Rail Accident Investigation Branch

Rail Accident Report

Fire on HGV shuttle in the Channel Tunnel 21 August 2006

Department for Transport

Report 37/2007
October 2007

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Contents

Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by AirSea Packing Group Ltd, Eurotunnel plc, International Consultants Targeting Security (ICTS), Kent Fire and Rescue Service and Kent Police to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

- acronyms and abbreviations are explained in Appendix A; and
- technical terms (shown in italics the first time they appear in the report) are explained in Appendix B.

5 Unless otherwise stated, all times quoted in this report are in *Concession Time* as used by Eurotunnel. This was 1 hour ahead of British Summer Time on 21 August 2006.

Summary of the report

Key facts about the accident

6 On 21 August 2006 a fire broke out in the load compartment of a lorry on HGV *Shuttle Mission* 7370, the 13:23 hrs service from the UK terminal to France. The shuttle train was brought to a controlled stop at PK3050, 20.5 km from the UK portal, at 13:40 hrs. All 34 persons on board (30 lorry drivers and 4 Eurotunnel staff) were evacuated into the *service tunnel* by 13:49 hrs without injury. They were subsequently evacuated out of the service tunnel to the French terminal, reaching the French service tunnel portal at 15:47 hrs.

7 The UK *Second Line of Response* (SLOR) started fire fighting at 15:45 hrs and confirmed the fire extinguished at 16:05 hrs. The *carrier wagon* was structurally damaged, but able to be moved from the tunnel after inspection and without receiving any repairs at the site of the incident. The overhead *catenary* became parted and the tunnel lining damaged to a depth of about 30 mm at the *crown* of the tunnel in the proximity of the fire over a length of 10 m.

8 Trains were able to start running through the unaffected parts of the tunnel from 17:10 hrs on 21 August 2006 and normal operation through the whole tunnel resumed at 16:15 hrs on 22 August 2006.

Figure 1: Extract from Ordnance Survey map showing location of accident

Key findings

Immediate cause

9 The immediate cause of the accident was a fire in the load compartment of a lorry on the penultimate wagon of an HGV shuttle.

Contributory factors

10 A contributory factor was the difficulty in detecting a smouldering fire within the load compartment of a lorry.

Factors concerning the effectiveness of detection and surveillance in the terminal

11 Loading staff are well placed to detect a fire during loading. However, current procedures do not specifically refer to visually checking the roof and doors of a lorry's load compartment for signs of smoke escaping. Instructions to staff do make reference to checking the area of brake drums/axles for smoke.

12 The staff responsible for checking the departing HGV shuttles for signs of fire have difficulty in observing the passage of the rearmost wagons.

13 The positioning of the above staff and the proximity of the UK portal of the tunnel to the terminal limit the time available in which to stop a shuttle on which a fire is observed. In the case of a fire noted on a lorry towards the back of a shuttle there is insufficient time to alert the control centre and for the shuttle to be stopped before it has already passed the portal.

Factors concerning the effectiveness of the incident management

14 Overall, the incident was well managed by staff on the train, by the controllers and by the emergency services.

15 The evacuation of passengers and crew from Mission 7370 was completed within 20 minutes of the first activation of a *smoke detector* in *Cross Passage Door* (CP) 1626 and within 10 minutes of the shuttle stopping. No injuries were sustained by passengers or crew and the evacuation was achieved in a calm and efficient manner.

16 The fixed and on-board fire detection systems gave an early warning of the presence of fire on the moving HGV shuttle. This enabled timely implementation of the emergency procedures.

17 The tunnel's electrical and mechanical systems functioned correctly during the incident enabling the efficient evacuation of the HGV shuttle into the service tunnel and the effective management of smoke.

18 Emergency procedures were generally implemented correctly by staff in the control centre and onboard the HGV shuttle. Those errors that were made did not affect the achievement of a safe outcome but should nevertheless be addressed by Eurotunnel (see paragraph 19).

19 The investigation has not revealed any evidence of a requirement for a change in the existing safety strategy following the detection of fire on an HGV shuttle nor any need for modification of the rolling stock. However, a number of issues have arisen during the investigation that should be addressed in order to improve the efficiency of any future emergency response. These are summarised below:

- The driver of the HGV shuttle did not advise the control centre that he had received an indication that the on-board fire detection system had been activated.
- The *Rail Traffic Management* (RTM) controller did not broadcast a message to all trains in both running tunnels to close their air conditioning units.
- Two shuttles did not respond correctly to instructions given by the control centre. The probable cause is the variable reception achieved by the radio system.
- Following the stop imposed by the signalling system, the RTM controller did not instruct the driver of both shuttles in the *Running Tunnel South* (RTS) to control their speed to 10 km/h, which resulted in them accelerating to 30 km/h. In different circumstances this could have had an adverse effect on the management of airflows.
- The driver of the HGV shuttle was uncertain of the location of the zone in which he was not permitted to stop. As a consequence he did not stop at the first available cross passage beyond this zone.
- The driver of the HGV shuttle did not contact the control centre to advise the RTM controller of his final stopping position.
- Opening the cross passage doors before the incident shuttle's final stopping position was confirmed contravened the relevant procedure. This had no adverse consequences, but could have caused a loss of control of airflow in different circumstances.
- The *Engineering Management Systems* (EMS) controller did not specify the tunnel in which the incident had occurred before switching off one of the two fans at each ventilation plant, which resulted in a reduction in smoke-controlling airflow past the incident train. The layout of data on the EMS screen is likely to have contributed to this error.
- The *Fire Detection Controller* (FDC) took excessive time to establish an appropriate postcode to meet the needs of the UK police and ambulance services.
- No single person in the *Incident Co-ordination Centre* (ICC) had a complete and accurate view of events in the tunnel.
- There has been no formal debriefing meeting between the emergency services and Eurotunnel to review the response, the joint working arrangements and the lessons to be learned.

Recommendations

20 Recommendations can be found in paragraph 378. They relate to the following areas:

- Three recommendations arising from issues associated with detection and surveillance in the terminal.
- Twelve issues associated with the management of incidents. These concern procedures and the design of systems.
- One issue arising from an observation.

The Incident

Summary of the incident

21 On 21 August 2006 a fire broke out in the load compartment of a lorry on HGV Shuttle Mission 7370, the 13:23 hrs service from the UK terminal to France. The shuttle train was brought to a controlled stop at PK3050, 20.5 km from the UK portal, at 13:40 hrs. All 34 persons on board (30 lorry drivers and 4 Eurotunnel staff) were evacuated into the service tunnel by 13:49 hrs without injury. They were subsequently evacuated out of the service tunnel to the French terminal, reaching the French service tunnel portal at 15:47 hrs.

22 The UK Second Line of Response (SLOR) started fire fighting at 15:45 hrs and confirmed the fire extinguished at 16:05 hrs.

23 The fire was close to the rear of the train on the penultimate carrier wagon, destroyed the lorry on which it occurred, and damaged the adjacent ones. The carrier wagon was structurally damaged, but able to be moved from the tunnel after inspection and without receiving any repairs at the site of the incident. The overhead catenary became parted and the tunnel lining was damaged to a depth of about 30 mm at the crown of the tunnel in the proximity of the fire over a length of 10 m.

24 The Channel Tunnel was closed to all traffic at 14:04 hrs. The Running Tunnel South was reopened at 17:10 hrs and the *Running Tunnel North* was reopened in stages from 18:20 hrs. Normal operation resumed at 16:15 hrs on 22 August 2006.

The parties involved

25 Eurotunnel plc is the operator of shuttle trains through the Channel Tunnel system and also the infrastructure manager.

26 AirSea Packing Group Ltd of Twickenham, Middlesex owned and operated the lorry which caught fire.

Location

27 The fire was initially detected while the shuttle was travelling through *Interval* 2, 6.2 km from the portal, in the Running Tunnel North (Figure 2). The shuttle was brought to a controlled stop by the driver using the train brake for evacuation in Interval 4, with the *Amenity Coach* (AMC) adjacent to CP3050.

28 The entire incident took place within British jurisdiction. The frontier between Britain and France is at the tunnel midpoint, 27 km from the UK portal.

29 As the Channel Tunnel runs in a north-west/south-east axis, the tunnels are identified as the Running Tunnel North and the Running Tunnel South. Locations within the tunnel are defined by their position relative to a point 10 km before the UK portal and given to the nearest 10 m. The last digit is even for the Running Tunnel North and odd for the Running Tunnel South. Thus CP3050 is 20.5 km into the Running Tunnel North. This is under the sea and about 11 km from the UK coastline.

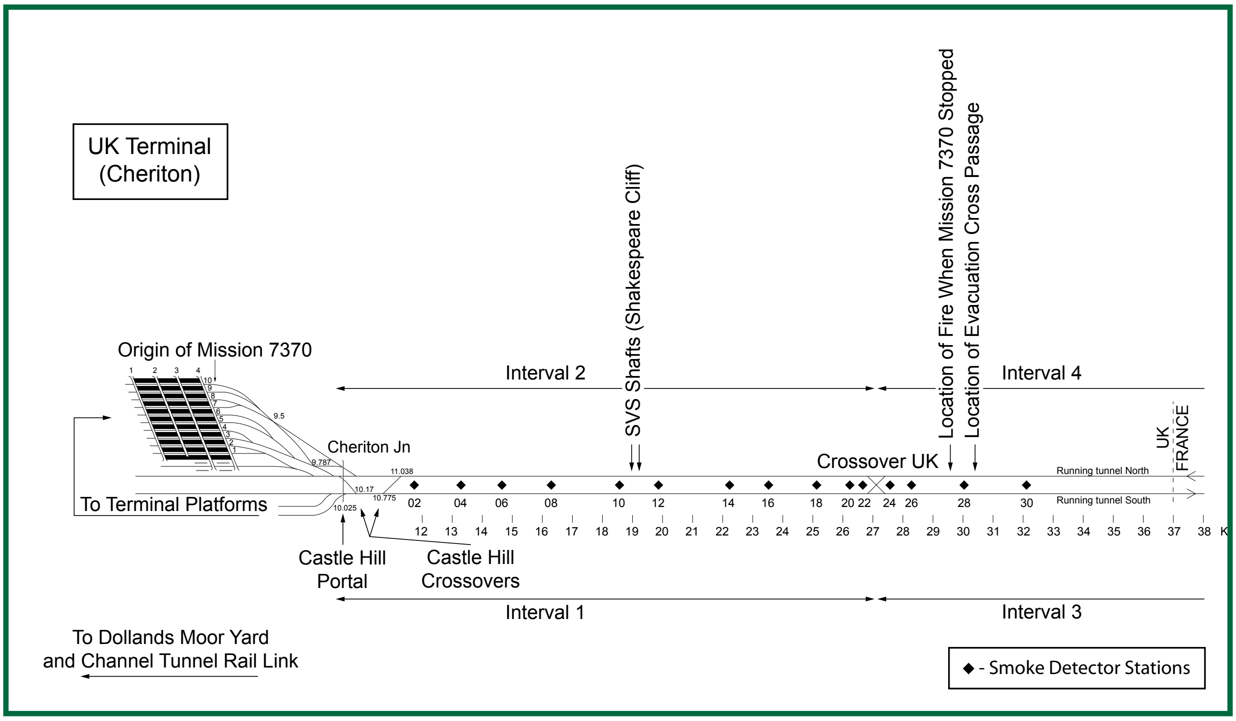

Figure 2: Diagram of the Channel Tunnel system

Train and rail equipment

30 The train involved was an HGV Shuttle made up of an electric locomotive at each end, an AMC, and a combination of *loader* and carrier wagons. It is described in detail at paragraphs 87 to 100.

Events preceding the incident

31 The lorry was being driven to France transporting packaging material comprising rolls of corrugated paper, brown paper, empty wooden boxes, sheeted cardboard and also a chair. The driver had loaded the lorry that morning after 09:00 hrs in Twickenham, closed and sealed the load compartment at about 10:30 hrs and started the journey to the Channel Tunnel at approximately 11:00 hrs.

32 The journey by road to the Channel Tunnel was reported as uneventful. The driver did smoke during the journey. He finished his last cigarette near Ashford and disposed of the remains by throwing them out of the cab window.

33 The lorry passed through the toll area at 12:45 hrs (11:45 hrs BST). Apart from a short period (when he left it to obtain some money), the driver remained with the lorry until he drove it onto the penultimate carrier of the shuttle on platform 10 and joined the bus to take him to the AMC.

34 The staff responsible for loading the train secured and inspected the lorries in the normal manner and observed the departure of the shuttle as required by Eurotunnel's operating procedures. They did not note anything out of order with the shuttle or the lorries being carried.

35 Before the shuttle entered the tunnel, smoke had begun to emerge in discrete puffs from the top of the load compartment of the lorry. This was recorded by an unmonitored security camera located some 100 metres from the entrance to the tunnel and facing towards the tunnel.

Events during the incident

36 The first detection of smoke was by fixed tunnel smoke detector station (SD) SD08 located at CPD1626 in the Running Tunnel North at 13:30:31 hrs. Detector stations are numbered from the UK portal and given even numbers in the Running Tunnel North. Detector stations SD12 at CP1990 and SD14 at CP2214 similarly detected smoke at 13:32:39 hrs and 13:33:10 hrs respectively. The locations of the smoke detector stations are shown at Figure 2.

37 In accordance with Eurotunnel's operating instructions, at 13:31 hrs the *Railway Control Centre* (RCC) sent out a verbal general call to all trains to reduce speed to 100 km/h on receipt of the first smoke detection.

38 At 13:33:20 hrs the RCC supervisor issued instructions to stop Mission 7370 with the intention of evacuation and at 13:34 hrs the RTM controller instructed Mission 7370 to carry out a controlled stop. Immediately afterwards, at 13:35 hrs, all trains were verbally instructed to reduce speed to 10 km/h.

39 From their respective fire equipment management workstations, the FDC mobilised the French and UK *First Line of Response* (FLOR).

40 The EMS Controller started the process of isolating the two running tunnels and preparing the tunnel ventilation systems to deal with an evacuation from a train in the presence of smoke.

41 Meanwhile, at approximately 13:30:45 hrs, the *Chef de Train* received an indication on the control panel in the AMC of a fire alarm on his shuttle and advised the driver. The driver did not advise the RCC of the activation of the alarm on the shuttle. The Chef de Train then closed the AMC's ventilation dampers to prevent any smoke entering and walked through the AMC warning the lorry drivers that an evacuation was likely. On the Chef de Train's return to the AMC control panel, the driver confirmed to him that he had been instructed to make a controlled stop and would do so once the shuttle had cleared the '*go zone'* through which the shuttle was passing.

42 As soon as the driver was certain he had passed fully through the 'go zone', he brought the shuttle to a stand at CP3050 at 13:40 hrs (Figure 3). After receiving a call from the RCC authorising an evacuation, he assisted the Chef de Train with the process.

43 The Chef de Train ensured that the position of the train and the conditions in the tunnel were suitable for a safe evacuation to be made and then led the lorry drivers through the *cross passage* to the service tunnel. The driver checked the AMC was empty and advised the Chef de Train who carried out a head count.

44 At 13:49 hrs the Chef de Train advised the RCC by telephone that the shuttle had been evacuated and the CP could be closed.

45 At 13:48 hrs trains in the Running Tunnel South were permitted to increase speed to 60 km/h to enable them to clear the tunnel quickly.

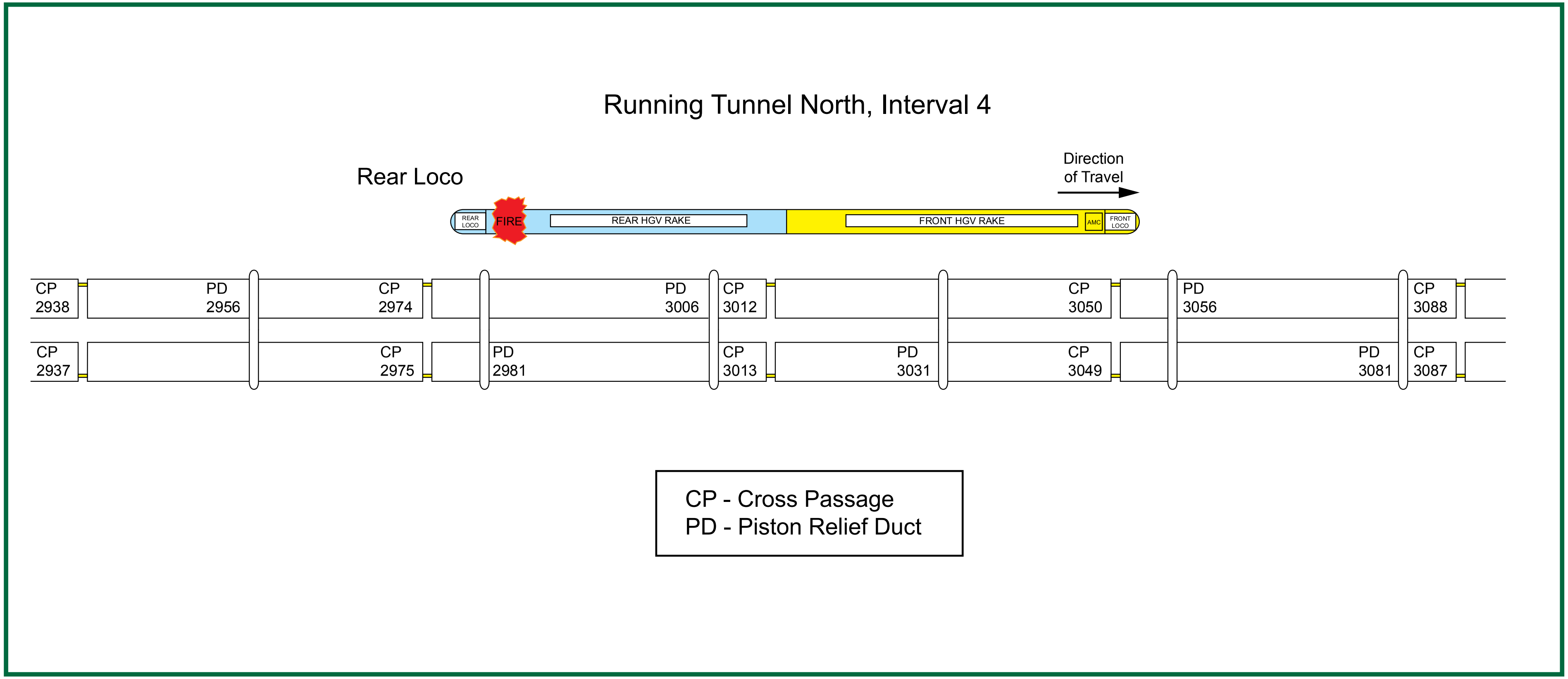

Figure 3: Diagram of the area in which Mission 7370 came to a stand

Consequences of the fire

46 No passengers or staff were injured during the incident.

47 Damage to the tunnel infrastructure was confined to the immediate area of the fire over a length of approximately 12 metres. Cables running along the tunnel wall were damaged. The overhead catenary sustained damage as the copper *contact wire* parted. The tunnel lining immediately above the fire was penetrated to a depth of 30 mm, which was just sufficient to expose the steel reinforcements, but did not cause the dislodgement of large concrete sections.

48 The lorry concerned was destroyed by the fire (Figure 4). The lorry immediately behind it suffered destructive damage to the plastic covering over the refrigeration unit (Figure 5); the lorry ahead sustained light damage to the rear involving distortion to the registration plate, rear lights and mud flap (Figure 6).

Figure 4: Burnt out HGV (at original site)

Figure 5: Damage to refrigeration unit of HGV behind incident wagon

Figure 6: Damage to rear of HGV ahead of incident wagon

49 The carrier wagon transporting the lorry suffered slight distortion of the floor and damage to the roof, lighting and load indicators operated by the brake equipment. However, it was not enough to cause an *unsolicited application of the brakes.* The wagon could still be hauled from the location of the fire by rail. After an examination in France by Eurotunnel rolling stock staff, it was declared fit to return to the UK. It was the only wagon damaged.

50 Commercial services were formally suspended in both running tunnels at 14:04 hrs and the railways affected in the UK and France advised.

Events following the fire

Evacuation to the portal

51 The *Service Tunnel Transport System (STTS)* vehicles were used to transport the evacuated passengers to the French terminal reaching it at 16:15 hrs.

Firefighting

52 The UK FLOR reached CP3050 at 13:54 hrs. They attempted to investigate the fire from CP2974 towards the rear of the shuttle at 14:27 hrs, but the presence of dense black smoke immediately made this impractical. At 14:36 hrs access was gained through CP3012 in the centre of the shuttle and a request made for the catenary to be *earthed*. The EMS controller confirmed that the catenary was *isolated* but not earthed.

53 The UK FLOR observed a fire towards the rear of the shuttle at 14:39 hrs and prepared a fire hose from the hydrant in CP3012 pending the earthing of the catenary.

54 At 14:40 hrs the UK FLOR requested the transfer of control of the tunnel to the emergency services. This is the implementation of the Emergency Plan *'BINAT'*.

55 Earths were applied at the UK tunnel entrance and mid-point at 15:40 hrs to enable fire fighting to start.

56 At 16:05 hrs the FLOR confirmed that the fire had been extinguished. BINAT was withdrawn at 17:03 hrs.

57 The *Supplementary Ventilation System* (SVS) was switched off and the ventilation returned to normal at 17:03 hrs.

Restoration of service

58 On the withdrawal of BINAT, commercial operations were resumed in the Running Tunnel South with a *flight* of 5 *Eurostar* trains travelling from the UK to France entering the tunnel at 17:29 hrs.

59 Intervals 6 and 2 in the Running Tunnel North were opened to traffic successively during the early evening.

60 After the shuttle had been removed, repair work was undertaken in Interval 4 in the Running Tunnel North which was reinstated at 16:15 hrs on 22 August 2006 and normal working resumed.

61 Because of damage to the catenary close to the UK end of the shuttle, it was agreed that the shuttle could be returned to the UK by running it forward to France, around the terminal loop and back through the Running Tunnel South. A diesel rescue train reached the French end of the fire-damaged shuttle at 21:25 hrs. After the site had been examined by RAIB inspectors and the condition of the train checked by Eurotunnel technicians, the incident train was hauled to France at 23:12 hrs, reaching the French terminal at 00:45 hrs on 22 August.

62 Upon its arrival in France, the shuttle was moved into the maintenance shed for inspection prior to it starting its return journey. At this point the French local government authorities instructed that the incident wagons, and those on either side, be retained in order that they could be examined by the police.

63 On the following day, 22 August, the RAIB and BEA-TT were given access to the impounded wagons in order to carry out an initial examination. That day it was agreed with the *Sous-Préfet* that the wagons could be returned to the UK for more detailed forensic analysis. This movement subsequently took place during the night of 26/27 August.

The Investigation

Investigation process

64 The investigation was led by the RAIB because the incident occurred under British jurisdiction. Assistance was given by BEA-TT, the RAIB's French counterpart, who was kept advised of the progress of the investigation and enabled observations of shuttle loading processes to take place in France.

65 The investigation focussed on establishing the cause of the fire, the suitability of the procedures in place to detect and respond to a fire, the reaction of the personnel involved and the performance of equipment concerned. The report on the fire which took place on an HGV shuttle in 1996 (described in paragraphs 215-222) and its recommendations were examined to establish any relevance to the incident on 21 August 2006.

66 The RAIB was able to examine Mission 7370 at the site of the fire before it was removed from the tunnel. The relevant wagons were eventually returned to the UK. There the fire debris and the remains of the wagon involved were examined by a fire investigation specialist under the supervision of the RAIB.

67 Examination of CCTV tapes and security camera images confirmed which lorry had been the seat of the fire and established that the fire had started before the shuttle had entered the Channel Tunnel.

68 Eurotunnel, contractors and emergency services staff involved in the incident were interviewed, together with the appropriate managers.

69 The shuttle loading and departure examination procedures were observed in the UK and France. The shuttle driving conditions were also observed.

Sources of evidence

70 These comprised:

- examination of the site of the incident;
- witness statements;
- examination of CCTV and still camera security images;
- procedural documents supplied by Eurotunnel;
- recordings of verbal communications;
- archival documents showing status of key items of equipment during the incident;
- discussions with Eurotunnel, and Eurotunnel sub-contractors' personnel;
- observation of the loading and departure operation in the UK and France;
- observation of the train driving conditions and techniques;
- debris examination by Forensic Scientific Services;
- discussions with Kent Police;
- discussions with Kent Fire & Rescue Service;
- discussions with AirSea Packing Group personnel; and
- examination of a lorry similar to that involved in the incident.

Key information

The Channel Tunnel System

71 Eurotunnel plc is the concessionaire for the fixed rail link between the UK and France through the Channel Tunnel. The *Concession* includes the entire link comprising the running and service tunnels, all underground and surface installations, the terminals at Folkestone and Calais and the connections to the railway networks in Britain and France.

72 Eurotunnel controls and maintains the Channel Tunnel, operating its own trains to transport road vehicles between the terminals. It also provides *paths* for the passage of conventional freight and Eurostar trains between the national railway systems.

73 The movement of trains is controlled from one of two control offices, the Railway Control Centre (RCC), in each terminal, either of which can take complete real time management of the tunnel. Additional offices control the movement of road vehicles within the terminal complexes.

74 The railway is electrified throughout using the 25 kV ac overhead line system and the tracks are laid to the *standard gauge*.

<u>Infrastructure and systems</u>

75 The Channel Tunnel itself comprises two running tunnels and a central service tunnel (Figures 3 and 7).

76 Each running tunnel carries a single track railway line used for the passage of all types of trains. During normal operation, trains run on the left hand track in the direction of travel in accordance with British and French practice so that the Running Tunnel North is usually used by trains travelling to France. Both tunnels are *reversibly signalled*.

77 The signalling system indicates the permitted speed to the driver through an illuminated display on the locomotive control desk. Instead of traditional lineside signals, fixed boards beside the track indicate to the driver where he is to stop if required to do so by the signalling system. These also inform a driver of his location which enables him to tell the RCC where he has stopped his train.

78 The running tunnels are each divided into 3 intervals and connected by larger diameter *crossover* tunnels between the intervals. The crossovers enable trains to be directed from one tunnel to the other so that, using the reversible signalling, one or more intervals can be taken out of use without necessitating the closure of the Channel Tunnel. The intervals are identified by number, being numbered in the direction of the UK to France with the even numbers applying to the Running Tunnel North (Figure 2).

79 The service tunnel enables access to the running tunnels for routine and out of course purposes, including emergencies. Movement of personnel and equipment in the service tunnel uses Service Tunnel Transport System vehicles. These run on pneumatic tyres but are guided by wires buried in the tunnel floor rather than steered within the service tunnel.

80 The passage of trains causes significant changes in air pressure. *Piston Relief Ducts* (PRD) connect the running tunnels between the cross passages, to enable pressure changes to be dissipated through the other running tunnel. The ducts include dampers which can be closed in the event of a fire to reduce smoke reaching the other running tunnel.

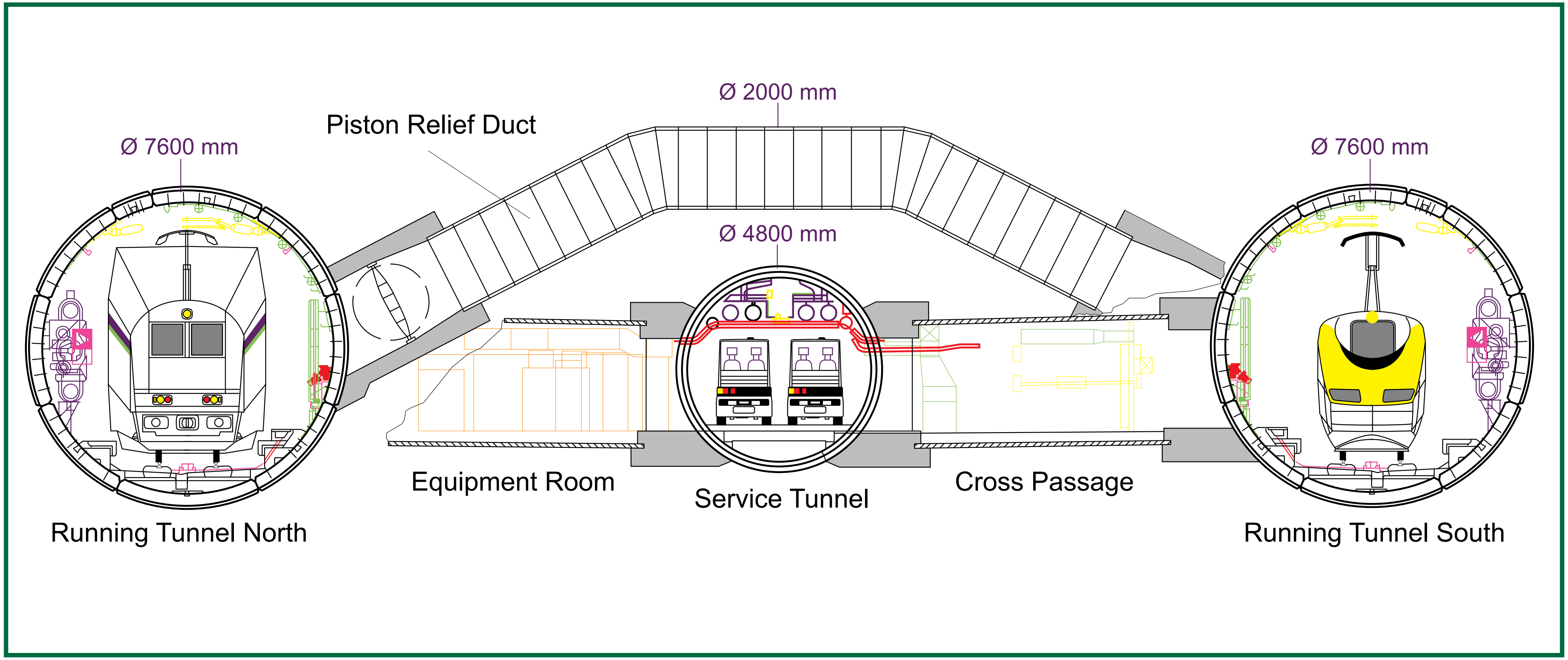

Figure 7: Cross section showing two running tunnels and the service tunnel

81 Access from the service tunnel to the running tunnels is gained through cross passages, nominally every 375 metres. The doors between the service and running tunnels are normally under the control of the EMS Controller, though control is always available locally through a local panel adjacent to each door. Eurotunnel's operational procedures only permit them to be opened when trains are stationary or moving at low speed (10 km/h or less) in that interval. The service tunnel is maintained at a higher air pressure than the running tunnels to ensure that in the event of an evacuation clean air will pass from the service tunnel into the running tunnel and smoke will not enter the service tunnel.

82 The ventilation systems and the piston relief duct dampers are controlled from the RCC.

83 There are two ventilation systems within the Channel Tunnel, both of which have a role to play in an emergency involving a train or shuttle:

- The *Normal Ventilation System* (NVS) supplies air to the service tunnel from ventilation plants located at Shakespeare Cliff in the UK and Sangatte in France. A key function of the NVS is to keep the service tunnel at a higher pressure than the running tunnels. If it is necessary to evacuate from a running tunnel to the service tunnel when smoke is present in the running tunnel, the higher pressure in the service tunnel ensures that it remains free from smoke and thus offers a 'safe haven' for evacuating passengers and crew. In order to ensure that pressure is maintained in the service tunnel, there are *airlocks* at either end. The NVS is always switched on and the fans at each end of the service tunnel are always configured in supply mode. The rate at which air is supplied can be varied by adjusting the *blade angle* of the NVS fans. The blade angles available vary from 0 to 7. At blade angle 0, no air is being supplied and at blade angle 7, air is being supplied at the maximum rate. Blade angles between 0 and 7 represent proportionate graduations between zero and maximum.
- A Supplementary Ventilation System (SVS) is provided to direct and increase the flow of ventilating air in the running tunnels in the event of an emergency such as a fire. This will enable the combustion products of a fire to be blown away from the evacuation point and supply clean air to escaping people. The SVS is normally switched off and is only operated when there is smoke or fumes to be cleared from the tunnel or to supply air to stalled trains. The SVS plants are located at Shakespeare Cliff in the UK and Sangatte in France. There are two fans at each plant. When smoke or fume clearance is needed, the fans operate in push/pull mode, i.e. the fan(s) at one end are configured to supply air and the fan(s) at the other end configured to extract air. Depending on the scenario, one or two fans at each plant may be operative. The SVS fans are linked to the running tunnels by shafts. These are connected by a system of dampers which can be opened or closed in order to direct the air towards either or both tunnels as required. The rate at which air is supplied can be varied by adjusting the blade angle of the SVS fans. The blade angles available vary from 0 to 7; the higher the number the greater the rate of air supply. As with the NVS fans, at blade angle 0, no air is being supplied and at blade angle 7, air is being supplied at the maximum rate. Blade angles between 0 and 7 represent even graduations between zero and maximum. When the fans are supplying at one shaft and extracting at the other shaft at blade angle 7, an airflow rate of approximately 2.5 metres per second can be achieved in a running tunnel, The blade angles are referred to as '+7' when supplying and '-7' when extracting at the maximum rate.

84 The way in which the two ventilation systems should be configured is scenario-specific, depending on such factors as which tunnel is affected, whether crossover doors are (or can be) closed and whether there are other trains in the same tunnel as the incident train. The scenarios are defined in Eurotunnel's procedures. The overriding requirement is to ensure that pressure in the service tunnel remains higher than that in the running tunnel, but that the difference in pressure is not so great as to create unacceptable air velocities through a cross passage when the door is open. Scenario-specific fan settings for the NVS and SVS are aimed at achieving this, together with strict discipline regarding the number of cross passage doors that can be open at any one time, the sequence in which they are opened and the speed at which other trains in the tunnel are permitted to move while cross passage doors are opened. The EMS Controller will normally configure the systems via a computer screen which prompts the Controller for specific information about the location and nature of the incident and adjusts the ventilation systems accordingly. Paper-based procedures are available as a back-up if the computer-based system fails.

85 Static smoke and flame detectors are installed at intervals of approximately 1500 metres in each running tunnel. These draw air through a pipe that is fixed around the tunnel lining and monitor it for ionised particles, smoke obscuration and carbon monoxide. Any detection is indicated to the RCC.

86 A fire main is provided in the service tunnel to supply fire fighting equipment. At each cross passage a branch leads to each running tunnel, which in turn splits into two branches providing a fire hydrant on each side of the cross passage door 75 metres from the cross passage.

Trains

87 Eurotunnel transports road vehicles through the Channel Tunnel between Folkestone and Calais on specially built shuttles. These shuttles comprise an electric locomotive at each end and a combination of loader and carrier wagons.

88 Cars and road coaches are carried on enclosed wagons while the passengers remain with their vehicles. Each wagon is separated from the adjacent ones by fire resistant screens containing a roller shutter and separate doors to permit people to pass from one wagon to another during the transit of the Channel Tunnel.

89 Should a fire be detected on a passenger shuttle, the safety principle is to contain the fire within the wagon concerned, moving any people on that wagon to those on either side. The shuttle continues its journey and is evacuated on leaving the tunnel where fire fighting takes place.

90 Shuttles for HGVs and other lorries comprise open sided wagons while the drivers and other occupants travel in a separate railway carriage, the AMC.

91 HGV shuttles comprise two locomotives, an AMC, up to 30 carrier wagons and three flat-bed loader wagons. The normal formation of these shuttles varies according to the type of carrier wagon and are as shown at Figure 8.

92 Both types of shuttle run around loops before entering each terminal so that the AMC remains at the front of the shuttle. Under certain operational or climatic conditions the loops cannot be used. The AMC will then be at the rear of the shuttle during the transit in one direction.

93 The carrier wagons are provided with a walkway along each side within the side framework. This enables the loading staff to pass the length of the shuttle examining and securing the lorries. Lorry drivers use this walkway when leaving and rejoining their vehicles.

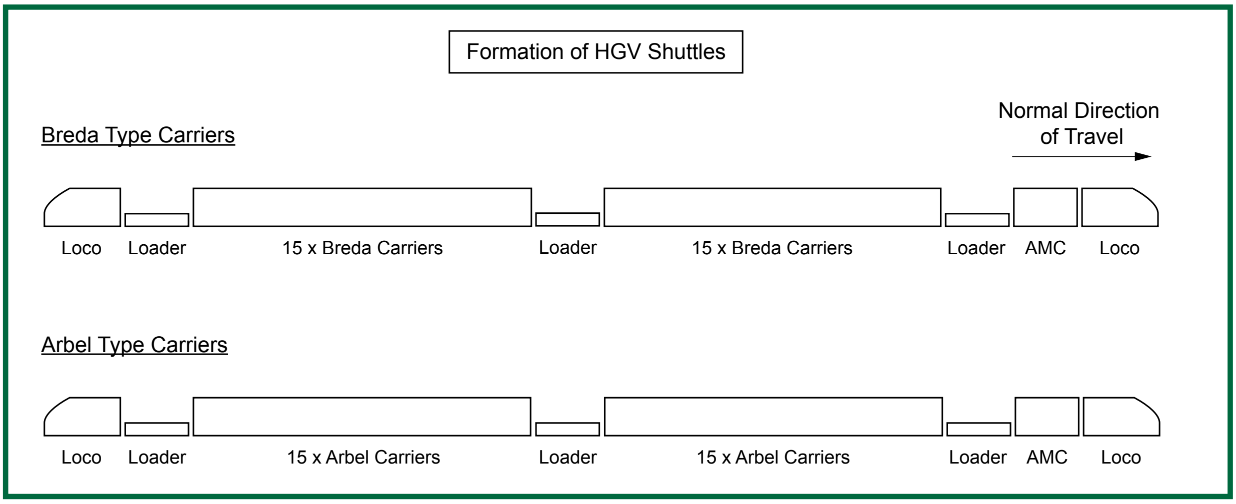

Figure 8: Diagram of HGV shuttle formations (Breda and Arbel)

94 The sides of the wagons are arranged to have one opening at floor level which allows the lorry drivers to pass to and from the platform.

95 The HGV wagons originally supplied were manufactured by Breda in Italy. They are constructed such that sides and roof contribute to their overall structural strength.

96 Subsequent wagons were supplied by Arbel from France and built to different principles. The strength of the wagon is provided by the *underframe* and the floor plates on which the lorries are parked. The roof is not structural and is fitted to give protection from the overhead catenary against such incidents as drivers climbing above lorry cab level or the possibility of lorry radio aerials causing a 'flash' to earth. Side frames are provided partly to support the roof but also to protect the loading staff. HGV shuttles operate with only one type of carrier wagon on any one train.

97 The shuttle involved in the fire was made up of Arbel wagons.

98 Smoke detectors are fitted to the end loader wagons of all trains. These sample air drawn in from the shuttle's annulus through an array of pipes and transmit any alarms to a panel located in the Chef de Train's cabin within the AMC.

99 The open nature of the wagons effectively prevents fire containment, leading to a different principle of fire protection, whereby the shuttle is stopped and people are evacuated to a place of safety in the service tunnel (see paragraphs 118 and 119).

100 The other trains passing through the Channel Tunnel are Eurostar passenger trains and conventional freight trains. Both are staffed by the companies operating them and use paths provided by Eurotunnel within the timetable.

Operations

101 Overall control of the railway elements of the Channel Tunnel system is exercised from the RCC. A shift Supervisor is in overall control of the RCC and there are a number of Controllers present who are responsible for specific aspects of the operation. The EMS Controller is responsible for the systems in the tunnel such as power supply, ventilation and lighting. The EMS Controller is also responsible for key items of equipment such as the PRD dampers, cross passage doors and crossover doors. The FD Controller is responsible for monitoring the status of fire detection stations in the tunnel. The RTM Controller is responsible for controlling train movements through the tunnel and is the principal point of contact for train drivers.

102 There is also a Terminals Controller for each of the French and UK terminals, with overall responsibility for the smooth operation of terminal processes such as the movement of lorries from the tolls to the shuttle trains and the safety of each location.

103 The drivers of lorries arriving for transit are initially processed at the toll booths. They then drive their lorries through the immigration and security controls to the specified holding lane to wait to be called forward to load their vehicles.

104 Random checks on the loads being transported are carried out by security contractors' staff, but this is directed towards the legality of the cargo and to confirm its general nature rather than establish the absence of a fire. To meet the requirements of the *Intergovernmental Commission* (IGC), certain highly dangerous goods are prohibited from being transported through the tunnel. Typically, these include bulk consignments of flammable compounds such as petrol, paint or adhesives, explosives or substances which are highly toxic or significantly corrosive.

105 When a shuttle is ready for loading, one or two lines of lorries are called forward and down one of two ramps onto the platform. The ramps issue onto the platform either at the centre or rear of the shuttle.

106 The leading lorry of each line is driven onto the shuttle across the loader wagon and forward until it reaches the carrier wagon before the next loader wagon, where it is signalled to stop by the loading staff. The following lorries are parked closely one behind another but not across the connections between carrier wagons or on the loader wagon.

107 Lorries are transported on the *rake* of carrier wagons ahead of the loader wagon across which they were driven onto the shuttle.

108 The driver secures the lorry, leaves the cab and steps from the shuttle onto the adjacent platform. He joins a bus which travels from the rear of either section of carrier wagons to the AMC.

109 The loading staff examine and chock the lorries, calling back the drivers of any lorries giving cause for concern.

110 As the drivers enter the AMC a head count is carried out to ensure agreement between the numbers of people checked in at the toll and those on the shuttle.

111 Once the shuttle is loaded, two of the loading staff (designated '*Agents de Feu*') remain to observe the departure for signs of fire or any other abnormal situation. One stands at platform level and the other on an overbridge. Both are close to the leading end of the shuttle before its departure and stand so that they observe different sides.

112 If an emergency requires a departing shuttle to be stopped, the RCC is contacted by radio or telephone and the requirement given to the RTM controller, who takes immediate action to stop the shuttle.

113 Each loading team is directly supervised by a Eurotunnel employee who is also responsible for driving the bus. The UK loading teams are employed by International Consultants Targeting Security (ICTS), a general security company contracted by Eurotunnel to provide security services in the UK terminal complex.

114 ICTS is contractually responsible for the recruitment, training, standards and management of the loading staff to Eurotunnel's requirements. Eurotunnel specify daily which shuttles are attended by which loading teams in accordance with the timetable.

115 The HGV shuttles are staffed by a driver and Chef de Train, both Eurotunnel staff, who remain on the locomotive and AMC respectively. Additional staff are employed to assist with the serving of food and beverages to lorry drivers during the transit.

116 Direct responsibility for the safety of those in the AMC rests with the Chef de Train. He is responsible for giving safety instructions and issuing safety equipment in the event of an incident.

Design development and fire safety strategy

117 The history of the design and development of the infrastructure and HGV shuttle design to address the risk of fire is summarised in Appendix E.

118 The key features of the safety concept established by the start of service in July 1994 for the transportation of lorries on HGV shuttles, and the associated demonstrations of safety, are summarised in Table 1.

Changes to the fire safety strategy following the HGV fire in November 1996

119 Following the major fire that occurred on an HGV shuttle on 18 November 1996 various additional safety measures were agreed with the IGC prior to the recommencement of HGV services in March 1997. These additional measures are summarised in Table 2.

Details of the incident

120 The events are described below in relation to each item of equipment and feature of the incident. A time line is provided in Appendix F which connects these events to each other in a single sequence.

The road vehicle involved

121 The lorry involved in the fire was owned and operated by AirSea Packing Group Ltd of Twickenham, Middlesex (Figure 9). It was a rigid chassis vehicle with separate cab and load compartment. The latter comprised an alloy and steel frame to which was attached the aluminium side panels and the roof. A side door to the rear of the near side and a full height rear tailgate gave access to the interior.

Figure 9: Incident HGV before the fire (photograph courtesy of Kent Police)

Safety measure	Demonstration
Loading staff to check HGVs for potential sources of fire and to check that refrigeration units are switched off.	
All HGV drivers to be conveyed in an amenity coach at the front or rear of the shuttle (i.e. separate from their vehicles).	
Presence of fire to be detected using tunnel mounted fire detectors (alarm transmitted to the RCC).	• Tested during commissioning. • Dynamic proving test performed using a steam locomotive.
Presence of fire to be detected using smoke detectors mounted on each loader wagon (alarm transmitted to the amenity coach).	• Prototype tested using a real fire on a moving flat-bed wagon on the Old Dalby test track. • Correct operation confirmed on actual HGV shuttles in the Channel Tunnel using artificial smoke.
RCC procedures to ensure that trains following an HGV shuttle with fire onboard are immediately stopped (in order to maximise the distance between the incident and the following train).	• Operational procedures tested during commissioning
Once fire is detected on an HGV shuttle it should continue to drive out of the tunnel.	• See item below
Fire resistance of the floor to protect the running gear, brakes and train lines for the time taken to drive out of the tunnel or to carry out a controlled stop if the route to the portal was not clear.	• Floor structure subjected to ISO 834 fire tests
If an HGV shuttle with fire onboard is stopped in the tunnel the SVS to be used to blow smoke away from the amenity coach thereby ensuring clear air conditions for evacuation into the service tunnel.	• A full scale fire test was carried out to demonstrate the capability of the specified airflow rates to control the backflow of hot gases generated by fires with heat outputs in excess of 100MW • The above tests supplemented by a programme of ⅓ scale fire tests at the Health and Safety Laboratory and computer numerical simulations
The amenity coach to resist heat and smoke for sufficient time to protect occupants whilst waiting for the SVS to blow smoke clear.	• Full scale fire tests performed using specially designed test rig
Design and procedures to enable the safe evacuation of train crew and passengers from the amenity coach to the service tunnel.	• Tunnel systems and associated operational procedures tested during commissioning
RTM/signalling system to impose a minimum 5 km distance behind each HGV shuttle to avoid a following train approaching too close. This would provide additional time for the following train to reverse before smoke reaches it.	• Tested as part of the signalling system during commissioning

Table 1: Summary of the fire safety strategy established at start of service (July 1994)

New/altered safety measure	Comment
First three carrier wagons next to the amenity coach to remain unloaded	This restriction was lifted on 30 September 1998. Currently there is a prohibition on the loading of HGVs with high fire loads on the three wagons closest to the amenity coach, the nature of the load being advised to Eurotunnel by the customer.
Loading staff to be deployed at the platform ends to observe the departure of shuttles in order to detect fire or smoke (Agents de Feu)	
Simplification of control room procedures and automation of emergency response actions	
Provision of a control room simulator	
Procedures altered to include a requirement for HGV shuttles to carry out a controlled stop following a confirmed fire alarm (except if the HGV shuttle is on the final approach to the portal)	
Smoke hoods provided in the amenity coach for use by the train crew and HGV drivers	
Improved seals to limit smoke ingress to the amenity coach	
Enhanced training for train crew on the management of evacuation (including use of full size simulation of a section of tunnel and an associated cross passage)	

Table 2: Summary of the additional safety measures established following the fire in November 1996

122 A service and safety inspection carried out on 9 August 2006 certified that the vehicle was in a roadworthy condition.

123 The lorry was loaded and its load compartment was sealed at the AirSea Packing premises in Twickenham.

124 This lorry was recorded on CCTV while the driver checked in at the toll booth, indicating its presence there at 12:45 hrs. No smoke was visible on the recording. The lorry was later driven onto Mission 7370 and parked at the front of the penultimate carrier wagon.

Actions during loading

125 Loading staff employed by ICTS walk the length of the shuttle inside the wagons to ensure that the lorries are made secure. They apply chocks each side of the lorries to front and rear wheels to prevent movement. They check that cab heaters are switched off, that fuel filler caps are correctly in place, that refrigeration units are not running and they also endeavour to ensure that nobody has remained in any cab. The loading staff also look for any signs of fire, particularly in the cab interiors and around the chassis level.

126 If any unusual situation is observed, the driver of the lorry in question is approached and the matter addressed.

127 This process took place normally on Mission 7370 with no untoward condition noted.

128 Once the shuttle is loaded, two loading staff move to the front of the shuttle to observe the departure from opposite sides of the shuttle as a final check for any unsafe condition and specifically an outbreak of fire. This duty is known as an 'Agent de Feu'. Usually, one stands at platform level and the other on the overbridge. As the Mission 7370 was departing from track 10, one was on the platform and the other at ground level (it was not possible to stand on that particular overbridge because of poor visibility from the overbridge at that platform).

129 Neither Agent de Feu noted anything out of order when the shuttle departed from the loading platform.

Evidence from CCTV at the tunnel portal

130 CCTV cameras are installed within the terminal complex. The output from these cameras is not monitored continuously, though the data is stored for up to seven days. However, as soon as an incident is announced the data is retained until the appropriate authority either collects the tape or issues written permission for it to be reused. One such camera is directed to departing trains and shuttles shortly before they enter the tunnel, positioned so that they are seen going away from the camera.

131 Examination of the black and white images recorded by this camera showed that the shuttle forming Mission 7370 was running at the expected speed of the order of 50 km/h as it approached the tunnel portal.

132 These images also showed what appear to be at least three discrete emissions of smoke from the top of the lorry in question on the left hand side facing in the direction of travel as it approached the tunnel portal.

Tunnel fire detection system

133 The time and location of fire alarms registered by the tunnel fire detection system are plotted on the graph at Figure 10.

134 The first indication to the RCC that an incident was developing occurred when the ionisation smoke detectors in the fire detector station SD08, 6.2 km from the UK portal, registered an alarm. This detection caused the RCC to impose a verbal speed restriction of 100 km/h on all shuttles at 13:31 hrs.

135 Detector station SD10 registered nothing, but the ionisation smoke detectors in SD12, SD14, SD18 and SD22 registered smoke. The ionisation smoke detectors at SD22 and SD26 registered smoke and also detected flames.

136 The times at which detection occurred are commensurate with the progress of the shuttle through the tunnel until it stopped with the fire located 310 m west of SD28.

137 One minute after the shuttle first came to a stand smoke and high CO levels were detected at SD28. This shows that the smoke had been pushed forward towards the front of the shuttle by the residual airflows once it had come to a stand.

138 All detector stations between the site of the fire and the Shakespeare Cliff ventilation shaft registered the presence of smoke and carbon monoxide between 13:50 hrs and 14:58 hrs as the plug of smoke and other combustion products was drawn back along the tunnel to the ventilation shaft through the action of the SVS.

139 The dispersion of carbon monoxide was registered by a reduction below the dangerous concentration about an hour later with full dispersion occurring after approximately a further 30 minutes.

140 The recorded activation of detectors thus corresponds with the movement of the shuttle and the associated tunnel airflows.

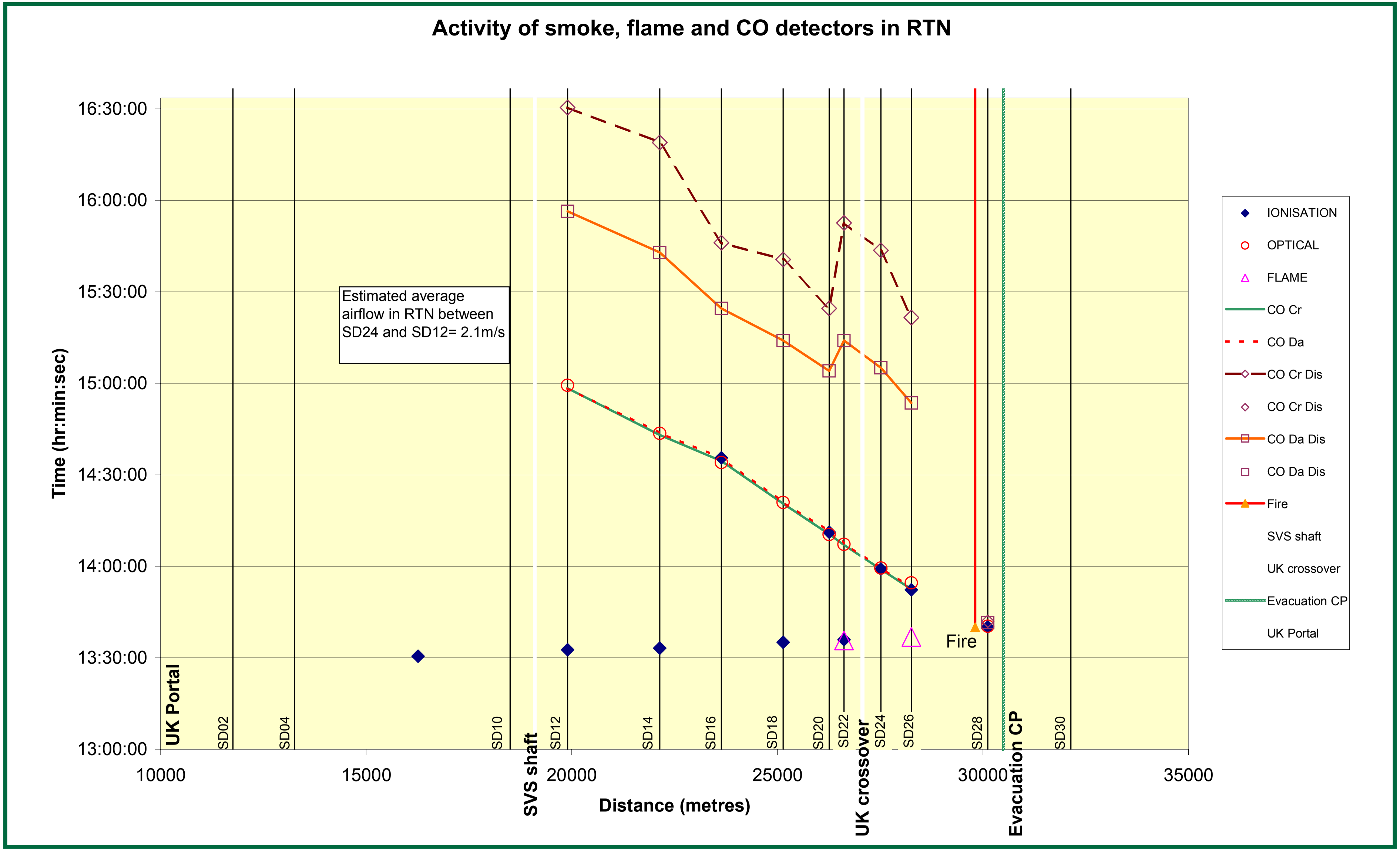

Figure 10: Graph showing sequence of activation of fire detectors

Actions in the RCC

141 The RCC controls the Eurotunnel railway operation including the signalling and control of all trains passing through the tunnel. An overview of the function and staffing of the RCC is provided in paragraph 101. In addition to the Supervisor in charge of the RCC, there were three key posts with tasks to perform during the handling of the fire on Mission 7370. Those posts were the Rail Traffic Management (RTM) Controller, the Engineering Management Systems (EMS) Controller and the Fire Detection (FD) Controller.

142 The tasks to be performed by each post are defined within procedures manuals, with each post having its own manual. In the event that emergency procedures need to be implemented, some actions are automated to the extent that one action by the relevant controller results in a number of other actions being undertaken automatically. Table 5 provides an illustration of this feature; the EMS controller has only to input the relevant tunnel in which the incident has occurred (Running Tunnel North or Running Tunnel South) for the system to close the appropriate *air distribution units* (ADU) between the service tunnel and the running tunnel, close PRD dampers to isolate the two tunnels and switch on tunnel lighting. However, in some cases, the controller has the option to undertake each action separately. This is discussed further in paragraph 158.

143 In the event of a fire on a shuttle, the actions in the RCC are governed by the nature of the alarm that is received, which is defined as Level 1 or Level 2. The fire detection stations contain an ionisation smoke detector, an optical smoke detector and a flame detector. If either of the smoke detectors is activated, a Level 1 alarm is declared. If the flame detector or two smoke detectors are activated, a Level 2 alarm is declared. A Level 2 alarm is also declared if single ionisation or optical smoke detector is activated in two consecutive detector stations.

144 The declaration of the level of the alarm is made in the RCC by the Supervisor, based on the information on the status of fire detection equipment supplied to him or her by the FD Controller.

145 The RTM Controller was responsible for the interface between the RCC and trains (including Mission 7370), supervising train movements on the Channel Tunnel system. In the first instance, the RTM Controller's actions were triggered by the declaration of a Level 1 alarm. The actions taken are precautionary. They include the temporary suspension of departures from both terminals, the stopping of trains following the one that is believed to have activated the alarm and slowing other trains in the tunnel. The actions lay the foundations for a rapid and effective response to a Level 2 alarm without bringing operations in the tunnel to a near standstill.

146 The Level 1 alarm was declared at 13:30:31 hrs. Table 3 sets out the principal procedural actions that should be taken by the RTM Controller on receipt of the Level 1 alarm and compares them with the actions taken on the day.

147 If no further alarms are triggered, then the steps described in Table 3 are rescinded by the RTM Controller and the tunnel is returned to normal operation. However, Mission 7370, having failed to trigger the next smoke detector, then triggered two consecutive detectors at CPs 1990 and 2214 at 13:32:39 hrs and 13:33:10 hrs respectively, which caused the RCC Supervisor to declare a Level 2 alarm. The actions now taken by the RTM Controller are geared towards stopping the incident train at a suitable cross passage and ensuring that conditions in the tunnel are appropriate for an evacuation to take place. The Level 2 alarm was declared by the Supervisor at 13:33:20 hrs. Table 4 sets out the principal procedural actions that should be taken by the RTM Controller on receipt of the Level 2 alarm and compares them with the actions taken on the day.

Principal Procedural Requirements	Whether Implemented by RTM Controller	Comment
Send a stop command to trains following the train that has activated the alarm.	Not applicable	No following train
Make a general call to all trains in both running tunnels to reduce their speed to 100 km/h	Yes	Response implemented 29 seconds after Mission 7370 activated the smoke detector in CP 1626
Ask all trains in both running tunnels to close their air conditioning intakes	No	Not carried out.
Switch terminal operation to manual mode	Yes	Response implemented 40 seconds after Mission 7370 activated the smoke detector in CP 1626

Table 3: Procedural requirements and actions taken by the RTM Controller on declaration of a Level 1 alarm

Principal Procedural Requirements	Whether Implemented by RTM Controller	Comment
Use the track-to-train radio system to order the incident train to stop	Yes	Action taken c.40 seconds after Level 2 incident declared
Order trains in both tunnels to run at 10 km/h	Yes	Action taken c.100 seconds after Level 2 incident declared
Establish which cross passage door is to be opened for evacuation	Yes	This driver of the incident train would normally provide this information but the RTM Controller requested it on this occasion.

Table 4: Procedural requirements and actions taken by the RTM Controller on declaration of a Level 2 alarm

148 There is no requirement for the RTM Controller to give authority for evacuation to commence in the circumstances prevailing on 21 August 2006 because the Chef de Train is permitted by the procedures governing an evacuation from an HGV Shuttle Train to make that decision based on a number of criteria including the temperature outside the shuttle, visibility and whether a cross passage can be seen and is open. In the event, the RTM Controller did give authority for evacuation to take place.

149 The two requests for trains in the tunnel to reduce speed (to 100 km/h after the Level 1 alarm and to 10 km/h after the Level 2 alarm as described in paragraphs 37 and 38) are made via the *track-to-train radio* (TTR) system and subsequently enforced through the *TVM signalling* system. While all trains responded to the RTM Controller's radio request to reduce speed to 100 km/h and were therefore travelling at that speed when it was enforced through the signalling system, two shuttles in the Running Tunnel South did not respond to the RTM Controller's request to reduce speed to 10 km/h. As a result, when the TVM system imposed the lowest speed limit possible (30 km/h), Missions 7367 and 7369 were still running at 100 km/h and were brought to an emergency stop by the 'unexpected' change in *speed code*.

150 The procedural response for drivers in these circumstances is to call in to the RTM Controller to report the unexpected change in signalling speed code, which both drivers did. The RTM Controller explained the circumstances to the two drivers but did not emphasise that when they restarted, they should limit their speed to 10 km/h. Both drivers should have been aware of this requirement once the circumstances had been explained to them. However, with the TVM system only able to enforce a lowest speed of 30 km/h, both drivers accelerated to that speed. The RTM Controller realised that they were proceeding too quickly within 3 minutes of restarting and contacted the drivers to ask for the shuttles to be slowed to 10 km/h.

151 The remainder of the actions taken by the RTM Controller were dictated by the need to clear the tunnel of all remaining trains which was accomplished when Mission 7369 left the Running Tunnel South at approximately 14:20 hrs. Had it been decided to evacuate the crew and passengers from Mission 7370 from the service tunnel to the terminal by means of an evacuation train in the Running Tunnel South, the responsibility for arranging this would have fallen to the RTM Controller. However, the decision was taken to evacuate these people via the service tunnel using STTS vehicles.

152 The EMS Controller is responsible for managing tunnel systems such as lighting, heating, ventilation and power supply. The EMS Controller also operates equipment such as the CPDs, crossover doors and the PRD dampers, which are closed when it is necessary to ensure that the Running Tunnel South and the Running Tunnel North are isolated from each other. In the event of an emergency involving a fire in the tunnel and the need to evacuate passengers and crew from a train to the service tunnel, the EMS Controller's responsibility is to ensure that the necessary adjustments are made to tunnel systems to facilitate the safety of passengers, crew and fire fighters.

153 As with the RTM Controller, the EMS Controller's actions are triggered by a statement from the Supervisor that a Level 1 alarm has been declared. The actions taken by the EMS Controller once the Level 1 alarm is declared are also precautionary. The Level 1 alarm was declared at 13:30:31 hrs. Table 5 sets out the principal procedural actions that should be taken by the EMS Controller on receipt of the Level 1 alarm and compares them with the actions taken on the day. In practice, the EMS Controller has only to initiate the sequence of actions by identifying that a Level 1 alarm has occurred in either the Running Tunnel South or the Running Tunnel North on a computer screen; the three actions listed below are then taken 'automatically' without further intervention from the EMS Controller. The sequence of actions was triggered by the EMS Controller at 13:32:06 hrs, 95 seconds after the first alarm was received:

Principal Procedural Requirements	Whether Implemented by EMS Controller	Comment
Close all Air Distribution Units in the non-incident tunnel	Yes (automatic after EMC Controller identifies incident tunnel on screen)	Closures started 11 seconds after sequence initiated
Adjust the Normal Ventilation System at both English and French stations to +5	Yes (automatic after EMC Controller identifies incident tunnel on screen)	NVS adjusted 12 seconds after sequence initiated
Switch on the lighting in the tunnel	Yes (automatic after EMC Controller identifies incident tunnel on screen)	Lighting on 6 seconds after sequence initiated

Table 5: Procedural requirements and actions taken by the EMS Controller on declaration of a Level 1 alarm

154 As soon as the Level 2 alarm is declared, the EMS Controller must initially take steps to ensure that the two tunnels are physically isolated. This involves closure of the PRD dampers and, if necessary, closure of the crossover doors and cross passage doors. In practice, CPDs and crossover doors are only likely to be open during overnight maintenance activities when trains are not running in one of the six tunnel intervals.

155 Beyond the physical separation of the two tunnels, the EMS Controller is also required to establish a ventilation regime which facilitates the evacuation of passengers and crew from the running tunnel to the service tunnel in clean air conditions and to open and close CPDs to enable evacuation and fire fighting.

156 The Level 2 alarm was declared by the Supervisor at 13:33:20 hrs. Table 6 sets out the principal procedural actions that should be taken by the EMS Controller on receipt of the Level 2 alarm and compares them with the actions taken on the day. Again, in practice, some of these steps are implemented by a computerised system, which the EMS Controller activates on the screen by inputting specific details about the location of the incident which enables 'the system' to select the most appropriate response:

Principal Procedural Requirements	Whether Implemented by EMS Controller	Comment
Close all Piston Relief Duct Dampers	Yes (automatic)	Closure sequence started 22 seconds after second alarm declared by Supervisor
Close crossover doors (if necessary)	Not applicable	Already closed
Close cross passage doors (if necessary)	Not applicable	None open
Once the RTM Controller has arranged for the 10 km/h speed limit to be imposed, switch on the Supplementary Ventilation System to direct smoke away from evacuating passengers	Yes	SVS initiated at 13:36:57 hrs, approximately two minutes after the RTM Controller had broadcast the 10 km/h speed restriction
Once the RTM Controller has confirmed that the incident train has stopped and its location, open the appropriate cross passage doors for evacuation	Yes	Cross passage doors were opened before the stopping location of Mission 7370 had been established

Table 6: Procedural requirements and actions taken by the EMS Controller on declaration of a Level 2 alarm

157 The EMS Controller anticipated the final stopping position of Mission 7370 and opened two CPDs before confirmation had been received from the RTM Controller that the shuttle was stationary in its final stopping position. In the event, although Mission 7370 did move forward to position the AMC door adjacent the cross passage accurately, the doors opened by the EMS Controller were the appropriate ones for evacuation to take place.

158 Although the initiation of the SVS was undertaken promptly and the EMS Controller used the computerised system to set up the necessary airflow, the conditions for evacuating passengers and crew were suboptimal. The SVS fans are initially configured to supply air to both running tunnels at the maximum rate, using two fans in each ventilation plant.

The EMS Controller then refines the default settings by identifying which tunnel needs to be ventilated and the fan settings required, which are dependent on where the incident is located within that tunnel. As part of the transition from the default setting to the bespoke setting for the incident, the damper between the ventilation shaft and the non-incident tunnel is closed and one fan at each plant is switched off. The EMS Controller adjusted the fan settings for the scenario before identifying the incident tunnel to the system. This resulted in a single fan at each ventilation plant ventilating both running tunnels, thereby providing approximately half of the desired airflow in the incident tunnel. Paragraph 142 refers to automated procedures. Had the EMS Controller firstly input Running Tunnel North to the system as the incident tunnel, the system would have shut the dampers to Running Tunnel South as part of the sequence of shutting down one fan at each station, thereby maintaining the optimum airflow past the incident train. The detailed sequence of events is illustrated in Table 7.

Time	Ventilation System Event	Comment
13:36:57	UK and French SVS start command from EMS Controller. Direction of airflow governed by an HGV Shuttle being involved with the AMC at the front of the train (airflow directed away from the front of the train)	French SVS on supply, UK on exhaust. Both fans at each plant started. Tunnel not being ventilated at this stage because dampers to the Running Tunnel North and the Running Tunnel South are closed
13:38:55	UK SVS dampers to the Running Tunnel North and the Running Tunnel South opened	
13:39:34	French SVS dampers to the Running Tunnel North and the Running Tunnel South opened	Both running tunnels are now being ventilated by both fans operating at each plant
13:41:01	(UK SVS configuration fault)	This issue is dealt with separately within this report (see paragraph 295)
13:41:32	(UK SVS configuration fault cleared)	
13:42:31	EMS Controller reduces the UK SVS to a single fan operating	
13:42:50	UK SVS blade angle 4 selected by EMS Controller	This is the correct blade angle for this scenario
c.13:43:00	(Evacuation commences from Mission 7370)	
13:43:09	EMS Controller reduces the French SVS to a single fan operating	At this stage, both running tunnels are being ventilated by a single fan operating in each plant resulting in only half of the desired airflow past the incident shuttle.
13:46:36	UK SVS damper closed to the Running Tunnel South	
13:46:42	French SVS damper closed to the Running Tunnel South	Running Tunnel North only is now being ventilated by a single fan operating at each plant (the correct configuration for this scenario)
c.13:49:00	(Evacuation completed from Mission 7370)	For approximately half the time evacuation was taking place, the SVS airflow in Running Tunnel North was only 50 % of that identified within Eurotunnel's procedures as being required for this scenario

Table 7: Detailed breakdown of key events associated with operation of the supplementary ventilation system

159 It can be seen from Table 7 that for a short period when evacuation was taking place, the SVS configuration had been reduced to a single fan in each plant but with the dampers open to both running tunnels. This would have resulted in a rate of airflow in the Running Tunnel North that was approximately 50 % below that required for this scenario. In the conditions present on 21 August 2006 (relatively small fire located at the rear of the shuttle), it is unlikely that this reduced airflow would have affected the ability of the SVS to control the direction of smoke movement. However, it would have had more serious implications if the fire had been bigger or if it had been located closer to the front of the shuttle.

160 The FD Controller is responsible for monitoring the performance of the fire detection systems in the tunnel and in the event of smoke being detected, advising the RCC Supervisor of the nature of the alarm(s) and their location. This action is taken verbally as the FD Controller is located in close proximity to the Supervisor. Although there is no record of when the FD Controller alerted the RCC to the initial alarm, that the RTM Controller had commenced his response to a first alarm within 29 seconds of smoke detector activation indicates that the FD Controller and the Supervisor responded promptly to the initial alarm.

161 The FD Controller continued to advise the RCC Supervisor of the activation of alarms. After smoke detectors in two consecutive detection stations had been activated at 13:33:10 hrs, the Supervisor declared a Level 2 alarm. As the RCC Supervisor declared a second alarm at 13:33:20 hrs, this is an indication that the FD Controller responded immediately to the activation of the second consecutive detector.

162 Once the Level 2 alarm is declared, the FD Controller has a number of responsibilities with regard to initiating the deployment of internal and external emergency response teams to the scene of the incident. Table 8 sets out the principal procedural actions that should be taken by the FD Controller on receipt of the Level 2 alarm (at 13:33:20 hrs) and compares them with the actions taken on the day.

Principal Procedural Requirements	Whether Implemented by FD Controller	Comment
Call both FEMCs and request deployment of FLOR for a second alarm stopping train incident	Yes	By 13:35:00 hrs, both FLORs had been asked to deploy to the tunnel; train stopping point not known at this stage
Order opening of airlock doors to allow FLOR to enter, starting with doors nearest to the incident	Yes	Service Tunnel airlock initially into local mode on French side at 13:36:07 hrs. UK FLOR already in Service Tunnel
Advise FLORs of CP location where train has stopped and details of type of train involved	Yes	Shuttle involved identified to UK FLOR at 13:35 hrs and stopping position of shuttle at 13:44 hrs
Alert the emergency services	Yes	Calls made to UK emergency services starting at 13:36 hrs.
Continue to monitor alarms particularly with regard to CO levels and report to Supervisor and FLOR immediately	Yes	High CO levels advised to and discussed with FLOR at 13:44 hrs, 13:54 hrs and 14:23 hrs.

Table 8: Procedural requirements and actions taken by the FD Controller on declaration of a Level 2 alarm

163 Table 8 shows that the actions of the FD Controller were timely and appropriate. One specific issue that did arise directly from the FD Controller's actions was a delay in achieving a response from the Police and Ambulance Service in the UK. The individuals with whom the FD Controller made contact were unable to recognise the Channel Tunnel as a location in its own right and sought clarification by means of a post code. The FD Controller did not have this information readily to hand and this resulted in a delay in completing the calls to the UK emergency services until the necessary information could be obtained.

Actions on the shuttle

164 Mission 7370 departed from the UK terminal at approximately 13:25 hrs, entering the tunnel about a minute later. The crew on board were a driver, a Chef de Train and a contractor who was responsible for serving meals to the HGV drivers on board. One of the passengers on board was an RCC Controller travelling from the UK to France to take up a shift at 14:30 hrs. Everyone on the shuttle apart from the driver was located in the AMC, positioned immediately behind the leading locomotive.

165 At approximately 13:30:45 hrs, the Chef de Train received a fire detection indication on his panel. Fire detectors are located on the front and rear loading vehicles of each shuttle and the indication on the panel shows which alarm(s) have activated. In this case, only the alarm on the rear loading vehicle activated. The Chef de Train immediately advised the driver of Mission 7370, who received the message at the same time as he was also receiving a message from the RTM Controller to slow to 100 km/h (approximately 13:31 hrs). The driver responded to the request to slow to 100 km/h but took no action in relation to the information from the Chef de Train. Meanwhile, the Chef de Train issued a preliminary warning to the passengers and catering contractor in the AMC that an evacuation might be necessary.

166 A Level 2 alarm was declared at 13:33:20 hrs and the RTM Controller ordered Mission 7370 to make a controlled stop at 13:34 hrs. The driver advised the Chef de Train that a controlled stop was necessary, but that it could not be made immediately because the shuttle was approaching the 'go zone' at the UK crossover. Drivers are instructed to avoid stopping in the 'go zone' if possible, since doing so for an evacuation could result in the train stopping in the proximity of the crossover where the two running tunnel lines are connected as described in paragraph 78. Were this to happen, it would make the evacuation more difficult because the service tunnel is at a different level from the running tunnels and can only be accessed via stairs, there is no continuous walkway and the larger tunnel cross-section makes smoke control more difficult to achieve. The decision whether or not to stop in the 'go zone' rests with the driver.

167 Given the time the shuttle had been in the tunnel, the driver knew that the 'go zone' was imminent. He therefore continued at 100 km/h until the shuttle had cleared the UK crossover and was also clear of any cross passages located in the 'go zone'. The implication of this was a delay in stopping the shuttle for evacuation purposes. The need to continue beyond the crossover delayed the stopping (and therefore evacuation) of the shuttle by approximately three and a half minutes.

168 Cumulative delays totalling a further one minute were caused by two other factors:

- The driver stopped Mission 7370 two cross passages beyond the first standard cross passage that could have been used for evacuation.
- Having stopped the shuttle, the driver moved it forward again for a few metres in order to ensure that the AMC was positioned alongside the cross passage.

169 Mission 7370 stopped in position for evacuation at approximately 13:40 hrs, some six minutes after the order to stop was given by the RTM Controller. Once stationary, the driver received a call from the RTM Controller to establish the stopping position of the shuttle. Permission was given by the RCC for the shuttle to be evacuated and the driver informed the Chef de Train accordingly. The Chef de Train, in the meantime, had prepared the passengers for evacuation by briefing them on what was to take place and issuing them with smoke hoods. He was assisted in this activity by the catering contractor.

The evacuation

170 The Chef de Train and driver organised the evacuation of passengers from the AMC to the service tunnel. As the amenity coach of Mission 7370 had been positioned adjacent to a cross passage, the evacuation was straightforward and accomplished in approximately four minutes. The exact timing of the evacuation is not known, but confirmation of the shuttle's stopping position was obtained at around 13:41 hrs. After finally checking that no-one had been left in the AMC and taking a headcount of people evacuated to the service tunnel, the Chef de Train confirmed that everyone had been evacuated safely at approximately 13:49 hrs.

171 There were no injuries sustained by anybody during the evacuation, which was accomplished in accordance with the procedures. At no time during the evacuation were the crew aware of the presence of fire or smoke in the tunnel or on their shuttle.

Events following the evacuation

172 This section contains details of the key steps taken from the time that evacuation of passengers and crew was completed to the point at which normal operations were resumed through all of the tunnel intervals. It includes details on the overall management of the incident and the tactical intervention of the team deployed to fight the fire on the HGV shuttle.

Exit of passengers and train crew from the service tunnel

173 The key timings in the evacuation of passengers and crew from the service tunnel to the French terminal are summarised in Table 9.

Time	Event	Comment
13:49	Evacuation into Service Tunnel complete	
13:59	EMS Controller asks for STTS vehicles to be made available to evacuate passengers and crew from tunnel to the French terminal	Early decision to use the STTS for evacuation
14:22	Confirmation from MCC to the EMS Controller that sufficient vehicles were available	Two vehicles and drivers required
14:40	Vehicles despatched from the French terminal to the tunnel	
14:48	Two STTS vehicles through airlock into tunnel	
c.15:20	STTS vehicles arrive on site for evacuation	
c.15:25	STTS vehicles depart for the French terminal with all evacuated passengers and crew on board except the driver of Mission7370 who remained on site in case it was necessary for him to move the shuttle	
c.16:05	Two STTS vehicles through the airlock	
c.16:15	STTS vehicles arrive at French terminal	Total evacuation time c.2.5 hours

Table 9: Key events in the evacuation of crew and passengers out of the service tunnel

174 It is probable that the passengers and crew evacuated from Mission 7370 could have reached one of the terminals more quickly if they had been evacuated from the tunnel by means of a shuttle train in RTS rather than travelling on STTS vehicles in the service tunnel. Mission 7369 (an HGV Shuttle) in RTS had not yet passed the location of the incident at the time that evacuation took place and could have been stopped to allow those evacuated from Mission 7370 to board. It is likely that the evacuated passengers would have reached the UK terminal up to 90 minutes earlier than they actually arrived in the French terminal.

175 However, the use of a train in RTS to evacuate passengers and crew from Mission 7370 would have created further hazards. At the time that they would have been boarding Mission 7369 in RTS, the FLOR was also on site and needing to gain access to RTN to evaluate the fire and make preparations for fighting it. The 'safe haven' of the service tunnel is achieved by maintaining it at a higher pressure than the two adjacent running tunnels. When a CPD is open, there is a reduction in the pressure differential between the service tunnel and the relevant running tunnel. If too many CPDs are opened, there is a danger that the pressure differential is reversed and the service tunnel drops to a lower pressure than the running tunnel. If there is smoke in the running tunnel, this can then be sucked into the service tunnel, thereby breaching the safe haven.

176 The simultaneous opening of CPDs to both running tunnels is prohibited in Eurotunnel's procedures, but it is still possible that a mistake could be made and too many doors opened at once. If that happens, it results in the three tunnels being aerodynamically linked and renders the service tunnel safe haven vulnerable to adverse effects of train movement in any part of either running tunnel. For example, a train moving out of RTS when CPDs are open to RTN and RTS may lead to air (and, in this case, smoke) being pulled from RTN, through the service tunnel to RTS, thereby jeopardising the FLOR and SLOR in the service tunnel, the passengers and crew from Mission 7370 evacuating to Mission 7369 and the passengers and crew on Mission 7369.

177 Assuming that the procedures had been implemented correctly, the FLOR would have been prevented from entering RTN until the passengers and crew from Mission 7370 had been evacuated onto Mission 7369 in RTS. The need to undertake this operation with care would have added an unnecessary complication to the emergency operation to deal with the incident. The RAIB considers that the decision to use the STTS rather than a train in RTS to evacuate the passengers from Mission 7370 did not compromise their safety and had the benefit of permitting the FLOR and SLOR to commence their own activities in a safe and timely manner.

178 The aspiration expressed in the *Concession Agreement* is that passengers and crew should be evacuated in 90 minutes from the tunnel. This was not achieved in the circumstances present on the day; the service tunnel vehicles had to come from the farther (French) terminal which affected the STTS vehicles' transit times into and out of the tunnel. It took 41 minutes from the request being made for the STTS to the time that the vehicles actually left the French terminal, the delay being attributed to finding drivers for the vehicles. Although the evacuation time could have been reduced if STTS drivers had been made available earlier, the safety of the evacuated passengers was not compromised by the delay as they were located in a place of safety. Evacuation in less than 90 minutes might have been possible had a shuttle in RTS been used instead of the STTS. Paragraphs 175-177 explain why the RAIB believes that Eurotunnel were right to use the STTS and incur the longer evacuation times rather than risk the safety of passengers and staff by using a train in RTS for the purposes of evacuation.

Firefighting

179 The UK FLOR was the first fire fighting team to arrive on site at 13:54 hrs. The FLOR comprises 4 fire fighters with emergency equipment travelling in an STTS vehicle.

180 There was no sign of a fire in the vicinity of CPDs 3050 and 3088 when they were opened at 14:02 hrs to enable the UK FLOR to inspect the train. At 14:15 hrs the UK FLOR requested that both those CPDs be closed as they were moving to CP2974 to investigate the situation there. At 14:27 hrs CP2974 was opened for the UK FLOR who found smoke but no flames. The CP was closed at 14:29 hrs.

181 BINAT, the process of alerting all resources that an incident is to be declared bi-national rather than local, that resources are expected to be required from both sides of the Channel and that bi-nationally agreed procedures are to be implemented, was initiated at 14:40 hrs. In the event of BINAT being declared in connection with an incident on the UK side of the frontier, it is the responsibility of Kent police to alert the French civil authority of a BINAT declaration.

182 Although the catenary had tripped at approximately 13:41 hrs, and had been kept electrically isolated, KF&RS requested that it be earthed before fire fighting started. The head count had confirmed that all passengers and train crew had been evacuated to a place of safety. Since the fire remained confined to the running tunnel there was no danger to life. Consequently, KF&RS were unwilling to expose their fire fighters to the increased risk posed by the absence of earthing in accordance with their risk assessed procedures.

183 The catenary was earthed by Eurotunnel staff by applying local earths close to the fire on the French side and at the UK portal. At 15:41 hrs the EMS confirmed this to the UK FLOR. The UK FLOR responded that they would start fire fighting and reported at 16:05 hrs that the fire had been extinguished and smoke clearance had begun.

184 BINAT was withdrawn at 17:03 hrs.

Overall management of the incident

185 The responsibility for managing the incident initially fell to the Supervisor in the RCC. The work performed by the three key controllers (RTM, EMS and FD) has been described above. The Supervisor, within a minute of declaring the Level 2 alarm and arranging for Mission 7370 to be stopped had also contacted the Rail Operations Manager, who, in turn arranged for the EMS Manager to go to the RCC immediately.

186 Eurotunnel's own structure for dealing with emergency incidents is for a senior manager to coordinate and direct the incident, at least initially. This position, designated as the *Emergency On-Call Director* (EOCD), is covered by senior Eurotunnel managers on rotation (one week in eight). On 21 August 2006, the EOCD's role was being covered by a member of staff who was working at the French terminal and he was able to go to the RCC as this was also being run from France on that day. The EOCD receives support from an *Emergency Operations On Call Coordinator* (EOCC), who may be the shift Operations Duty Manager stepping into this role.

187 For significant incidents, such as that which occurred on 21 August 2006, a Incident Co-ordination Centre (ICC) is established adjacent to the RCC. The ICC was therefore located in France. The EOCD, who takes charge, is normally located in the ICC together with other senior Eurotunnel staff to assist. In addition, senior Eurotunnel personnel located in the other terminal (in this case, the UK terminal) establish a video link with the ICC for that incident, using the ICC room at the other terminal. The UK Freight Terminal Manager established a video link with the ICC in France. His principal role was to support the EOCD in France and provide a point of contact with senior personnel from the emergency services when they arrived in the UK ICC room.

188 Over the course of the first sixty minutes of the incident, Eurotunnel's EOCD remained in charge. During that time, he made decisions regarding the evacuation of the passengers and crew from the service tunnel to the French terminal and monitored the information coming from the response teams who had been sent to fight the fire. The role of EOCD also has a commercial dimension; taking decisions about when to close the terminal(s) for incoming road traffic and liaising with other operators such as SNCF, Eurostar and EWS who use the tunnel. The EOCD also decides when to invoke the reciprocal arrangements Eurotunnel has with ferry operators for dealing with service suspensions.

189 Approximately one hour after Mission 7370 stopped in the tunnel for evacuation, a bi-national (BINAT) incident was declared. Most incidents are located wholly within either the French or the UK section of the tunnel. The use of the BINAT procedure permits emergency response staff from one nation to cross the tunnel mid-point for the purposes of supporting their counterparts from the nation in which the incident is located. Responsibility for declaring BINAT resides with the lead nation. In this case, as the incident had occurred within the UK section of the tunnel, BINAT was declared by the FLOR on the UK side.

190 BINAT was declared at 14:40 hrs. At around the same time, responsibility for coordinating the incident was assumed by *Silver Command* in the UK ICC, supported by the ICC already established in France and the RCC. During the time that the BINAT was in force, firefighting was undertaken and the passengers and crew from Mission 7370 were evacuated from the tunnel. Once the firefighting phase was completed and the work of the FLOR and SLOR largely complete, the BINAT was ended at 17:03 hrs. Eurotunnel began preparations for the restoration of train services through the tunnel.

191 During the incident, there were some issues associated with communication between the teams working in the service tunnel and fighting the fire on the one hand and those in charge of strategy in the ICC (Eurotunnel and emergency services) on the other:

- With the UK FLOR and SLOR fighting the fire, they were in the best position to relay details of the situation in the running tunnel to those at the surface. The flow of communication from these teams was sporadic. In particular, the EMS Controller, who was responsible for ensuring that all tunnel systems were configured correctly for the firefighting activity, had very little contact with the FLOR team who would have been able to relay details about conditions in the tunnel and receive information about changes made to systems in order to facilitate their activities.

- More information was supplied by the French FLOR, although they were not involved in fighting the fire and did not always have accurate information about the activities that were taking place. This resulted in confusion over who was fighting the fire (at one stage, it was thought in the ICC that the French FLOR was fighting the fire). Conflicting information was also supplied by the French FLOR regarding the source of the fire (at one time alleged to be in the refrigeration unit of a HGV and then on the rear locomotive of the shuttle).

- The communication routes from the tunnel to the surface were not unified. The primary means of communication from the French FLOR was to the French Incident Control Room, which was not the primary incident control room once the BINAT had been declared (paragraph 190). The UK FLOR communicated directly with Kent Fire & Rescue and this information was then relayed directly to the ICC in the UK. In addition, both FLORs had a line of communication to their respective *Fire & Emergency Management Centres* (FEMC).

192 Rescue services from both sides of the Channel and the Kent Police were involved in the immediate response to the incident. Both the Fire and Rescue Service and Police conducted their own internal debriefs, followed by a formal joint debrief from which an action matrix was produced. It is understood that no meeting has been held between these organisations and Eurotunnel to review the incident and establish lessons to be learnt, though Eurotunnel intend to hold a debrief with external parties after the publication of the RAIB report.

Restoration of service

193 The shuttle which had formed Mission 7370 had come to a stand in Interval 4 clear of the crossovers, permitting Intervals 2 and 6 to be reopened.

194 On the withdrawal of BINAT, commercial operations were resumed in the Running Tunnel South. There was residual smoke in this tunnel and to clear it a passenger shuttle was run empty as Mission 6438, leaving the UK terminal at 17:23 hrs. The first of a flight of 5 Eurostar trains followed entering the tunnel at 17:29 hrs.

195 Interval 6 in the Running Tunnel North was opened to traffic at 18:20 hrs. The first of a flight of 5 Eurostar trains left France for the UK at 18:31 hrs, followed at 19:04 hrs by 2 loaded shuttles.

196 Interval 2 in the Running Tunnel North was opened at 19:35 hrs and at 20:00 hrs the first loaded Eurotunnel shuttles left the UK for France.

197 Repair work was undertaken in Interval 4 in the Running Tunnel North after the shuttle had been removed. This interval was reinstated and normal working resumed at 16:15 hrs on 22 August 2006.

Performance of staff and equipment during the incident

The performance of the signalling and communications systems

198 The principal communication channels between train drivers and the RCC are through the TVM signalling system and voice communication via the track-to-train radio (TTR) system.

199 Should the driver exceed the permitted speed, the signalling system will intervene to reduce the speed of the train to the correct value. The driver is required to contact the RTM Controller to advise that his or her train has been subjected to an emergency brake application. The RTM controller can use the system to impose a speed restriction, but will warn drivers before doing so to prevent an 'unexpected' speed imposition causing trains to be slowed by the signalling system using the emergency brake rather than by the driver at a lower braking rate (which is more comfortable for passengers). The lowest speed the system can impose is 30 km/h.

200 The TTR enables a driver to initiate a call to the RCC or for a controller in the RCC to call either a specific train or to make a general call to all trains. It is used by all trains passing through the tunnel, whether operated by Eurotunnel or another train operator.

201 Following the initial smoke alarm, at 13:31 hrs the RTM Controller used the TTR to put out the initial call to all trains to reduce speed to 100 km/h and at 13:35 hrs the subsequent call to all trains to reduce speed to 10 km/h. It is likely that the drivers of two shuttles in the Running Tunnel South did not receive this radio message. As a consequence they did not slow as required. This resulted in an unexpected enforced application of the brakes imposed by the TVM signalling system.

202 The driver of a works train running ahead of Mission 7370 in the Running Tunnel North also experienced communication difficulties with the TTR.

203 The verbal instruction to the driver of Mission 7370 at 13:34 hrs to carry out a controlled stop and the authority to evacuate were given through the TTR. While the instruction to stop was received, it had to be repeated. The driver then experienced difficulty with the radio communication in the region of CP3050. The Chef de Train used the fixed telephone in the service tunnel to advise the RCC that the shuttle had been evacuated and the CPDs could be closed.

The performance of the ventilation systems

204 The information supplied from the EMS archive indicates that the correct configuration of NVS fans was applied throughout the incident. The NVS was configured to supply air at blade angle 5 from the UK and France. This ensured maintenance of a higher pressure in the service tunnel than in the running tunnels. When two CPDs were opened to facilitate evacuation of Mission 7370, the airflow through those doors (felt by evacuating passengers and crew) was from the service tunnel to the running tunnel and at a velocity that did not affect the ability of people to walk normally. See paragraph 84 for a description of how the ventilation systems are configured to ensure that conditions for passenger evacuation are safe.

205 At 13:43:29 hrs (during evacuation), the blade angle on the UK NVS was correctly adjusted to supply air at blade angle 2.

206 It is concluded that the NVS worked correctly throughout the scenario and there are no issues in relation to its actual performance.

207 The SVS was configured automatically on the basis of information input by the EMS Controller. On start-up, the SVS initially configured to blade angle 0, then rapidly increased to blade angle 7, ventilating both running tunnels. The input from the EMS Controller at this stage merely established in which direction airflow was needed.

208 Once further details of the scenario were established (e.g. status of equipment such as PRDs and crossover doors), the EMS Controller input the information to define the scenario and the system selected the setting for the dampers and for the SVS blades. In this incident, the correct setting was for a single French SVS fan to supply air in the Running Tunnel North at blade angle 7 and a single UK SVS fan to extract air from the Running Tunnel North at blade angle 4. The correct fan settings were applied automatically once the EMS Controller had input to the system the section of the tunnel in which the incident had occurred.

209 As indicated in paragraphs 158 and 159, for three minutes during the evacuation a single fan at each plant was ventilating both running tunnels instead of the Running Tunnel North alone. The UK SVS fan also suffered a short 'configuration failure' reducing the air extraction slightly. The reconfiguration of the UK SVS fans occurred at about the time that evacuation started as a result of the EMS Controller selecting an appropriate fan configuration before nominating the tunnel to which it should apply. The evacuating passengers and crew reported no sight or smell of smoke during evacuation.

210 Once evacuation was completed, the role of the SVS was to maintain an airflow along the tunnel to maintain a clear approach path for firefighters. The SVS was correctly configured for this purpose and performed effectively.

The performance of other tunnel equipment

211 The STTS vehicles transported emergency and Eurotunnel staff to the site and evacuated the passengers and crew from the HGV shuttle without difficulty.

212 The fire main was used to supply fire fighting water and performed satisfactorily.

213 The catenary contact wire parted when subjected to the heat generated by the fire. Although it is significantly below its melting point, the copper wire will part when it reaches a temperature of the order of 300 ºC as the contact wire is under significant mechanical tension. A failure of this nature is to be expected under these conditions.

214 The *circuit breakers* operated correctly to provide electrical isolation when the contact wire parted and touched the roof of the Mission 7370.

Previous occurrences of a similar character

The 1996 fire

Outline of incident

215 On 18 November 1996, a fire occurred on an HGV shuttle travelling from France to the UK. Security guards near the French portal noticed the fire as the shuttle entered the tunnel at 21:48 hrs and informed the RCC. Fixed fire detection stations in the tunnel also detected the fire at 21:49 hrs and 2 minutes later the RCC advised the driver that the shuttle would be diverted to the emergency siding in the UK terminal in accordance with instructions then in force.

216 The RCC prevented any other trains entering the tunnel and set the running speed in both tunnels to 100 km/h. An HGV shuttle in the Running Tunnel North reported thick smoke at the French crossover. The doors at both crossovers were open, but the RCC activated the closure of the UK crossover doors at 21:57 hrs.

217 At 21:56 hrs, after the incident HGV shuttle had passed the French crossover, the driver received a stop warning on his control desk and made a controlled stop at CPD4131. Thick smoke prevented both him and the Chef de Train establishing the exact position of the CP and evacuating the shuttle.

218 The RCC attempted to activate the SVS at 22:13 hrs to drive air from the UK to France, and therefore the smoke away from the AMC, but set the fan blades wrongly so that it had no effect. This was corrected at 22:20 hrs and enabled the Chef de Train to locate the CP and evacuate the shuttle some 20 minutes after it stopped.

Investigation into causes and recommendations

219 The 1996 fire was investigated by the *Channel Tunnel Safety Authority* (CTSA), in accordance with the Treaty of Canterbury, who published an undated report to the Intergovernmental Commission.

220 The cause of the fire was not established, but it was concluded that it had started before the shuttle entered the tunnel and probably began between the 5th and 7th carrier wagons from the rear of the shuttle.

221 Thirty six recommendations were made of which 7 discussed below are relevant to the fire of 21 August 2006.

Recommendations relevant to 2006 fire

222 Abridged versions of IGC/CTSA recommendations regarded as relevant to the 2006 fire are given below and quoted fully in Appendix D. A commentary on the current situation is in Table 10.

	Key Recommendation (summary)	**Actions taken**	**Comment** *(based on performance during August 2006 fire event)*
6	Review the performance of the radio and telephone systems.	Tests were performed to demonstrate correct performance.	Since 1996 the performance of the TTR system is known to have deteriorated. During the fire event of August 2006 a number of communication failures were recorded (see paragraphs 286 to 290).
8	Review calibration of on-board detection system.	Calibration of detectors was checked and found to be satisfactory Currently on board detector testing takes place every 15 days and includes a smoke test.	During the fire event of August 2006 the on-board detection system gave an alarm shortly after the first detection by the tunnel system.
11	Abandonment of the 'drive through' policy in the event of a fire on a freight shuttle.	This policy was abandoned in favour of stopping and evacuating a shuttle.	The altered policy proved effective.
20	Training of staff of all Railway Operators (Eurotunnel, Eurostar, EWS...) using the Channel Tunnel in handling of emergencies.	A tunnel simulator has been brought into use which includes a working cross passage door, walkways, an AMC and the ability to simulate smoke during evacuation training. The shuttle crews receive annual training.	This met the intent of the IGC recommendation.
21	Condition of reflective position marker panels.	An enhanced cleaning regime was established. A procedure is in place to audit the condition of marker panels by inspection from a locomotive.	The visibility of markers did not cause any concerns during the fire event of August 2006.
29	Control procedures to be improved to avoid trains being subjected to unexpected braking.	The procedure was adapted to clarify the requirement for a general call to reduce speed 3 minutes before the speed restriction is imposed by the signalling system.	During the fire event of August 2006 this procedure was applied by the RTM controller. However, correct implementation was prevented by failures of the TTR.
35	Stopping point to be agreed between RCC and driver in event of an emergency.	This was not implemented by Eurotunnel due to concerns that it would prolong the stopping process and increase the risk of human error.	During the fire event of August 2006 the RCC requested that the driver confirm his stopping position.

Table 10: Summary of recommendations following fire in November 1996 (showing current status)

Analysis

The source of the fire

223 The CCTV images showed that smoke was issuing from the load compartment of the lorry before it entered the Channel Tunnel.

224 The compartment was severely damaged and the roof and metal framework were no longer specifically recognisable. However, the metal seals applied during loading, which would have secured the lorry's side and tailgate doors closed, were found intact during a forensic examination of the remaining debris, suggesting that the doors had been secure prior to the smouldering breaking into fire.

225 No evidence was found of a viable ignition source in the cab. The engine revealed patterns of melting of alloy castings that suggested that the fire had spread from the back of the lorry to the front.

226 Following the fire, the debris was examined by a fire specialist from Forensic Scientific Services (FSS). This examination suggested that the fire was most likely to have started in the front or mid-section of the load compartment. The degree of destruction prevented a more accurate determination.

227 The vehicle owner indicated that an interior light was fitted to the load compartment, but this was not used during loading and therefore was unlikely to have been the source of ignition.

228 Since the driver stated the compartment was not opened after the lorry was loaded in Twickenham, it is probable that the source of ignition was introduced during loading.

229 Given the nature of the load, it is possible that an ignition source (such as a cigarette end discarded during the loading) could have started a slow smouldering process. The specialists from FSS explained that in an enclosed container with limited air flow smouldering can take up to several hours to develop into a flaming fire.

230 A prohibition on smoking during the loading of lorries before their journey to the Channel Tunnel would effectively eliminate the possibility of a fire of this nature recurring. However, such a prohibition would be impossible to enforce across all parties using the HGV shuttles. Therefore no recommendation can be practically made in this respect.

Detection of the fire and fire development

231 Assuming the scenario outlined above to be correct, the lorry was driven from Twickenham and then passed through the entire reception and loading process with an undetected fire developing in the load compartment.

232 Current detection procedures rely on staff becoming aware of smoke, flames or radiated heat during the examination of lorries as part of the loading and departure process. It is almost entirely visual and tactile, principally depending on emissions being seen or heat felt. Touching the sides of lorries to detect a fire is not reliable as the temperature felt is related to the climatic conditions prevailing at the time and the colour of an individual lorry's livery. Were it to be adopted as a standard procedure it would be likely to lead to lorries being examined unnecessarily.

233 In overall terms, using loading staff to examine the lorries at close quarters after they are parked on the shuttle is a sound method of inspecting for the presence of a fire. However, the existing procedures do not include a specific reference to visually examining the roof and doors of the load compartment for signs of smoke escaping.

Options for enhancement of detection measures in the terminals

234 Eurotunnel's measures to detect fire and the potential sources of fire on lorries prior to their entry into the tunnel are at least equivalent to those utilised by other long tunnels in Europe. Nevertheless, the investigation has considered the ways in which a fire developing in the load compartment might be detected prior to the entry of a shuttle into the tunnel and the reasonable practicability of any such solutions. Options considered include each of the following:

(a) inspection of loads for signs of fire in the terminal (possibly in conjunction with the existing *Euroscan* equipment);

(b) enhanced checking by staff during loading onto the HGV shuttle to include the roof and doors of the load compartment;

(c) detection of products of combustion (e.g. smoke and CO) using detectors installed in the load compartment;

(d) detection of products of combustion (e.g. smoke and CO) using an aspiration tube inserted into the load compartment prior to loading onto the HGV shuttle;

(e) detection of heat sources in the load compartment or on the outside surface of the load compartment using fixed equipment in the terminal; and

(f) detection of heat emitted from the load compartment when stopped on the carrier wagon.

235 The predicted efficacy and operational impact of each of the above options has been reviewed. The results of this review are summarised in Appendix C.

236 All of the measures examined are capable of enhancing the ability to detect a developing fire in the load compartment of a lorry, although all would be limited by their ability to detect fire reliably. However, many of the measures considered would also introduce important operational disbenefits that would need to be taken into account when assessing the reasonable practicability of a given measure.

237 The most significant operational disbenefits are attached to options (a), (c) and (d). These disbenefits are more modest in the case of options (e) and (f). There are no significant disbenefits attached to option (b).

238 All options other than (b) are likely to require significant levels of investment by Eurotunnel and/or road haulage operators. It is therefore relevant to consider the safety benefit derived by any such investment.

239 In all options other than (e) the safety benefit is primarily related to the detection of developing fires in the load compartment of lorries. This means that only option (e) is likely to deliver any safety benefit in relation to fires developing on other parts of the lorry (e.g. engine, transmission, brakes or cab). This is significant since fires are in fact more likely to start in the engine, transmission, brakes or cab than the load compartment[1].

[1] BEA-TT Report

240 The following factors are relevant to an assessment of the safety benefit to be derived:

- there have only been two fires on lorries in the Channel Tunnel (i.e. November 1996 and August 2006);
- of the above, only one (August 2006) is thought to have developed from inside the load;
- to date no fatalities have been caused by a fire on a shuttle in the Channel Tunnel;
- there is no evidence of significant flaws in the Channel Tunnel's systems or procedures that would generate a high level of risk in the event of another fire on an HGV shuttle;
- none of the detection measures considered would be capable of reliably detecting a smouldering fire in the load.

241 Given the above, it is considered that the safety benefit derived for most of the options examined will be unlikely to justify the costs and operational disbenefits incurred. For this reason no recommendation is made in respect of options (a), (c), (d), (e) and (f).

242 Option (b) concerns enhanced checking by staff during loading to include the roof and doors of the load compartment. In this case it is considered that the costs and operational disbenefits are likely to be low. For this reason it is judged that this option is worthy of more detailed consideration despite the modest safety benefit likely to be derived.

Surveillance of HGV shuttles during departure

243 When the HGV shuttles are observed as they depart from the platform, the Agents de Feu tend to look at the chassis level rather than the tops of the lorries. Statistics show that where vehicles have caught fire in road tunnels the source of the fire has usually been an overheated engine or transmission component, making the chassis the appropriate part to examine.

244 Given that when the rear of the shuttle leaves the platforms it is generally travelling at approximately 50 km/h, the depth of the examination is inevitably limited particularly in respect of the rear half of the shuttle.

245 A further weakness (apart from the speed at which the Agents de Feu are expected to examine the rear of a passing train) lies in the method of stopping a train as it leaves the UK terminal. The length of the shuttle is such that as the rear wagon passes the Agent de Feu, the leading locomotive is very close to the tunnel portal. The need to contact the RCC to instruct the controller to stop a shuttle introduces a delay into the process as the request is made and the controller confirms which shuttle is to be stopped. This delay is sufficient to ensure that the leading part of the shuttle has entered the tunnel before it is stopped. However, this issue did not contribute to the outcome of this incident.

246 The delay could be eliminated by enabling the Agent de Feu to operate a visual or audible indication instructing the driver to stop directly without involving the RCC. This would provide more rapid response than the use of a direct Agent de Feu to driver radio link and could be achieved without affecting the existing signalling system.

Other factors for consideration

247 This section considers the effect on the outcome of the performance of the people and systems involved with the operation of Mission 7370 and the management of the incident.

Commentary on overall management of incident

248 Three distinct phases to the overall management of the incident can be identified:

- The initial phase when the RCC was managing the incident. This covered the period between 13:30 hrs, when the first smoke detector was triggered, and 13:50 hrs, when the passengers and crew were evacuated into the service tunnel.
- The second phase when Eurotunnel's ICC took charge of the incident, with the EOCD in overall control. This phase started when the evacuation of passengers and crew from Mission 7370 was completed at 13:50 hrs and ended when the BINAT was declared at approximately 14:40 hrs.
- The BINAT phase lasted from 14:40 hrs to 17:03 hrs and covered all of the firefighting activities, stopping at the same time as fire fighting and damping down had been completed and the SVS had been switched off.

249 The transition between the phases was made at an appropriate time. The RCC dealt with the immediate issue of ensuring that the passengers and crew from Mission 7370 had been evacuated safely into the service tunnel. As the RCC had direct contact with the driver and Chef de Train, it was appropriate that the RCC managed this phase.

250 In the event of a major incident, Eurotunnel's procedures require the establishment of an ICC under the leadership of a senior manager. Once the initial objective of safe evacuation of passengers and crew had been achieved, it was appropriate for the ICC to take charge of events. At this stage, there were still other trains running in the Channel Tunnel which was still therefore an operating railway. The last train to leave the tunnel did so at approximately 14:20 hrs. Based on information from those at the scene of the incident, it became apparent that fire fighting would be necessary and that there was no immediate prospect of the resumption of commercial operations. Therefore, by 14:40 hrs, it had been agreed between Eurotunnel and the emergency services that commercial services would need to be suspended for the foreseeable future and the focus given to extinguishing the fire.

251 The BINAT was declared at 14:40 hrs when the fire fighting phase was about to commence. It was appropriate that control of the incident should pass to the emergency services as their activity was the principal activity to take place in the tunnel at this time and a necessary precursor for the return to commercial operations. The BINAT remained in place until 17:03 hrs, covering the period when fire fighting and damping down was taking place. Once the fire fighters had completed their work in the tunnel, it was possible to switch off the SVS fans which had been providing them with clean air conditions while they worked. This happened at 17:03 hrs when the fire fighters had left Running Tunnel North. With the focus now on restoring commercial operations through the unaffected sections of the tunnel, it was appropriate that Eurotunnel should resume control and the BINAT be rescinded. The first commercial trains entered the Running Tunnel South at 17:29 hrs.

252 Communication issues are described in paragraph 191. The Eurotunnel Manager in charge of the ICC initially, and the Silver Command during the BINAT, were not always receiving timely, accurate or comprehensive information from those dealing directly with the incident. Some information was relayed directly to the operational ICC and some to the non-operational ICC. Other information was passed to the UK and French FEMCs. This was a manifestation of procedures not being implemented in an optimal manner rather than an absence of appropriate procedures. A flow of accurate, timely and consistent information from those at site to those in the relevant ICC allows those involved in the strategic management of the incident to make effective decisions.

253 Rescue services from both sides of the Channel and the Kent Police were involved in the immediate response to the incident. It is understood that no meeting has been held between these organisations and Eurotunnel to review the incident and establish lessons to be learnt.

Commentary on the actions of the train crew

254 The driver of Mission 7370 first became aware of the possibility of a fire on board his shuttle at approximately 13:31 hrs when a warning light illuminated on his driving desk and the Chef de Train advised him that he had received an alarm on his console in the AMC. At the same time as he was speaking with the Chef de Train, the driver received a radio request from the Control Centre to slow to 100 km/h, a message that was being conveyed to all trains in the tunnel.

255 The relevant Eurotunnel procedure for the driver states that in the event of advice from the Chef de Train of a fire being detected on an HGV shuttle, the driver should make an emergency call to the RCC. The driver did not do so. Instead, he continued at 100 km/h until, at approximately 13:34 hrs, he received a message from the RCC instructing him to make a controlled halt. This instruction from the RCC was issued because two consecutive tunnel smoke detectors had been triggered, not because they were aware that there had been a fire alarm on Mission 7370 (see paragraph 147).

256 Had the driver contacted the RCC as soon as he became aware that there was a fire alarm on his shuttle, he would probably have been instructed to stop immediately. The relevant Eurotunnel procedure that governs the response by the Supervisor to notification of a fire alarm from an HGV shuttle is unambiguous: a Level 2 alarm should be declared immediately.

257 Assuming that the Supervisor would have declared a Level 2 alarm if an emergency call had been made from Mission 7370, it is likely that the RTM Controller could have been in a position to instruct the driver to stop by 13:32 hrs at the latest. With the request to stop being received approximately two minutes earlier than was actually the case, it is probable that the driver of Mission 7370 would have stopped the shuttle immediately rather than delaying the stop to clear the 'go zone'. Under these circumstances, Mission 7370 would have stopped as much as six minutes earlier than it did. In the event, the delay had no bearing on the outcome of the incident, but stopping a shuttle six minutes earlier might have significantly mitigated the consequences under different circumstances.

258 When the driver of Mission 7370 was asked to undertake a controlled stop at 13:34 hrs, he elected to continue until he could be sure that the shuttle had cleared the 'go zone' in the vicinity of the UK crossover. He knew from the length of time that he had been in the tunnel that he must be approaching the 'go zone'. In fact, at the time the RTM Controller asked Mission 7370 to make a controlled stop, there were still four cross passages between it and the first cross passage in the 'go zone'. It would therefore have been possible for the driver to stop Mission 7370 immediately and remain outside the 'go zone'. However, in view of the difficulty that drivers experience in establishing their exact position in relation to the 'go zone' , continuing was the correct course of action.

259 'Go zones' are identified to drivers by specific markings on cross passage plates. Drivers rely on their knowledge of the route to know when they are approaching a 'go zone' and when they will clear it. There is no warning of the approach to either boundary.

260 A similar issue manifested itself as Mission 7370 cleared the 'go zone'. It is safe for a driver to stop a train at the first cross passage not identified as being in the 'go zone' as all the train has then cleared the 'go zone'. The absence of a warning probably caused the driver not to begin braking until he had passed at least one CP marker outside the 'go zone'. He therefore stopped the shuttle 2 CPDs further along the tunnel than necessary.

261 Had warnings of the approach to the entry to and exit from the 'go zones' been given, the driver would have known for certain whether he could have stopped the shuttle before entering the 'go zone' at the UK crossover and when he was about to reach a point at which the shuttle could be safely stopped.

262 The initial stopping of Mission 7370 was a few metres short of the optimum location for evacuation of the AMC. The optimum position is marked on the tunnel wall and the driver is expected to bring the locomotive to a stand alongside the marker. The driver therefore restarted his shuttle to move it to the correct position.

263 In normal operation, the stopping of trains in the tunnel sections is unusual. Eurotunnel drivers bring their shuttles to a stand about 6 times per shift, but they do so repeatedly at a platform in the open on level track and at a consistent and predetermined point. There are additional features which act as unconscious prompts to assist the driver in estimating speed and provide additional guides to the correct stopping position. These are not available in the tunnel, where the number of visual cues is limited. The driver has only the speedometer and the CP marker to use in bringing the shuttle to a stand at the right place and, should he pass the right place, cannot reverse the shuttle to correct the error. The difficulty is compounded by the changes in gradient in the tunnel for which the driver has to compensate during braking.

264 Drivers are given practice in making out of course stops in the tunnel, but it occurs during night working when traffic volumes are low and therefore the disruption incurred by such practice is minimised. It is also random in that it is the driver who happens to be driving the mission used who gets the practice. Drivers do not systematically practise stopping in the tunnel.

265 Once the shuttle had stopped, the RTM Controller quickly made contact with the driver instead to establish where Mission 7370 had stopped.

266 The driver assisted the Chef de Train, who had already prepared for an evacuation, as described in paragraphs 165 and 169, and this was achieved promptly and efficiently.

267 As soon as the shuttle stopped, the Chef de Train noted that the cross passage door for CP3050 was open and, after placing a safety barrier across the walkway, started evacuating the AMC. He arranged for the AMC to be checked and undertook a headcount of passengers in the service tunnel as a second check that everyone had been evacuated. Evacuation was completed and the CP closed within 10 minutes of the shuttle stopping.

<u>Commentary on the role of the RCC and procedures</u>

268 The RCC had the key responsibility of managing the incident initially and ensuring that the correct procedures were implemented based on the information coming from the tunnel-based fire detection systems and the crew of Mission 7370. The declaration of Level 1 and Level 2 alarms was timely and enabled a rapid response to the incident. In less than 20 minutes from the first alarm by the detector in CP1626, all passengers and crew from Mission 7370 were safely evacuated to the service tunnel. That this might have been achieved up to seven minutes earlier was not attributable to the actions of those located in the RCC.

EMS Controller

269 The EMS Controller took 95 seconds to initiate the response to the Level 1 alarm. This was because the individual concerned had to leave the position in the RCC for a short period. As soon as the Level 1 alarm was declared, the Controller returned quickly to the EMS workstation and commenced the response to the Level 1 alarm, as described in Table 5.

270 When the Level 2 alarm was declared by the Supervisor, the EMS Controller was in position to make a rapid start on the relevant responses (see Table 6), which were initiated 28 seconds after the Level 2 alarm was declared.

271 The changes in status of tunnel systems required by the EMS Controller are largely initiated through the incident screen following general information input by the Controller. However, one of the specific activities undertaken cannot be implemented in this way: the opening of CPDs for evacuation. The relevant Eurotunnel procedure calls for the EMS Controller to identify the correct doors to be opened once the stopping position of the train is known. However, the EMS Controller opened two cross passage doors before the final stopping position of the shuttle was confirmed.

272 When an HGV shuttle is to be evacuated, the driver calls the RTM Controller in the RCC when he knows which cross passage door is adjacent to the AMC (paragraph 265). The relevant Eurotunnel procedure then calls for the EMS Controller to open the CPD ahead of the shuttle followed by the CPD adjacent to the AMC. The doors are opened in this sequence to allow rapid evacuation to take place as airflows through the first CPDs to be opened may be quite high.

273 By the time the RTM Controller had established the exact stopping position of the train (paragraph 265), the EMS Controller had already opened two CPDs. In the event, this had no bearing on safety, but it had the potential to cause a breach of the safe haven concept in the service tunnel; if Mission 7370 had moved forward, the airflow generated might have reversed the difference in pressure between the service tunnel and the running tunnel (paragraph 81).

274 The EMS Controller could not be certain that the correct cross passages had been identified until assurance had been received about the shuttle's final stopping position. The EMS Controller has a mimic diagram which shows the location of cross passages and track circuits. There is, however, a difference in spacing; track circuits are generally 500 metres in length while cross passages are spaced every 375 metres. The mimic diagram does not have a sufficient degree of resolution to enable the EMS controller to be sure exactly where the front of the shuttle is in relation to the cross passage. Furthermore, although an alarm sounds when a train occupies a track circuit for an unusual length of time, this cannot be taken as proof that the shuttle has stopped because the shuttle also activates the alarm if it is moving slowly.

275 When establishing the SVS airflow appropriate to the incident in the Running Tunnel North, the EMS controller uses the incident screen. There is more than one way to navigate through the screen and only one of the routes is optimal. The EMS Controller chose a sub-optimal route with the result that a critical part of the sequence was undertaken in the wrong order as described in paragraphs 158 and 159 (see also Table 7). This resulted in reducing the SVS airflow by about 50 % for approximately three minutes when evacuation was taking place. Had the fire been larger, this period of sub-optimal airflow could have resulted in a failure to arrest the backflow of smoke towards the AMC potentially impeding safe evacuation.

RTM Controller

276 The RTM Controller carried the key responsibility of coordinating train movements throughout the tunnel during the incident and liaising directly with the crew on the incident shuttle. His actions are described in detail in paragraphs 145 to 151. He instituted the response to the Level 1 and Level 2 alarms in a timely and efficient manner, apart from not asking drivers to close heating, ventilation and air conditioning (HVAC) dampers. Within 20 seconds of the Level 1 alarm being declared, the RTM Controller had made a call for all trains in the tunnel to slow to 100 km/h and within 40 seconds of the Level 2 alarm being declared had spoken with the driver of Mission 7370 to ask him to make a controlled stop.

277 The RTM Controller then correctly asked drivers of other trains in the tunnel to slow to 10 km/h to help to create the optimum conditions for the evacuation of Mission 7370. The drivers of Missions 7367 and 7369 in the Running Tunnel South did not hear the call to slow to 10 km/h and the driver of the only other train in the Running Tunnel North required the message to be repeated. The reasons why the drivers did not receive the message are discussed in paragraph 288.

278 Paragraphs 149 and 150 describe how Missions 7367 and 7369 subsequently came to be moving at 30 km/h when their speed should not have exceeded 10 km/h.

279 In the event, this had no bearing on the safety of the incident, but under slightly different circumstances, it might have done. Although the two shuttles involved were not running in the same tunnel as Mission 7370, had one or more PRD dampers failed to close in the vicinity of the incident, the airflow generated through the open PRD could have fluctuated in direction, thereby affecting the overall rate and direction of airflow being achieved by the SVS. In these circumstances, the positive smoke control being exercised by the SVS might have been adversely affected for a period of time. It is also possible that the fluctuation in airflow in Running Tunnel North created by trains running in Running Tunnel South might have affected the airflow between service tunnel and Running Tunnel North. In the worst case, this could have resulted in reversal of the airflow, allowing smoke into the service tunnel. The operation of the Missions 7367 and 7369 in the Running Tunnel South at 30 km/h was happening during the period 13:40 hrs – 13:45 hrs, at the same time as evacuation was taking place.

280 However, the overall performance of the RTM Controller in managing the incident was effective despite not asking drivers to close their HVAC dampers and not reminding the drivers of Mission 7367 and 7369 to proceed at 10 km/h after they had been stopped by an intervention from the TVM.

Fire Detection Controller

281 The FD Controller alerted the Supervisor to the activation of detectors in the tunnel in a timely manner. Appropriate responses to both the Level 1 and Level 2 alarms were made within less than a minute of the alarms being activated. The FD Controller also continued to monitor CO detectors throughout the incident and was able to provide advice to the teams fighting the fire about CO levels in the vicinity of areas where fire fighting was being considered.

282 Reference is made in paragraph 163 to the problems experienced by the FD Controller in providing details of the location of the Channel Tunnel to the police and ambulance services in the UK. The principal difficulty arose from the request by those services for a postcode for the Channel Tunnel or for an address that would have allowed them to establish a postcode. The information was not immediately available to the FD Controller, resulting in a delay of less than five minutes until the necessary information could be provided.

283 Apart from the issue described in paragraph 282, the performance of the FD Controller in managing the incident was effective.

Observation on procedures

284 Paragraph 256 makes reference to the procedure followed by the RCC Supervisor if a rolling stock alarm on a HGV shuttle is activated and the driver of the shuttle advises the RCC that this has occurred. However, the emergency call from the HGV shuttle goes to the RTM Controller rather than the Supervisor, and the procedure that governs this situation does not state explicitly that the RTM Controller should advise the Supervisor. The RTM Controller is located in close proximity to the Supervisor in the French RCC and it is unlikely that the Supervisor would not have been aware of the problem with Mission 7370. However, it would assist the work of the RTM Controller if the relevant procedure made the requirement to alert the Supervisor explicit.

285 The procedure followed by the RTM Controller on receipt of the notification of a rolling stock alarm requires the controller to take a number of actions, including stopping trains following the incident train and slowing other trains in the tunnel to 100 km/h. As soon as a Level 2 alarm is declared by the Supervisor, the RTM Controller is required to stop the incident train. In a situation where the notification of the rolling stock alarm and the declaration of a Level 2 alarm are almost simultaneous, there is a danger that the RTM Controller will not undertake his actions in the optimum sequence. In particular, there is a danger that the RTM Controller might stop the incident train before stopping the following train(s), thereby decreasing the separation between the incident train and the following train to the minimum enforced by the signalling system (4.5 km). The emergency screen used by RTM Controllers during an incident will prevent this happening as it imposes the correct sequence. However, in the event that the RTM Controller has to use paper-based procedures (for example, because of non-availability of the emergency screen), there would be a possibility of the incident train being stopped before those trains following it.

Commentary on the performance of communications and signalling systems

286 The TVM signalling system was used by the RCC in conjunction with the TTR to impose maximum speeds during the management of the incident.

287 The signalling worked properly throughout in that the speeds input by the RTM controller were transmitted to the trains which responded correctly. A constraint was that the speed limit of 10 km/h had to be instructed verbally through a ‘general call’ to all trains since the lowest speed that the TVM signalling can indicate to drivers and impose is 30 km/h.

288 In contrast, the TTR did not operate satisfactorily throughout the length of either running tunnel and its performance suggests that there were at least 3 locations where the effectiveness of this equipment was insufficient.

289 Eurotunnel were previously aware that the TTR system was becoming unreliable. This was believed by Eurotunnel to be as a consequence of the build up of brake dust and other contaminants on the *leaky feeder* through which radio signals are propagated.

290 The result was to compound the problem of the TVM signalling being unable to impose the required speed of 10 km/h in that reliance was placed on the RTM controller issuing a verbal instruction to that effect. Had the TVM signalling been able to specify the speed of 10 km/h, the demands on the RTM controller, and therefore the RCC as a whole, would have been reduced.

Commentary on the performance of ventilation systems

291 The two tunnel ventilation systems, the NVS and the SVS, both worked in accordance with their design specification.

292 There were no issues with the performance of the NVS. Designed to provide a higher air pressure in the service tunnel than the running tunnels to ensure that the service tunnel remains a safe haven, free from smoke during a fire at all times, this objective was achieved throughout the event. The requirements of the fire fighters meant that a number of cross passage doors had to be opened at different times, but this was achieved safely without any breach of the safe haven.

293 The SVS was effective in achieving its design objective of directing smoke longitudinally along the Running Tunnel North, initially away from the evacuating passengers and subsequently to provide fire fighters with a clear approach path to enable them to bring the fire under control and then extinguish it. Evidence gained from the deactivation of carbon monoxide detectors in the tunnel indicates that the speed at which the plug of smoke was being pushed along the open tunnel was approximately 2.1 m/s (see Figure 10). This is consistent with the design intent of the SVS, which is to achieve a maximum air velocity of 2 m/s in open tunnel (the SVS was not configured to achieve maximum air velocity in this scenario).

294 Passengers and crew evacuating from the shuttle were not aware of the presence of smoke and this indicates that the SVS had managed to reverse the forward flow of smoke at an early stage.

295 During the early stages of SVS operation, a 'configuration fault' was recorded, which lasted for 31 seconds. This fault indication was generated by the detection of excessive current in the motors of one of the UK SVS fans when operating at the -7 setting (i.e. maximum extract). Excessive current is most likely to occur when fans are set to full extract when one or both of the tunnels is occupied by a train with dimensions that fill the greater part of the tunnel; such trains are referred to as having a large blockage ratio. (In the Channel Tunnel, it is the tourist shuttle that has the largest blockage ratio. The need for Eurostar and national freight trains to use national railways' infrastructure means that their blockage ratio is smaller than that of the two types of Eurotunnel shuttle train).

296 The blockage of the tunnel restricts the airflow over the blades causing the fan to slow down. In response the blade angle is automatically altered to angle 6 thereby reducing the current drawn as the fan runs faster. Once the current has fallen, the fan attempts to operate at the demanded blade angle 7 again and will do so if sufficient speed is then achieved to avoid drawing excessive current.

297 At the time of the incident, a tourist shuttle was located close to the Shakespeare Cliff ventilation shaft in the Running Tunnel South. The conditions were, therefore, present for the fans in the shaft on the UK side to experience problems in achieving the desired air extraction rate.

298 However, the slight reduction in SVS air velocity that was achieved through the running tunnels as a consequence of the reduction in power at the fans on the UK side was of no significance because it occurred when the fans were on the default setting of blade angle 7 (the maximum, see paragraphs 83 and 158). The required blade setting for the fan in the UK shaft was ultimately to be blade angle 4. Thus the required extraction rate was lower than that which could be achieved by the fans operating with the configuration fault present. The configuration fault, which lasted for 31 seconds, is therefore considered not to have posed a risk to the safety of the passengers or crew on Mission 7370.

Commentary on fire and smoke detection

299 The lack of registration by detector stations SD02, SD04 and SD06 indicates that the fire was not emitting sufficient smoke from the load compartment to trigger the smoke detectors as Mission 7370 passed them, as subsequent tests showed them to be operating correctly. However, by the time Mission 7370 passed detector SD08 the concentration of smoke in the annulus of the shuttle was sufficient to trigger the ionisation smoke detector.

300 The failure of detector stations SD10, SD16, SD24 and SD26 to register smoke is likely to be the result of changes in the nature of fire behaviour during the journey. Changes in the supply of oxygen to the fire and/or the materials involved are likely to have resulted in variable smoke output during the journey. In addition, the rate that smoke was emitted from the container would be influenced by the degree of containment and the pressure of hot gases within.

301 At some point during the journey flames would have impinged on the aluminium trailer walls and roof. Once the walls and roof failed the supply of oxygen to the fire would have increased so increasing the rate of combustion. A likely result of this would be a reduction in the density of smoke and the emergence of visible flames.

302 The first flame alarm was registered at 13:35:41 hrs by detector SD22 just before the UK crossover. This would suggest a complete loss of containment at about this time as the walls and/or roof failed. The lack of smoke alarms at the subsequent detector stations, SD24 and SD26 suggests that the fire was now burning intensely with reduced smoke output. Both registered the presence of smoke as the plug of combustion products passed back along the tunnel.

303 Once the shuttle came to a stand and the rate of residual airflow decayed, the extent of dilution of the smoke declined. At the same time the direction of airflow was reversed by the SVS. From this moment a plug of smoke and CO travelled along the tunnel towards the UK SVS shaft. The arrival of these products of combustion at the detector stations is indicated by the registration of optical smoke alarms and high CO levels at each detector station in turn from the source of the fire to the UK SVS shaft.

304 The data plotted at Figure 10 (paragraph 133) indicates that at about 14:45 hrs the concentration of CO in the plug of smoke had dropped below the ‘danger’ threshold (set at 200 ppm). The registration of the drop in the level of CO, first to the ‘danger’ threshold, and then to the ‘critical’ threshold (set at 50 ppm), can be plotted moving along the tunnel away from the fire as the trailing edge of the plug passes clear of successive detector stations. The dispersion appears to be slower in the vicinity of the tunnel crossover. This may be caused by the hotter gases being trapped at the top of the larger tunnel section and taking longer to disperse into the smaller single track running tunnel.

305 The above data suggests that by 14:45 hrs the size of the fire was already in decline as the limited combustible materials were consumed.

Commentary on fire fighting

306 The delay in applying earths to enable fire fighting to take place had no impact on the outcome of the event or the safety of those evacuated from the train. However, had persons been trapped by the fire, the rescue services would probably have considered it necessary to start fire fighting before the earths had been applied. Under those circumstances the fire and rescue service staff would have been exposed to additional risk until the catenary was eventually earthed.

307 Under different circumstances the fire could have spread to involve other vehicles. Had this occurred the delay in applying earths would have given additional time for the fire to spread, further complicating the management of the incident.

308 Given the above it is concluded that there is safety benefit to be derived from improving the speed of applying earths to the catenary.

Commentary of the performance of other tunnel equipment

309 The STTS, fire main, catenary and signalling equipment involved in the incident worked correctly. Damage was sustained by the catenary in the immediate vicinity of the fire when the copper contact wire parted, but, given the temperatures achieved locally, this was inevitable and does not reflect adversely on the equipment in any way. The controlling circuit breakers opened correctly isolating the catenary from the electrical power supply.

Four alternative scenarios

310 The fire on 21 August 2006 featured an HGV shuttle with the AMC behind the leading locomotive and the fire almost at the back of the shuttle. The response to and outcome of the incident was influenced by these two variables and by no train having followed Mission 7370 into the tunnel by the time that the first alarm had been acted upon.

311 Without considering any failure modes of tunnel equipment, there are four alternative scenarios which could have resulted in the need to handle the incident in a different way. The four scenarios are:

- lorry on fire at front of shuttle (adjacent to AMC);
- AMC at rear of shuttle;
- train stopped in tunnel behind the shuttle with fire on board; and
- fire spread to engage other vehicles on the shuttle.

312 The four scenarios are analysed in the following sections. Note that in each diagram, the following conditions always apply:

- each shuttle 'rake' includes an unloading 'flatbed' wagon at the front and a loading flatbed wagon at the rear;
- the leading three wagons on the HGV shuttle train always convey vehicles with a low fire load; in the event that no such vehicles are available for loading, the leading three wagons are left empty.

Lorry on fire at front of shuttle (adjacent to AMC)

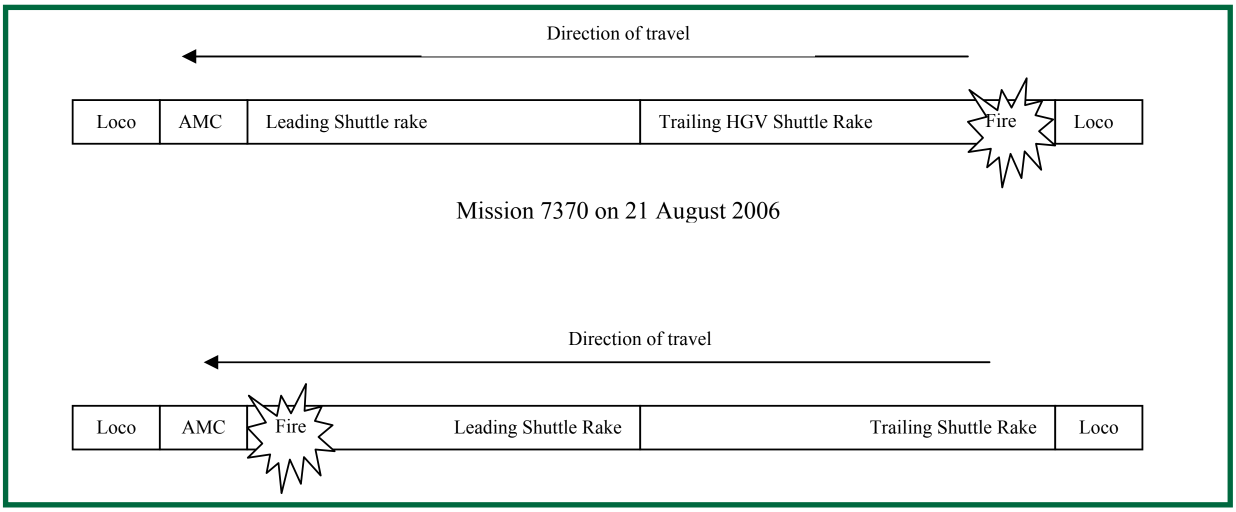

Figure 11: Alternative scenario involving fire at front of the shuttle

313 With a fire at the front of the shuttle and smoke present, the train crew would have been faced with three possibilities according to the relevant Eurotunnel procedure:

- if the CPD was open and visible despite the smoke, evacuation could take place immediately providing the external temperature was below 180 ºC:
- if the CPD was visible but closed or not visible but the external temperature was below 60 ºC and the walkway hand rail was visible, then evacuation could also take place immediately;
- if neither of these conditions could be met, then evacuation would need to be delayed until the SVS was capable of providing clean air conditions around the AMC.

314 It is not possible to be certain which possibility would have applied if the fire had been at the front of the shuttle. If either of the first two scenarios had applied, evacuation times would have been similar to those that were actually achieved. If the third scenario had been present, evacuation would have been delayed until positive smoke control had been achieved. During the incident on 21 August, the SVS was active by the time the shuttle stopped, although its effectiveness was diminished for a three minute period when a single fan at each plant was ventilating both running tunnels. Taking the resultant lower flow rate into account, the delay in the evacuation would not have exceeded 6 minutes, at which point the smoke would have been returned past the AMC, thereby permitting evacuation in clean air.

315 During the 1996 fire, positive control over the flow of smoke was not achieved at an early stage in the scenario. However, the flow of air from the service tunnel to the running tunnel is concentrated through the narrow opening of the CP and this creates a ‘bubble’ of clean air around the entrance to the cross passage. Providing that the shuttle has stopped with the AMC opposite the CP, passengers are still able to evacuate from the AMC to the service tunnel in virtually clean air, despite the presence of smoke in the running tunnel. This happened in 1996 and could have been important during the fire on 21 August 2006 had problems occurred with the performance of the SVS and the fire located towards the front of the shuttle.

316 If the AMC had been located at the rear of the shuttle any smoke from the HGV on fire would have been initially blown over the AMC. The Chef de Train would have closed the HVAC inlets to ensure that the AMC was sealed from smoke ingress.

AMC at rear of shuttle

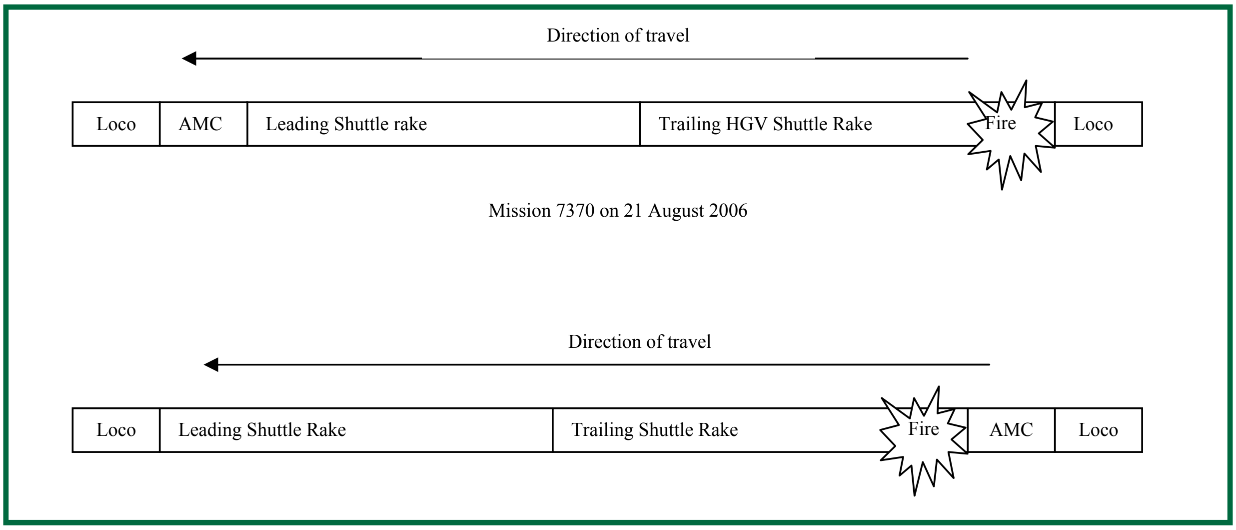

Figure 12: Alternative scenario involving fire and AMC at rear of shuttle

317 The relevant Eurotunnel procedure calls for the initial response to the incident by the EMS Controller to switch on the SVS fans and configure them to blow smoke away from the AMC. If the AMC had been at the rear of the shuttle, this would have meant blowing smoke in the opposite direction from that which was actually required on 21 August 2006, i.e. the SVS would have been configured to blow smoke from the UK to France, away from the back of the shuttle.

318 Once the shuttle's stopping position is known, the required actions would be dependent on the conditions present for immediate evacuation of the driver.

319 Two possibilities can be envisaged;

- Immediate evacuation of the driver followed by evacuation of the remainder of people on board the shuttle;
- Immediate evacuation of everyone on the shuttle except the driver followed by delayed evacuation of the driver. During the period when the driver is waiting to evacuate, the locomotive would be engulfed in smoke but the driver should remain inside in relatively clean air. Drivers are supplied with smoke hoods to enable them to remain in their cabs in safety, even if some smoke ingress occurs.

320 Had the AMC been located at the rear of the shuttle, it is likely that the driver would have been able to evacuate immediately. CPDs were opened promptly by the EMS Controller and it is likely that the locomotive cab would have been in clean air conditions long enough for the driver to evacuate. This is because when evacuation did take place during the incident, neither the Chef de Train nor the driver was aware of the presence of fumes or heat from a fire. The only difference if the AMC had been located at the rear of the shuttle would have been the SVS blowing smoke towards the driving cab rather than away from it. However, with the smoke still having approximately 700 metres to travel until it reached the driving cab and the air travelling at a maximum rate of 5 m/s (twice that of the open tunnel velocity because of the blockage provided by the shuttle itself), it is likely that the driver could have evacuated in the two minutes before the smoke plug reached his driving cab.

321 Even if smoke had reached the front of the train, the driver is permitted to evacuate by the relevant Eurotunnel procedure if one of the following conditions apply:

- the CP is visible;
- the CP is not visible through the smoke but the external temperature is below 120 ºC and the walkway hand rail is visible from the driving cab.

322 The bubble effect referred to in paragraph 315 might have aided the driver in evacuating from his cab if smoke had been present. Even if the driver had been unable to evacuate immediately and had to wait until the AMC had been evacuated (a process that should take no more than 10 minutes), the driver should still be able to evacuate safely. As soon as the evacuation of the AMC is complete, the SVS fans would be reversed and the smoke plug cleared from the front of the train, allowing the driver to evacuate in clean air.

Train stopped in tunnel behind the shuttle with fire on board

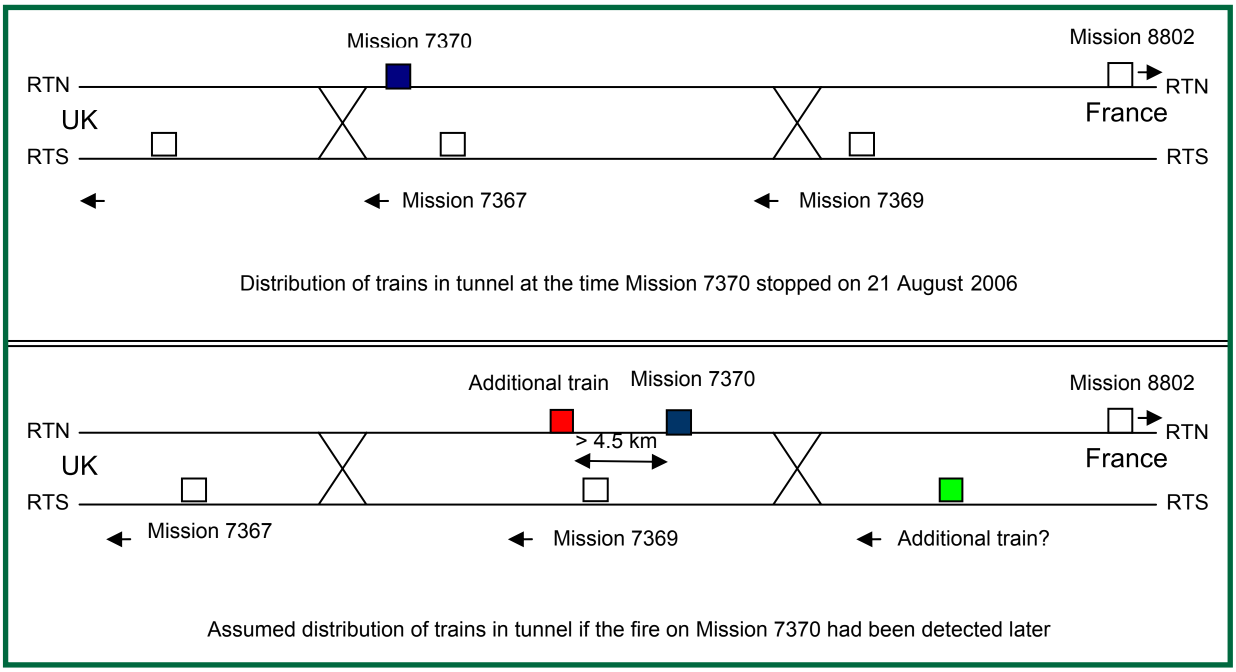

Figure 13: Alternative scenario involving an additional train in the running tunnel

323 The complication that potentially arises from having a train located in the running tunnel behind a HGV shuttle with a fire on board is that the need to blow smoke away from the AMC means that the smoke is being blown towards any train(s) following the incident shuttle.

324 Eurotunnel's procedures recognise this as a potential safety issue. HGV shuttles operate with an 'exclusion zone' behind them. This zone, enforced through the signalling system, ensures that an HGV shuttle in the tunnel has a gap of at least 4.5 km behind it.

325 If the fire that occurred on 21 August 2006 had been detected in the middle of the tunnel rather than at the beginning, the response to the first alarm would have been to stop the train following Mission 7370 immediately. Mission 7370 would have continued at this point, only being stopped when a second (consecutive) alarm had been activated. The effect would have been to increase the separation between Mission 7370 and the following train. Even if the driver of Mission 7370 had notified the RTM Controller of the fire alarm on his train, the following train would have stopped first as this is enforced through the RTM Controller's emergency screen. This would have resulted in the incident train and following train stopping at least 6 km apart.

However, in the event that the emergency screen was not available and the RTM controller was using paper-based procedures, there is the possibility that the stopping of the incident train and the one following it might be virtually simultaneous. In this case the separation between Mission 7370 and the following train could have been no greater than the 4.5 km minimum separation distance.

326 While the following train might have approached smoke trailed in the tunnel by Mission 7370, it is unlikely that this would have achieved a significant concentration as the smoke would be diluted by the volume of air through which the shuttle is passing. In addition, the plug of trailed smoke will be forced in the same direction as the following train due to the movement of air in the running tunnel.

327 The SVS can achieve a maximum velocity of 2.5 m/s in open tunnel. Once Mission 7370 stopped, the SVS would have blown smoke back towards the train standing 4.5 km behind. With the smoke plug approaching the following train at 2.5 m/s, it would have taken approximately 7 minutes for it to cover each kilometre. It would thus have taken approximately 30 minutes for the SVS to push the smoke plug back the 4.5 km to where the following train was located.

328 On August 21 2006, evacuation was completed within 10 minutes of Mission 7370 stopping. CPDs were closed and the EMS Controller would have been able to focus on the following train. There would have been two possibilities:

- reverse the SVS airflow to keep the following train in clean air conditions;
- ask the following train to reverse, thereby taking it away from the approaching smoke plug

329 Either course of action would have resulted in the following train being kept clear of the smoke plug. The second course of action would, in any case, have been necessary as the following train would otherwise have been detained for a number of hours by the presence of the immobilised Mission 7370 in front. Had the decision been taken immediately to reverse the following train, the driver would have had at least 30 minutes to walk to the other end of the train (along the tunnel walkway if necessary) and prepare to depart. This is equivalent to an average walking speed of 25 metres/minute or 1.5 km/h. Even if it took 15 minutes for the RCC to decide on that course of action, the driver of a following train would still have been able to walk to the other end of the train at a speed no greater than 3 km/h and reach the rear cab before smoke reached the front of his train.

330 Freight trains do not have a locomotive at the rear and only carry staff on the locomotive. In this case, the strategy would have involved the driver evacuating to the service tunnel. While this could not have been undertaken immediately (a maximum of 2 CPDs can be open at any one time), a freight train driver could have evacuated approximately 15-20 minutes after Mission 7370 stopped (once the evacuating passengers and crew from Mission 7370 were in the service tunnel and the CP doors closed) and before the smoke plug reached the freight train. Had a train with passengers on board been located between the incident train and a freight train, a different procedure would have applied, involving propelling the freight train out of the tunnel in order that the train conveying passengers could be driven out of the tunnel.

331 It is therefore concluded that a train following Mission 7370 in the Running Tunnel North would not have created any safety concerns on that train for passengers or crew and would not have affected the safe evacuation of Mission 7370.

Fire spread to engage other vehicles on the shuttle (AMC at front of shuttle)

332 The physical condition of the HGVs on the wagons immediately in front and behind the wagon on which the fire occurred showed limited evidence of fire damage. This indicates that the fire did spread to adjacent HGVs, but did not fully engage the vehicles or their loads. If adjacent vehicles had been of a different construction, e.g. curtain sided, the fire could have spread to engage two or more HGVs. In the conditions that were present, this would have been unlikely to have affected the safety of the passengers and crew on board Mission 7370 because the shuttle was stopped within 10 minutes of the fire being detected and evacuation completed within a further 10 minutes.

333 During the ten minutes the vehicle was still travelling, rapid fire spread would have been towards the HGV located behind the wagon on which the fire occurred because of the direction of the airflow in the tunnel as the train was moving. Therefore, when the train stopped, the fire would have been no closer to the evacuating passengers and crew than it was on 21 August 2006. The SVS was operational by the time that the train stopped and the induced air velocity in the annulus of the train would have been 2.1-4.2 m/s (the lower values applying during the period when the fans were ventilating both running tunnels – see paragraph 158). As the fire was located approximately 650 metres from the evacuating passengers and crew, even if it had spread rapidly to engage vehicles in front, it is unlikely that it would have had any effect on the evacuation because the SVS would have slowed the forward movement of the fire for long enough to allow the passengers to evacuate. Indeed, the fire would have needed to advance at a net rate of 1 m/s against the SVS airflow to pose any threat to evacuating passengers. This is not considered credible over the full length of the train as it would imply that every vehicle was highly combustible and that the fire was able to maintain the same rate of progress in the gaps between vehicles.

334 The damage to HGV shuttle wagons and tunnel infrastructure might have been more severe and the time taken to restore normal operations both in the remaining tunnel intervals and through Interval 4 would probably have been longer. In addition, the work of the fire fighters would have been more hazardous as a result of the size of the fire and decisions would have been needed on whether to do so or to leave the fire to burn itself out, which might have had more profound implications for tunnel infrastructure.

335 Paragraphs 313-334 have shown that the four alternative scenarios considered would not, individually, have prevented a safe outcome from the incident. Combinations of the four scenarios have also been considered. A more difficult combination would be fire at the front of the train with fire spread to engage other vehicles on the shuttle (i.e. a large fire at the front of the train). However, these circumstances were present during the fire in 1996 and a safe outcome was achieved, even with no imposed airflow from the SVS fans.

336 The presence of other trains in the tunnel does not act as a significantly compounding feature in any scenario because of the distance between the incident train and the first train behind. Once evacuation of the small number of passengers and crew is complete, priority can be given to moving other trains out of the tunnel, irrespective of the location of the AMC.

337 The combination that would give greatest cause for concern would involve an HGV on fire at the front of the shuttle, with the AMC located at the rear and the fire spreading to engage adjacent loads. The primary concern would be the safety of the driver of the shuttle train, with smoke initially being driven towards the locomotive cab. Eurotunnel's procedures give priority to the driver's evacuation by initially calling for the nearest CPD to the front of the train to be opened. The driver is able to evacuate if he can see the CP (paragraph 321) and the bubble effect (paragraph 315) might assist him to do so.

In the circumstances present on 21 August 2006, it is still likely that the driver would have been able to evacuate before his safety was compromised by proximity to the fire and smoke. Had he been required to wait in the cab while the AMC was evacuated, he would have relied on the protection afforded by the locomotive itself and the smoke-hood provided (paragraph 319) to remain in a safe environment. Once evacuation of the AMC was complete, the SVS could be reversed to provide a clear environment for evacuation at the front of the train. In this scenario, the possibility of a rapid and safe evacuation for the driver would be enhanced by his achievement of a controlled stop in the correct location, adjacent to a CPD.

Commentary on the design of the HGV shuttle

338 Appendix E summarises the safety measures established in relation to HGV shuttles at the time of the start of commercial operations in July 1994 and the additional measures that were introduced in March 1997 in response to the fire of November 1996.

339 Table 11 recaps each of the safety measures relevant to the design of the shuttle and records how each performed during the fire.

Safety measure (rolling stock design related)	**Observations**
All HGV drivers to be conveyed in an amenity coach at the front or rear of the shuttle (i.e. separate from their vehicles).	The HGV drivers travelled in a single location on the shuttle. This enabled a fast and efficient evacuation whilst the SVS was operating to protect them from smoke.
Presence of fire to be detected using smoke detectors mounted on each loader wagon (alarm transmitted to the amenity coach).	The on-board fire detectors gave an early indication of the presence of smoke and an audible and visual alarm was correctly given to the Chef de Train. On-board alarms are not automatically transmitted to the RCC. This means that any actions to be taken by the RCC are dependent on the driver notifying the presence of an alarm. In this instance this did not occur.
Fire resistance of the floor to protect the running gear, brakes and train lines for the time taken to carry out a controlled stop.	The damage caused to the carrier wagon did not prevent the driver from carrying out a controlled stop *(this was also true in the fire in November 1996).*
The amenity coach to resist heat and smoke for sufficient time to protect occupants whilst waiting for the SVS to blow smoke clear.	No conclusion can be drawn since the amenity coach was not exposed to heat, smoke or flame *(during the fire in November 1996 the amenity coach was subjected to temperatures in excess of 200°C without structural failure. Some smoke ingress did occur).*
Improved seals to limit smoke ingress	No conclusion can be drawn since the amenity coach was not exposed to smoke.
Smoke hoods provided in the amenity coach for use by the train crew and HGV drivers	No conclusion can be drawn since the use of smoke hoods was not necessitated (however, they were distributed in readiness by the Chef de Train).

Table 11: Observations on the performance of rolling stock design measures

Containment and on-board fire suppression

340 The current design of the carrier wagons would not prevent the spread of the fire to involve many HGVs (as was the case in the fire in November 1996). A fire of this type could cause major structural damage to the tunnel and disruption of the tunnel's mechanical and electrical systems. It is most unlikely that intervention by firefighters would significantly control or limit the damage caused.

341 In order to prevent the spread of fire between carrier wagons it would be necessary to adopt one of the following solutions:

- containment of the carrier wagons;
- on-board fire suppression system; or
- a combination of the above.

342 For the reasons described in Appendix E the system's original designers, Transmanche Link, and Eurotunnel have previously concluded that any reliable system of containment is likely to cause an unacceptable axle load when conveying the heaviest HGVs. It would also create the requirement for the maintenance of two electrically operated fire barriers on each carrier wagon.

343 A prototype on-board fire suppression system was developed and tested by Eurotunnel over a period of six years following the fire of November 1996. This system was based on the provision of a water supply at one end of the shuttle and a system of pumps and pipes to distribute water along the length of the shuttle. If installed this system would enable the supply of water to an array of water mist sprays within a set of carrier wagons in which an abnormal heat source had been detected. Fire tests have shown that such a system would suppress the development of a fire for the time taken for the firefighters to intervene.

344 Despite the development of the prototype Eurotunnel concluded that the system would be unreliable in service, expensive to maintain, and would deliver few benefits to the safety of persons.

345 Thus there is no evidence of a requirement to modify the basis of the design concept arising from this investigation in order to provide improved safety in the event of an outbreak of fire. Given this acceptance of the current design concept, any recommendations made must be to ensure the suitability of Eurotunnel's procedures.

The on-board fire detection system

346 As indicated at paragraph 256 a six minute delay in the stopping of Mission 7370 occurred as a consequence of the driver not informing the RCC that the on-board fire detection system was showing an alarm. This omission by the driver delayed the implementation of the procedure to stop following trains by about two minutes. In the event, this had no effect on the handling of the incident as no trains entered the tunnel behind Mission 7370 during this period. It is, however, possible that another train could have entered during this time, and had this happened it would have complicated the management of the incident and resulted in another train being present in a tunnel contaminated by smoke. This potential for delay could be overcome were a confirmed alarm transmitted directly to the RCC by means of a radio signal. For this reason, consideration should be given to the installation of such a feature to the current system or, should this prove not to be reasonably practicable, when the radio system is upgraded.

Commentary on the safety strategy

347 The safety strategy for the HGV shuttle if a confirmed fire is detected on board is to undertake an immediate controlled stop and evacuate the passengers and crew to the service tunnel, unless the shuttle is close to the tunnel exit, in which case the strategy is to drive out to the terminal where there are facilities for dealing with the fire and passengers and crew can be evacuated immediately in the open.

348 The strategy of stopping an HGV shuttle immediately a fire is detected on board was adopted after the fire of 1996. Until that time, the strategy had been to attempt to drive out of the tunnel. In the 1996 incident, the driver, while initially attempting to do so, was ultimately prevented by a warning light on his console which indicated a failure on a key item of equipment which brought with it the potential to cause derailment of the shuttle.

349 The advantages of stopping a shuttle immediately with a fire detected on board are twofold:

- it is more likely that the driver will retain full control over power and braking and be able to stop with the AMC located adjacent to a cross passage, which facilitates the timely and safe evacuation of passengers and crew; and
- the fire has only been given limited time to develop, which means that the size of the fire will be smaller than might be the case if the shuttle were allowed to continue and then be forced to stop later.

350 The evacuation of passengers and crew from Mission 7370 was completed within 20 minutes of the first activation of a smoke detector in CP1626 and within 10 minutes of the shuttle stopping. No injuries were sustained by passengers or crew and the evacuation was achieved in a calm and efficient manner. The evacuating passengers and crew were unable to smell smoke at this stage and this may have contributed to the speed and efficiency of the evacuation.

351 In conclusion, this investigation has not revealed any evidence of a requirement for a change in the existing safety strategy following the detection of fire on an HGV shuttle.

Conclusions

Immediate cause

352 The immediate cause of the accident was a fire in the load compartment of a lorry on the penultimate wagon of an HGV shuttle. (Paragraphs 48, 132, 226).

Contributory factors

353 A contributory factor was the difficulty in detecting a smouldering fire within the load compartment of a lorry (paragraphs 231 to 242).

Factors concerning the effectiveness of detection and surveillance in the terminal

354 Loading staff are well placed to detect a fire during loading. However, current procedures do not specifically refer to a requirement to visually check the roof and doors of the load compartment for signs of smoke escaping. Instructions to staff do make reference to checking the area of brake drums/axles for smoke (paragraphs 233 and 242, Recommendation 1).

355 The Agents de Feu have difficulty in observing the passage of the rear of the shuttle (paragraphs 111 and 244, Recommendation 2).

356 The positioning of the Agents de Feu and the proximity of the UK portal of the tunnel to terminal limits the time available in which to stop a shuttle on which a fire is observed. In the case of a fire noted on a lorry towards the back of a shuttle there is insufficient time to alert the RCC and for the shuttle to be stopped before it has already passed the portal (paragraphs 245 and 246, Recommendation 3).

Factors concerning the effectiveness of the incident management

General

357 Overall, the incident was well managed by staff on the train, by the controllers and by the emergency services.

358 The evacuation of passengers and crew from Mission 7370 was completed within 20 minutes of the first activation of a smoke detector in CP1626 and within 10 minutes of the shuttle stopping. No injuries were sustained by passengers or crew and the evacuation was achieved in a calm and efficient manner.

359 The fixed and on-board fire detection systems gave an early warning of the presence of fire on the moving HGV shuttle. This enabled timely implementation of the emergency procedures.

360 The tunnel's electrical and mechanical systems functioned correctly during the incident enabling the efficient evacuation of the HGV shuttle into the service tunnel and the effective management of smoke.

361 Emergency procedures were generally implemented correctly by staff in the RCC and onboard the HGV shuttle. Those errors that were made did not affect the achievement of a safe outcome but should nevertheless be addressed by Eurotunnel.

362 The investigation has not revealed any evidence of a requirement for a change in the existing safety strategy following the detection of fire on an HGV shuttle nor any need for modification of the rolling stock. However, a number of specific issues have arisen during the investigation that should be addressed in order to improve the efficiency of any future emergency response.

Specific issues

363 The driver of the HGV shuttle did not advise the RCC that he had received an indication that the on-board fire detection system had been activated (paragraph 165, Recommendations 4 and 5).

364 The RTM controller did not broadcast a message to all trains in both running tunnels to close their air conditioning units (paragraph 146, Recommendation 10).

365 Two shuttles did not respond to the instruction to reduce speed to 10 km/h and another asked for the message to be repeated, probably because of a lack of radio reception. The driver of the incident shuttle also had difficulty in contacting the RCC after he had stopped his shuttle. The probable cause is the variable reception achieved by the track-to-train radio (paragraphs 201 and 203, Recommendation 6).

366 Following the stop imposed by the TVM system, the RTM controller did not instruct the driver of both shuttles in the Running Tunnel South to control their speed to 10 km/h, which resulted in them accelerating to 30 km/h. In different circumstances this could have had an adverse effect on the management of airflows. The lowest speed the TVM system can impose is 30 km/h (paragraph 150, Recommendations 7 and 10).

367 The driver of the HGV shuttle was uncertain of the location of the 'go zone' and did not stop at the first available subsequent cross passage (Paragraphs 167 and 168, Recommendation 8).

368 The driver of the HGV shuttle initially stopped the shuttle slightly short of the correct position and had to move it forward (paragraph 168, Recommendation 9).

369 Opening the cross passage doors before the incident shuttle's final stopping position was confirmed contravened the relevant procedure. This had no adverse consequences, but could have caused a loss of control of airflow in different circumstances (paragraph 273, Recommendation 10).

370 The EMS controller did not specify the tunnel in which the incident had occurred before switching off one of the two fans at each ventilation plant, which resulted in a reduction in smoke-controlling airflow past the incident train. The layout of data on the EMS screen is likely to have contributed to this error (paragraph 275, Recommendation 11).

371 The Fire Detection Controller took excessive time to establish an appropriate postcode to meet the needs of the UK police and ambulance services (paragraph 163, (Recommendation 12).

372 No single person in the ICC had a complete and accurate view of events in the tunnel (paragraph 252, Recommendation 14).

373 The start of fire fighting was delayed for at least one hour due to the time taken to earth the catenary. In different circumstances this delay could have resulted in additional risk to fire and rescue service staff or would have given additional time for the fire to spread (paragraph 308, Recommendation 13).

374 There has been no formal debriefing meeting between all the parties who attended the incident which would have provided an opportunity to ensure that lessons could be jointly learned (paragraph 253, Recommendation 15).

Other observations

375 The existing RTM procedure does not explicitly require the controller to advise the RCC Supervisor when a message regarding a fire alarm on an HGV shuttle has been received or provide guidance to the RTM Controller on the optimum sequence of actions when a fire alarm on a HGV shuttle and a Level 2 alarm are declared almost simultaneously (paragraphs 284 and 285, Recommendation 16).

Actions reported as already taken or in progress relevant to this report

376 Eurotunnel has initiated a programme of track-to-train radio system enhancements to overcome the existing transmission and reception problems (as described in paragraph 289). This work has involved the installation of new connections to the leaky feeder cable from the service tunnel into the running tunnel. The programme of works started in November 2006 and was completed during September 2007.

377 The Emergency Services have reviewed their procedures and protocols in the light of the events during and immediately following the incident.

Recommendations

378 The following safety recommendations to address the management of the consequences of the fire are made[2]:

Recommendations to address issues associated with detection and surveillance in the terminal

1 Eurotunnel should update the procedure for HGV loading staff to include the requirement to visually check the roof and doors of the load compartment for signs of smoke escaping (paragraph 354).

2 Eurotunnel should review alternative means of more reliably detecting signs of fire or other abnormal situations on the rear sections of departing shuttles, which would include the number and positioning of Agents de Feu and should implement improved measures as appropriate (paragraph 355).

3 Eurotunnel should investigate the possibility of providing the Agents de Feu with a direct method of stopping a departing shuttle and implement it if reasonably practicable (paragraph 356).

Recommendations to address issues associated with the management of incidents

4 Eurotunnel should provide a means for the automatic transmission of alarms from the on-board fire detection system on the HGV shuttles to the RCC (paragraph 363).

5 Eurotunnel should ensure that the findings of this investigation are incorporated into the briefing and training of HGV shuttle drivers. This should include a re-briefing in topic areas associated with the non-compliance with Eurotunnel procedures identified at paragraph 363.

6 Eurotunnel should undertake a detailed survey of radio reception in the tunnel and make further improvements as necessary (paragraphs 365 and 376).

7 Eurotunnel should examine the feasibility of using TVM to enforce a speed of 10 km/h and implement a modification to achieve this if it is found to be reasonably practicable (paragraph 366).

8 Eurotunnel should ensure that drivers are given a visual warning of the approach to the start and finish of go zones (paragraph 367).

9 Eurotunnel should ensure that all drivers routinely practise stopping at cross passage doors (paragraph 368).

continued

[2] Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on RAIB's web site at www.raib.gov.uk

10 Eurotunnel should ensure that the findings of this investigation are incorporated in the briefing and training procedures of RTM and EMS controllers. This should include a re-briefing in topic areas associated with the non-compliances with Eurotunnel procedures identified at paragraphs 364, 366 and 369.

11 Eurotunnel should review the design of the ventilation control system with a view to reducing the possibility of controllers selecting a sub-optimal configuration (paragraph 370).

12 Eurotunnel should ensure that the FDC has immediate access to the postcode of the Longport reception area (paragraph 371).

13 Eurotunnel, in consultation with the emergency services in France and the UK, should carry out a study to assess the feasibility of decreasing the time taken to earth the catenary during an emergency situation. The best solution identified should then be implemented if reasonably practicable to do so (paragraph 373).

14 Eurotunnel, in conjunction with the Emergency Services, should review its emergency plan (and associated bi-national arrangements) with a view to ensuring that accurate information from the incident site is available promptly to those making strategic decisions within the ICCs (paragraph 372).

15 Eurotunnel, in conjunction with the emergency services, should revise its arrangements for formal multi-party reviews of lessons to be learnt following major safety incidents (paragraph 374).

Recommendations to address other matters observed during the investigation

16 Eurotunnel should modify the RTM procedure to incorporate an explicit requirement to advise the RCC Supervisor when a message regarding a fire alarm on an HGV shuttle has been received and clarify the sequence of actions to be taken by the RTM Controller in the event that a rolling stock alarm and a Level 2 alarm are declared almost simultaneously (paragraph 375).

Appendices

Glossary of abbreviations and acronyms — Appendix A

Ac	Alternating current
AMC	Amenity Coach
ADU	Air Distribution Unit
BEA-TT	*Bureau d'Enquêtes sur les Accidents de Transport Terrestre*
BINAT	Channel Tunnel Bi–National Emergency Plan
CCTV	Closed Circuit Television
CP	Cross Passage Door
CTSA	Channel Tunnel Safety Authority
EMS	Engineering Management Systems
EOCC	Emergency On Call Co-ordinator
EOCD	Emergency On Call Director
FDC	Fire Detection Controller
FEMC	Fire & Emergency Management Centre
FLOR	First Line Of Response
FSS	Forensic Scientific Services
HGV	Heavy Goods Vehicle
HVAC	Heating, Ventilation and Air Conditioning
ICC	Incident Co-ordination Centre
ICTS	International Consultants Targeting Security
IGC	Intergovernmental Commission
KF&RS	Kent Fire and Rescue Service
NVS	Normal Ventilation System
PK	*Poste Kilometrique* (Kilometre Post)
PRD	Piston Relief Duct
RCC	Railway Control Centre
RTM	Rail Traffic Management
RTN	Running Tunnel North
RTS	Running Tunnel South
SD	Smoke Detector (Station de Detection)

SLOR	Second Line Of Response
STTS	Service Tunnel Transport System
SVS	Supplementary Ventilation System
TML	Transmanche Link
TTR	Track to Train Radio
TVM	Transmission Voie - Machine

Glossary of terms

Appendix B

All definitions marked with an asterisk, thus (*), have been taken from Ellis' British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com

Agent de Feu	A member of Eurotunnel or ICTS staff observing the departure of an HGV shuttle as a final security check.
Air distribution unit	Equipment which passes air from the service tunnel to the running tunnel.
Airlock	A system of doors enabling people to pass between chambers maintained at different air pressures.
Amenity coach	A rail passenger coach in which lorry drivers are carried on an HGV shuttle.
BINAT	The Bi–National Emergency Plan to facilitate the handling of emergencies in the tunnel by permitting emergency response teams from the non-incident side of the tunnel to cross the boundary between France and the UK to assist the team dealing with the emergency.
BINAT GO	The implementation of the BINAT procedure.
Blade angle	The angle at which the blades of the ventilation fans are set. It can be varied between 0 (no air flow) to 7 (maximum airflow).
Bureau d'Enquêtes les Accidents de Transport Terrestre	The French government agency responsible for the investigation of sur accidents involving land and inland waterway transport.
Catenary	The complete assembly of tensioned wires that make up the Overhead Line Electrification (OLE) system.*
Carrier wagon	A shuttle wagon used to carry either lorries or passenger carrying road vehicles.
Channel Tunnel Safety Authority	A body providing advice on Channel Tunnel safety to the Intergovernmental Commission.
Chef de Train	The member of train staff in overall charge of the shuttle who rides in the AMC on an HGV shuttle.
Circuit breaker	An item of equipment in an electrical circuit which enables the circuit to be isolated. It operates automatically to isolate the circuit should a fault develop causing an excessive electric current to flow.
Concession	The premises occupied and operated by Eurotunnel plc, including all terminal tracks and facilities.
Concession Agreement	The agreement between Eurotunnel and the UK and French Governments specifying the conditions under which Eurotunnel operates the Channel Tunnel.
Concession Time	The time used by Eurotunnel for all operating purposes. It corresponds with the time used in France and is usually 1 hour ahead of that in use in the UK.

Contact wire	The lowest wire in Overhead Line Equipment, it is this one that the current collector touches to draw power.
Cross Passage	Passages connecting the running tunnels with the service tunnel.
Cross Passage Door	Doors connecting the running tunnels to the cross passages.
Crossover	A section of track where the running tunnels are combined to enable a train to pass from one running tunnel to the other in either direction.
Crown	The top section of the tunnel lining.
Earth(ed)	To Earth is to connect an electrified item to the earth or another earthed conductor.*
Engineering Management Systems	The management of the ancillary systems such as ventilation and lighting servicing the tunnel.
Emergency On-Call Director	Senior Eurotunnel manager who take control of incidents within the ICC.
Emergency Operations On-Call Co-ordinator	A Eurotunnel manager supporting the EOCD, usually the Operations Duty Manager.
Euroscan	An installation used to examine the interior of lorries requiring the enclosure of the lorry and the evacuation of the cab.
Eurostar	The brand name of the European Passenger Service's (EPS) Class 373 Triple Voltage Trains, and now also the new name of the company.*
Fire Detection Controller	The controller in the RCC responsible for monitoring the smoke, fire and ionised gas detection equipment.
Fire & Emergency Management Centre	A control room in the fire and rescue service's facilities within the Eurotunnel concession.
First Line Of Response	A team of fire and rescue staff based at each of the fire stations within the concession at Cheriton or Coquelles. One is on patrol in the service tunnel at any time.
Flight	A group of trains travelling consecutively over the same railway line in the same direction.
Go zone	A section of the running tunnel in which trains making an out of course stop should avoid coming to a stand.
Incident Co-ordination Centre	A control office temporarily established adjacent to the RCC in the event of a significant incident, providing facilities for Eurotunnel emergency services staff.
Intergovernmental Commission	The safety authority responsible for the Channel Tunnel.

Interval	A section of one running tunnel either between a portal and one of the crossovers, or between the crossovers. They are numbered from the UK to France, odd numbers in the Running Tunnel South and even in the Running Tunnel North.
Isolated	Physically disconnected from the electrical power source, but not necessarily connected to earth.
Leaky feeder	A combination of a connecting cable and an aerial, used to allow two way radio frequency transmissions in tunnels. Leaky Feeders are laid along the complete length of the Tunnel, allowing these normally dead areas to send and receive radio and data traffic.*
Loader wagon	A shuttle wagon used to load either lorries or passenger carrying road vehicles. Vehicles are not carried on it during the transit.
Mission	A cross Channel journey carried out by a shuttle.
Normal Ventilation System	The air supply system used to ventilate the Channel Tunnel during normal operation.
Path	A clear route between two points built into a timetable.*
Poste Kilometrique	Kilometre post defining the location of a point in the Channel Tunnel
Piston Relief Duct	A duct connecting the 2 running tunnels allowing air to flow from one to the other, reducing the trains' power consumption and air turbulence. They can be closed remotely as required, for example to prevent the spread of fire.
Rail Traffic Management controller	The controller managing the movement of trains on the Channel Tunnel rail network.
Railway Control Centre	An office controlling the movement of trains and the associated infrastructure services in real time on the Channel Tunnel railway network.
Rake	A series of wagons coupled together as part of a semi-permanent formation.
Reversible signalling	The permanent provision of signals which enable a railway track to be operated in either direction.
Running Tunnel North	The northerly of the 2 rail tunnels, used by trains travelling from the UK to France during normal operation of the Channel Tunnel.
Running Tunnel South	The southerly of the 2 rail tunnels, used by trains travelling from France to the UK during normal operation of the Channel Tunnel.
Second Line Of Response	A team of fire and rescue staff which provide a back up to the First Line Of Response.
Service tunnel	A tunnel used to gain access to the running tunnels and the underground plant and equipment.

Service Tunnel Transport System	The transport system in place in the service tunnel using specialised guided road vehicles which can operate as conventional road vehicles on suitable surfaces.
Shuttle	A type of train operated by Eurotunnel to carry road vehicles between Folkestone and Calais.
Silver Command	The senior, strategic command level at the Channel Tunnel during an incident.
Smoke detector	An instrument to detect the presence of a fire by monitoring air for particulate smoke, ionised gas or carbon monoxide.
Sous-Préfet	The civil servant in charge of the local administrative area in France.
Speed code	A code transmitted to trains by the TVM signalling system indicating the maximum speed at which they are permitted to travel.
Standard gauge	The track gauge used by the main line railway systems in Britain and France.
Supplementary Ventilation System	An additional ventilation system brought into use when it has become necessary to stop trains for any significant period of time.
Track-to-train radio	A radio system enabling the RCC to speak to all train drivers either individually or generally and drivers to speak to the RCC.
Transmanche Link	The company that constructed the Channel Tunnel.
TVM signalling	The signalling system used in the Channel Tunnel which indicates to the driver the maximum permitted speed at any moment and overrides the driver's actions should it be exceeded.
Underframe	A structural assembly underneath the floor of a rail vehicle which supports the weight of the vehicle and its load and resists longitudinal forces.
Unsolicited brake application	An application of the train brakes which is not initiated by the driver or Chef de Train.

Review of possible detection measures in the terminals

Appendix C

	OPTION	EFFICACY OF FIRE DETECTION	OPERATIONAL IMPACT	OTHER ISSUES	Will it address other sources of fire on lorries?
(a)	**Inspection of loads for signs of fire in the terminal (possibly in conjunction with the existing Euroscan equipment).**	Will enable smoke to be seen or smelt. Smouldering fires remote from the access door may not be detected. Inspection may take place up to 45 minutes before loading onto the shuttle. This leaves sufficient time for a smouldering fire to grow after inspection.	Significant reduction in speed of throughput with consequent major impact on terminal operations Increased staffing Not all load compartments are easily accessible for inspection		No
(b)	**Enhanced checking by staff during loading onto HGV shuttles to include the roof and doors of the load compartment.**	May add value if staff are briefed to check the roof and doors of the load compartment for signs of smoke escaping.	Limited operational impact since loading staff are already tasked to be alert for signs of fire.	Main focus of checks by loading staff should continue to be the parts of the HGV most likely to be the source of fire (e.g. engine, brakes and tyres).	No

	OPTION	EFFICACY OF FIRE DETECTION	OPERATIONAL IMPACT	OTHER ISSUES	Will it address other sources of fire on lorries?
(c)	**Detection of products of combustion (e.g. smoke and CO) using detectors installed in the load compartment.**	A fire alarm in the load compartment may have detected the fire on 21 August 2006. Smoke detectors will be prone to false alarm in the dirty trailer environment. Heat detectors will be too slow to respond.	Must be fitted to large numbers of trailers and tractor units (i.e. all those that may conceivably operate via the Channel Tunnel). Tractors and trailers do not operate in fixed formation. Any one trailer will be hauled by different tractors. Any link between detector and alarm annunciator must be wired through the electrical couplers or transmitted by radio. This would introduce significant costs and introduce the need for a high degree of standardisation to enable the free exchange of trailers with tractors.	There is no easy means to enforce compliance. This measure has not been introduced in long road tunnels despite higher consequences of a fire event. Significant cost to the road haulage industry	No
(d)	**Detection of products of combustion (e.g. smoke and CO) using aspiration tube inserted into the load compartment prior to loading onto HGV shuttle.**	Will enable smoke to be detected before it escapes from the load compartment. Air could be sampled at late stage in loading process (e.g. whilst lorries are loaded on the shuttle). Smouldering fires remote from the aspiration point may not be detected.	All load compartments would need to be opened. Alternatively trailers would need to be provided with suitable holes for an aspiration tube to be inserted. This implies modification of large fleets of trailers. Additional staffing requirement.		No

	OPTION	EFFICACY OF FIRE DETECTION	OPERATIONAL IMPACT	OTHER ISSUES	Will it address other sources of fire on lorries?
(e)	**Detection of heat sources in the load compartment or on the outside surface of the load compartment using fixed equipment in the terminal.**	Small heat sources deep in the load (i.e. incipient fires) will be difficult to detect. If such a system were to be too sensitive it would be prone to false alarms due to surfaces heated by the sun and other sources of heat such as refrigeration units. If it were desensitised its efficacy would be reduced.	Likely to require additional staff to operate and maintain equipment.	Could be installed on overbridge down ramps.	Will add little safety benefit for fires on other parts of the lorry
(f)	**Detection of heat emitted from load compartment when stopped within carrier wagon.**	Heat detectors located in the roof of the shuttle would provide warning of heat emitted from the upper part of the load compartment (e.g. heated surface or smoke). Detection available immediately prior to the departure of the shuttle and during the journey. If such a system were to be too sensitive it would be prone to false alarms due to surfaces heated by the sun and other sources of heat such as refrigeration units. If it were desensitised its efficacy would be reduced.	Limited operational impact other than additional maintenance.	Would require to be installed all carrier wagons with control circuitry to allow transmission of an alarm (alternatively radio transmission facility). High installation cost	Will add little safety benefit for fires on other parts of the lorry

Recommendations made following 1996 fire — Appendix D

The following Recommendations were made which are relevant to the fire of 21 August 2006:

6. Eurotunnel must review the performance of the tunnel's entire hard-wired, telephone and radio links and up-grade them as necessary, to ensure that the original design requirements are met. The internal administrative system must be capable of switching to the public telephone network in the event of a local failure.

8. In order to ensure the early warning of fire, Eurotunnel must review the calibration of the on-board detection system or replace the type of detector used. The modifications to the detection system must be validated by realistic test conducted in the Channel Tunnel.

11. Eurotunnel must abandon the present drive-through policy. In developing new procedures, Eurotunnel must take into account in particular:
    - failure of a locomotive,
    - failure of a props and bridging plate control circuit,
    - failure of a brake line,
    - failure of the catenary,
    - the risk to people on following trains from smoke,
    - the risk to people on the incident train of the size of fire at the time of any eventual stop (planned or unplanned).

20. The train crews of Eurotunnel and all other Railway operators who use the tunnel must receive additional training in the handling of emergencies. The training should be practical in nature. A mock-up representing a running tunnel adjacent to a cross-passage should be built, which is capable of being used with the presence of smoke and crews should be trained in the environment.

21. Eurotunnel must improve the visibility of the reflective position marker panels and insure that they are kept as clean as possible.

29. The Rail Control procedures regarding reduced speed limit operations must be improved in order to ensure that other trains are not subject to unexpected braking.

35. The procedures relative to controlled stops must be improved to state that, except in derailment, the stopping point must be agreed between the driver and the Rail Control Centre prior to stopping. In order to guard against any inadvertent failure, Eurotunnel should consider the installation of an improved means of determining the position of the incident train when it has come to a halt.

History of the design and development of the infrastructure and HGV shuttle design to address fire risk — Appendix E

1 The Channel Tunnel was designed to accommodate the safe transit of the following types of trains:

- national passenger trains conveying passengers seated within railway carriages;
- 'tourist shuttles' conveying passengers seated within their own road vehicles;
- national freight trains conveying conventional freight wagons; and
- 'HGV shuttles' conveying heavy goods vehicles within specially designed railway wagons and their drivers in a separate amenity coach.

2 The design of the national passenger trains and the tourist shuttles was developed in order to meet a high level safety specification contained in the Channel Tunnel Concession agreement. This specification required that passenger trains be capable of being driven out of the tunnel despite the presence of fire onboard. This necessitated the provision of the range of design measures summarised in Table E.

Type of train	National passenger train	Tourist shuttle
Two locomotives, each capable of hauling the entire train out of the tunnel	✓	✓
Each wagon to be capable of containing a fire for 30 minutes		✓
Spread of fire to adjacent wagons to be prevented for a period of 30 minutes	✓	✓
Fire detection and suppression in passenger compartments		✓
Fire resistant floor to prevent spread of fire	✓	✓
Selection of materials to minimise toxicity of smoke	✓	✓
Ventilation systems to prevent the ingestion from the tunnel environment in case of fire	✓	✓
Measures to facilitate the rapid evacuation of passengers to adjacent wagons	✓	✓
Onboard communications systems to assist incident management	✓	✓

Table E: Channel Tunnel passenger trains – key fire safety measures

3 Both of the above types of train were to be operated by rolling stock that was designed for the purpose. On the other hand, national freight trains were to convey conventional wagons of the type already operating via the Dover train ferry. For this reason the fire safety strategy was based on the ability to detect fire using tunnel mounted detectors and the installation of tunnel systems to enable the achievement of the following objectives:

- evacuation of the driver to the service tunnel;
- the movement of other trains out of the tunnel;
- the management of smoke movement in the tunnels; and
- safe and effective fire fighting and rescue.

4 During 1987 the specification for the HGV shuttles was developed by consultants working on behalf of the main contractor, Transmanche Link (TML). This original specification was based on the design concept of an enclosed carrier wagon similar to that proposed for tourist shuttles. This concept featured a solid fire resistant roof, sides and gangway interconnections. Fire spread along the shuttle was to be prevented by barriers located at each end of every carrier wagon. This was to provide fire containment and a suitable environment for the installation of fire detection and suppression systems.

5 During 1988 and 1989 discussions with suppliers revealed that the specified design would impose a limitation on the weight of road vehicles that could be conveyed. This was because the enclosed wagon would be too heavy to accommodate the heaviest HGVs without the resulting wagon axle load exceeding the design limit of the tunnel track system (25 tonnes). Calculations carried out at this stage showed that the fully enclosed design would limit the weight of HGVs that could be conveyed to around 35 tonnes (these calculations included an allowance for uneven distribution of the HGV's weight across the two bogies). This proposed weight limit was well short of the EEC limit of 44 tonnes and would therefore have seriously undermined the viability of the Channel Tunnel project.

6 Attempts to reduce the weight of the HGV carrier wagon design were unsuccessful for the reasons below:

- the enclosing structure required great strength to resist the high aerodynamic forces in the tunnel;
- a lightweight design would be unlikely to create a suitable environment for the correct operation of fire detection and suppression systems;
- the lightweight designs could not accommodate a reliable and effective fire barrier at each end of the carrier wagons.

7 In addition to the above, TML also assessed the feasibility of installing triple axled bogies on the carrier wagons. This option was rejected given the unproven technology and predicted high rates of wear on the rails and wheel sets as shuttles traversed the curved tracks in the UK and French terminals.

8 In 1989 TML concluded that there was no viable means of significantly reducing the axle load of HGV carrier wagons. As a consequence TML proposed to Eurotunnel that the design concept be amended by removing altogether the requirement for enclosure of the carrier wagons. This change was supported by an argument that the HGV shuttles were in essence no different from the national freight trains and that it was therefore reasonable to apply the same basic safety measures.

9 The proposed change to the design concept was broadly supported by the Channel Tunnel project's independent technical advisors, the Maitre d'Oeuvre (MdO).

10 By the beginning of 1990 ET decided that it would agree to the design change and made a submission to its bi-national regulator, the Intergovernmental Commission (IGC).

11 By this time an uncontained carrier wagon design had already been developed by the selected supplier Breda Fiat. This design featured a solid roof, perforated sides, open ends and a fire resistant floor capable of carrying HGVs of up to 44 tonnes.

12 Over the following three years Eurotunnel and the IGC were engaged in a debate about the acceptability of the design change. This debate was centred on a series of safety submissions prepared by Eurotunnel (in conjunction with TML) in support of a revised fire safety strategy for HGV shuttles. These submissions included the following elements:

- an overview of the design concept;
- an overview of the safety strategy;
- reports of tests and demonstrations performed in support of the above strategy; and
- supporting risk assessments.

13 The above information formed part of a document known as an 'Avant Projet' that was required to be accepted by the IGC prior to the commencement of services. This acceptance was granted in the form of a letter from the IGC to Eurotunnel.

Time line of events Appendix F

All times are quoted in Concession time.

Items in italics refer to the lorry and shuttle Mission 7370.

Time	Control Room	*Lorry Shuttle* & Tunnel Systems
11:00		*Lorry departs from base in Twickenham*
12:45		*Lorry checks in at toll*
13:26		*Mission 7370 enters RTN*
13:30:31		First alarm SD08 in RTN (smoke)
		Rolling stock alarm activates
13:31	General call to all trains to reduce speed to 100 km/h.	
13:32:06	Activates first alarm sequence in RTN	
13:32:12		RTN lighting on
13:32:17		Air Distribution Units closed
13:32:18		Normal Ventilation System blade angle to +5
13:32:39		First alarm SD12 in RTN (smoke)
13:33:10		First alarm SD14 in RTN (smoke)
13:33:20	Supervisor declares 'second alarm' stopping Mission 7370	
13:33:48	Activates second alarm sequence	Piston Relief Ducts closed
13:34	Instructs Mission 7370 to carry out controlled stop	*Fire alarm on Mission 7370*
	French FEMC advised to send French FLOR	
13:34:18		Automatic imposition of 100 km/h speed limit in both running tunnels
13:35	UK FEMC advised to send UK FLOR	
	General call to all trains to reduce speed to 10 km/h	
13:35:04		First alarm SD18 in RTN (smoke)

Time	Control Room	*Lorry Shuttle* & Tunnel Systems
13:35:41		Second alarm SD22 in RTN at CP2662 (smoke and flame)
13:36	999 calls to UK Emergency Services. Delays with Police and Ambulance	
13:36:03		Fire confirmed in RTN at CP2662
13:36:49		First alarm SD26 in RTN at CP2826
13:36:57	Starts SVS in duplex mode. RTN and RTS dampers closed, no running tunnel ventilation	
13:37	Asks UK M&E to enter tunnel to go to incident at PK22	
13:39:24		RTN CP 1990, 2214, 2662 confirm fire
13:39:32		Automatic imposition of 30 km/h speed restriction in both tunnels
13:39:34	Opens SVS dampers to RTN and RTS. SVS now operating 2 fans in UK and French ventilation plants in both tunnels	
13:40		*Mission 7370 stops at PK3050*
	Missions 7367 and 7369 told to proceed, but no mention of 10 km/h speed restriction	Missions 7367 & 7369 in RTS stopped automatically by TVM when 30 km/h limit imposed (travelling at 100 km/h)
13:40:05		Second alarm SD28 in RTN at CP3012 (smoke and danger CO level)
		Catenary trip in RTN
13:40:47	Opens CPD 3088	
13:41	Call Mission 7370 to confirm where it has stopped.	Driver confirms stopping location as CP 3050
13:41:02	Opens CPD 3050	
13:42:31	UK SVS into simplex mode, blade angle 4	*Evacuation starts*
	Traffic Control confirms no dangerous goods on Mission 7370	

Time	Control Room	*Lorry Shuttle* **& Tunnel Systems**
13:43:29	French SVS into simplex mode (one fan in UK and French ventilation plants in both tunnels)	
13:44	Asks Missions 7367 and 7369 to reduce speed to 10 km/h Advises French FEMC of CP3050 and presence of CO	Drivers of Missions 7367 and 7369 moving at 30 km/h.
13:46:42	Closes SVS dampers to RTS. (SVS now operating on one fan per shaft in RTN – correct configuration for incident.	
13:47	Confirms to FLOR the shuttle stopped at CP 3050. Requires all STTSs to go to 3050	
13:48	Orders all train in RTS to increase speed to 60 km/h	
13:49		*Chef de Train advises that evacuation of 34 persons complete and CPD 3050 can be closed.*
13:50	Advises French FEMC that 34 people have been evacuated to service tunnel	
13:50:52	CPD 3050 closed	
13:51:06	CPD 3088 closed	
13:51:56	Catenary circuit breaker reset	
14:00		UK FLOR at CP 2954 reports 'thick smoke and flames'. Awaiting SLOR
14:02	Opens CPDs 3088 and 3050 for SLOR	
14:04	Commercial services formally suspended	
14:20		Commencing inspection from CP 2974 towards 3050

Time	Control Room	*Lorry Shuttle* & Tunnel Systems
14:36	Confirms that catenary is isolated from incident to midpoint, but no earths in place	UK FLOR requests catenary isolation around incident
14:40		UK FLOR requests *BINAT GO*
14:49		UK FLOR reports flames appearing under train at CPD 2974
15:24		FEMC France confirms evacuation. STTS vehicles are at PK38 en route to France.
15:31	CPD 1114 (tunnel entrance) opened, CPD 3050 closed to facilitate earthing of catenary in RTN	
15:40		Confirmed that earth protection in place at CP 1114 & 3538. CPDs can be closed
15:41	Confirms to FLOR leader that catenary is earthed and UK leader can start fire fighting	Confirms that fire fighting will start
15:47		*Evacuees from Mission 7370 arrive at French portal by STTS vehicle*
16:05		Confirmation that fire is out. Smoke clearance in action
16:36	Opens CPD 2974	CPD 2974 taken onto local control
17:03		End of BINAT
17:10	Resume commercial operation in RTS	
17:57	PRDs opened	
18:20	Interval 6 in RTN re-opened	
19:35	Interval 2 in RTN re-opened	
23:12		*Mission 7370 started to move to French portal hauled by diesel locomotive*
00:45		*Mission 7370 reaches French portal*
16:15	Interval 4 in RTN re-opened	

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