The Handsignalman must ensure that his handsignal does not conflict with the Danger aspect of any stop signal nearby which is applicable to the line concerned. When such signal exhibits a Danger aspect, the Handsignalman must exhibit a hand Danger signal at the signal. When the signal is cleared, he may then exhibit the appropriate handsignal in connection with the restriction.

APPENDIX 3 Health and Safety at Work etc Act 1974, sections 2(1) and 3(1)

2.—(1) It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.

3.—(1) It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety.

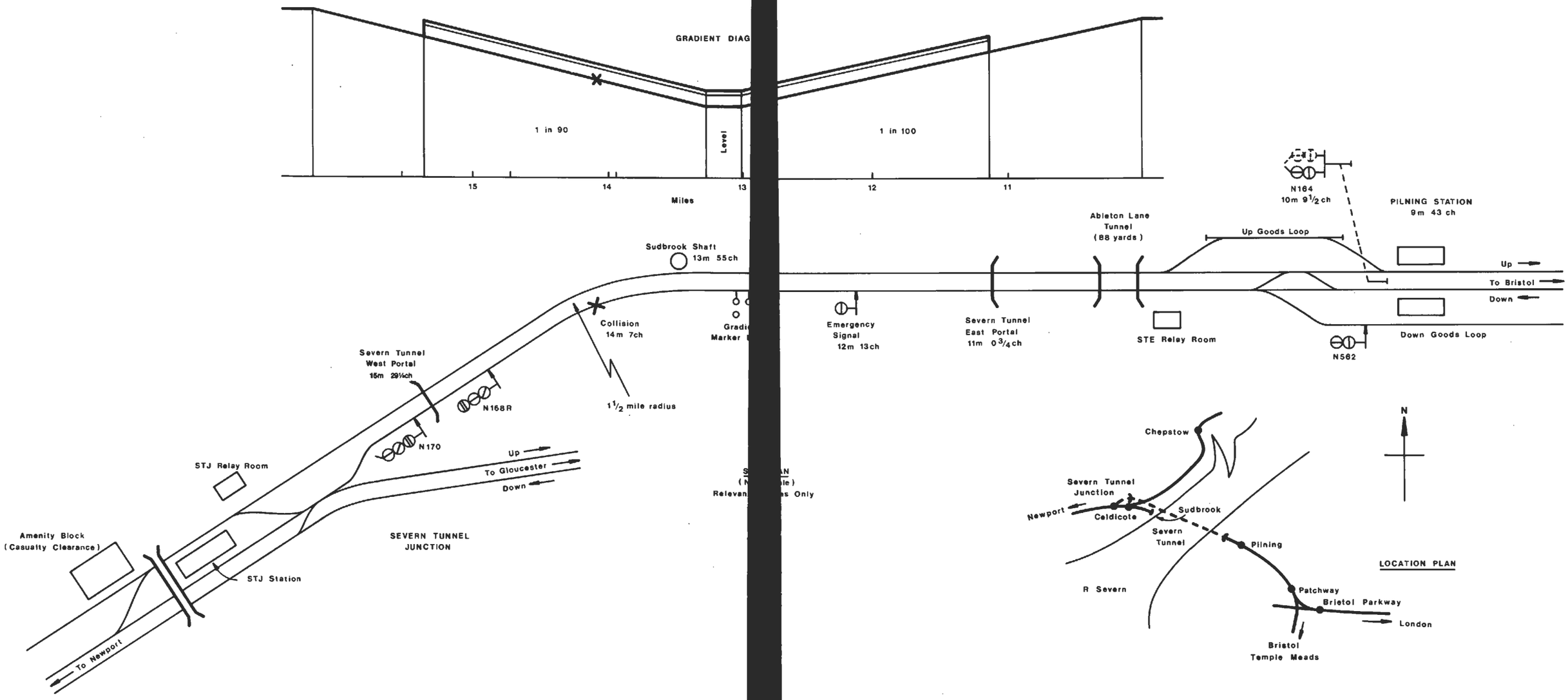
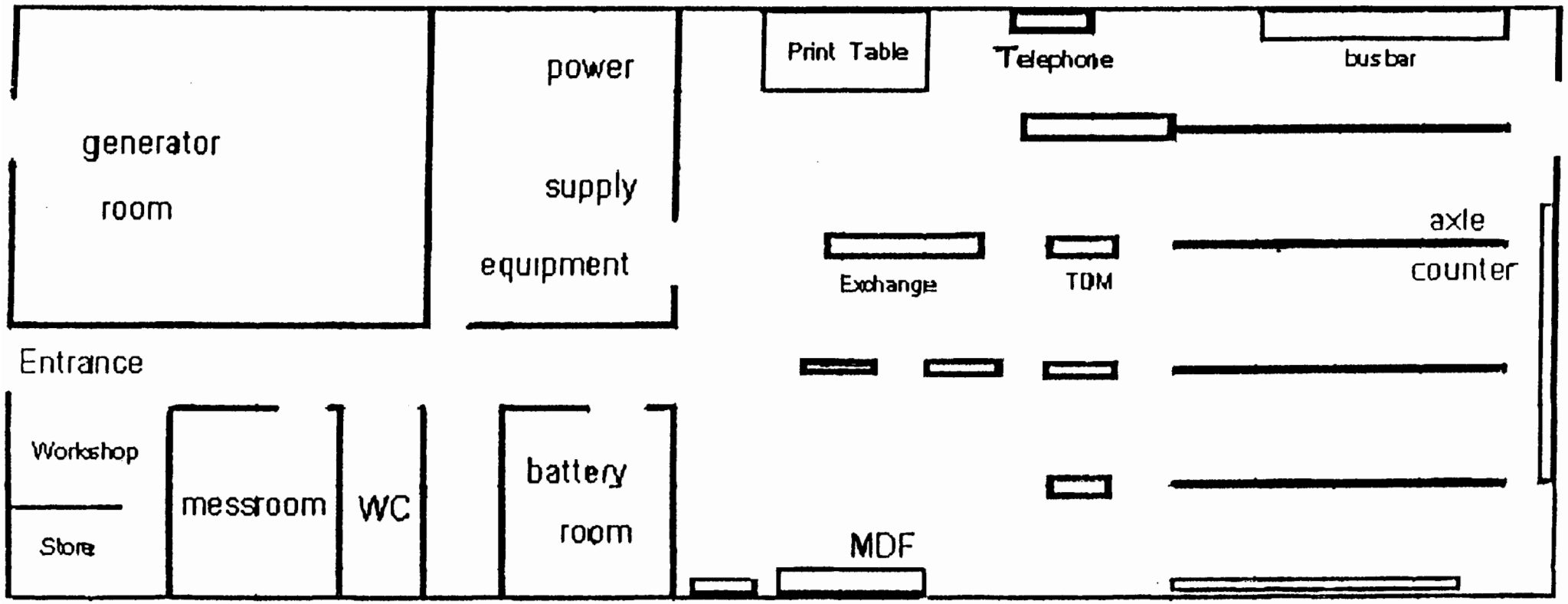


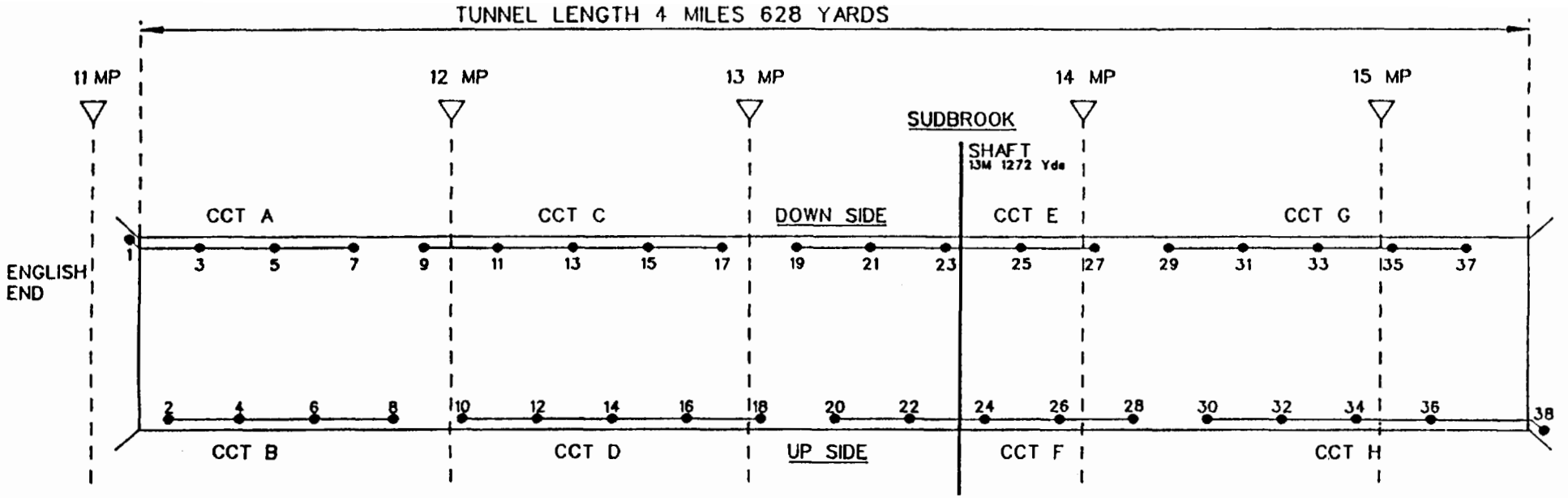
Figure 13 The Severn Tunnel route and signalling diagram

SEVERN TUNNEL JUNCTION RELAY ROOM LAYOUT



MDF = Main distribution frame

Figure 14 Severn Tunnel Junction Relay Room



TELEPHONES ENGLISH SIDE OF SUDBROOK SHAFT

TELEPHONE No.	CCT	MILES	CHAIN	DISTANCE FROM ENGLISH SIDE IN YARDS
1 E	A	11	1	0
2 E	B	11	11	224
3 E	A	11	20½	430
4 E	B	11	30	639
5 E	A	11	39½	846
6 E	B	11	49	1056
7 E	A	11	59½	1266
8 E	B	11	68	1475
9 E	C	11	76½	1663
10 E	D	12	7	1895
11 E	C	12	17½	2125
12 E	D	12	26	2312
13 E	C	12	37½	2565
14 E	D	12	45	2730
15 E	C	12	55	2954
16 E	D	12	65½	3183
17 E	C	12	74	3372
18 E	D	13	4½	3599
19 E	E	13	14	3808
20 E	F	13	23½	4018
21 E	E	13	33	4229
22 E	F	13	41	4394
23 E	E	13	50	4602

TELEPHONES WELSH SIDE OF SUDBROOK SHAFT

TELEPHONE No.	CCT	MILES	CHAIN	DISTANCE FROM ENGLISH SIDE IN YARDS
24 W	F	13	65	4924
25 W	E	13	72	5077
26 W	F	13	78½	5228
27 W	E	14	10	5479
28 W	F	14	18	5657
29 W	G	14	28	5870
30 W	H	14	37½	6087
31 W	G	14	46	6275
32 W	H	14	58	6528
33 W	G	14	68	6753
34 W	H	14	76	6930
35 W	G	15	5½	7140
36 W	H	15	16	7372
37 W	G	15	24½	7557
38 W	H	15	29	7648

Figure 15 Location of Severn Tunnel emergency phones

Printed in the UK for the Health and Safety Executive
C12 2/94

RAILWAY ACCIDENT IN THE SEVERN TUNNEL A report on a collision that occurred on 7 December 1991

HSE BOOKS

MAIL ORDER
HSE priced and free publications available from:
HSE Books
PO Box 1999
Sudbury
Suffolk CO10 6FS
Tel: 0787 881165
Fax: 0787 313995

RETAIL
HSE priced publications are available from Dillons Bookstores nationwide and can also be ordered at any branch of Ryman the Stationer or Ryman Computer Store
(*see Yellow Pages or telephone* 071 434 3000 *for local details*)

PUBLIC ENQUIRY POINT
Health and safety enquiries:
HSE Information Centre
Broad Lane
Sheffield S3 7HQ
Tel: 0742 892345
Fax: 0742 892333

ISBN 0-7176-0629-1

9 780717 606297

£ 12.50 net