Inquiry into the fire on Heavy Goods Vehicle shuttle 7539 on 18 November 1996

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The Channel Tunnel Safety Authority:

1. The Channel Tunnel Safety Authority was established by the Governments in accordance with the provisions of the Treaty of Canterbury, signed on 12 February 1986 between the Republic of France and the United Kingdom of Great Britain and Northern Ireland, and relating to the construction and operation by private Concessionaires of a cross-Channel Fixed Link. The Intergovernmental Commission, also established under the Treaty, supervises in the name and on behalf of both Governments, all matters concerning the construction and operation of the Fixed Link. The Safety Authority (under Article 11 of the Treaty) advises and assists the Intergovernmental Commission on all matters concerning safety of the Fixed Link.
2. The Channel Tunnel Safety Authority comprises delegations from France and the United Kingdom each with five members appointed by their respective governments and detailed in the Annex. The heads of the two delegations serve alternately as Chairman of the Channel Tunnel Safety Authority for a year at a time. At the time of the incident on 18 November 1996, the Chairman was the head of the French delegation. Since 1 April 1997 the Chair has been held by the Head of the UK Delegation.
3. In the context of its duties the Safety Authority is charged in particular (under Article 11 (1) (c) of the Treaty) with examining reports concerning any incident affecting safety, making such investigations as are necessary and reporting thereon to the Intergovernmental Commission. To fulfil this duty, the Channel Tunnel Safety Authority appointed two of its members, M. Pierre Desfray, Ingénieur Divisionnaire des Travaux Publics de lEtat in the French Ministry of Transport, and Mr Jeremy Beech, Chief Fire Officer of Kent, to act as Co-Rapporteurs for the Inquiry into the incident of 18 November 1996. The chairman of the Channel Tunnel Safety Authority wrote to Eurotunnel on 27 November 1996 to inform them of this decision and of the scope of the Inquiry. The Co-Rapporteurs were assisted in their task by a number of technical experts, by members of the French and United Kingdom emergency services, and by Eurotunnel and its staff (see Acknowledgements). On completion of their work the Channel Tunnel Safety Authority has been able to make this report to the Intergovernmental Commission and, at the same time, to the two Governments (Article 11.7 of the Treaty).
4. The Safety Authority wishes to commend the Co-Rapporteurs for the considerable effort which they have devoted to the investigation of the incident and the preparation of the Report.

Executive summary:

1. The objective of the designers, constructors, operators and regulators of a transport system must be to ensure that it provides an acceptable level of safety for the staff and users of the system. Such a level of safety depends upon well-designed, reliable equipment operated in accordance with clear and effective procedures, particularly in the management of emergencies. But no transport system can be made completely safe, involving as it does a complex interaction of engineering, technology and people. In the case of air transport, for example, the overall level of safety may be regarded as acceptable, but the consequences of an incident can be dramatic and absolute. A major incident such as the fire on a Heavy Goods Vehicle shuttle in the Channel Tunnel on 18 November 1996, inevitably raises serious questions about the particular type of train involved as well as wider issues concerning Eurotunnels overall safety arrangements and whether, and what, improvements need to be made. The Channel Tunnel Safety Authority consequently instituted a full Inquiry into the incident in order to ascertain the precise course of events, to examine the performance of the tunnel, fixed equipment and rolling stock. The Inquiry was also required to analyse the handling of the incident by Eurotunnel and the emergency services and to make recommendations in order to reduce the likelihood of such a fire occurring in the future, or to reduce the potential consequences.

2. Concerning the safety of the Eurotunnel system overall, approval was given to engineering, equipment and rolling stock designs only after much scrutiny by appropriate specialists and the production of a detailed safety case. Railway services were introduced progressively in a prolonged commissioning process in which operating procedures were developed and staff gained experience of a unique transportation system. That a fire has occurred is not a failure of the system overall. Fires will occur. Pending the findings of this Inquiry, the Channel Tunnel Safety Authority accepted that the overall level of safety afforded by the system and the different forms of rolling stock were such that Freight Trains, Eurostar and Tourist Shuttle services could recommence at a restricted level of operation due to the repair works having to be undertaken in the Tunnel and subject to certain other limitations.
3. The question of the safety of the Heavy Goods Vehicle shuttles is more difficult. The Channel Tunnel Safety Authority deliberated at great length before it was in a position in 1993 to recommend to the Intergovernmental Commission that no objection should be made on safety grounds to the Heavy Goods Vehicle shuttle design and its operating procedures. As early as 1992, the Channel Tunnel Safety Authority expressed concern about the possible size of a fire on a Heavy Goods Vehicle shuttle at the time of detection, the rate of fire development and spread, the size of a fire able to overcome the Supplementary Ventilation System, and the conditions concerning temperature, visibility and toxicity which would allow safe evacuation of passengers and crew into the Service Tunnel. These concerns were encapsulated in the Channel Tunnel Safety Authoritys view, at the time, that the overall objectives of the system must be to enable the passengers on the Amenity Coach to be safely evacuated either to the Service Tunnel or the open air in the presence of a fire anywhere in a Heavy Goods Vehicle shuttle, and to ensure the protection of passengers on other trains.
4. At the time, Eurotunnel put forward a substantial amount of evidence, backed up by an extensive programme of experiments and tests, to allay the Channel Tunnel Safety Authoritys concerns. This addressed, in particular:
    - the ability of the fire detection system to detect a fire early enough for evacuation to proceed safely.
    - the rate of fire development in a Heavy Goods Vehicle.
    - the ability of the tunnel ventilation systems to control the air flow in the vicinity of a fire.
    - the effectiveness of the procedures for dealing with an emergency in the tunnel, including the evacuation of the incident train and the movement of other trains in the Tunnel.
    - the ability of the Rail Traffic Management system to maintain, in all circumstances, the necessary minimum separation distance between Heavy Goods Vehicle shuttles and other trains.
5. On the basis of this evidence, the Channel Tunnel Safety Authority recommended to the Intergovernmental Commission in 1994 that a favourable response should be made to the request of Eurotunnel to the start of the Heavy Goods Vehicle shuttle service. By that time, Eurotunnel had developed emergency procedures giving priority to the option of directing any train with a fire on board, out of the tunnel to the emergency sidings, if possible.
6. In this Report, we conclude that the fire on 18 November 1996 was a severe test for the system and its operators, and we make a large number of recommendations arising from our findings. We note that many of the elements of the Eurotunnel system, the procedures and the people involved performed well during the incident and helped to ensure that it did not turn out to be an even more serious event than it undoubtedly was. A thorough analysis however, set out in this Inquiry Report, raises important questions about the overall safety of the system in these and similar circumstances, and has brought to light faults and weaknesses which must be corrected. Before commercial service may be resumed at its former level, all of these questions must be answered by Eurotunnel to the satisfaction of the Channel Tunnel Safety Authority. Eurotunnel must, in particular, convince the Safety Authority that it is possible to ensure the safe evacuation of passengers in all circumstances.
7. The cause of the fire is under investigation by a French Judicial Inquiry which is still in progress. For the purposes of the Safety Authoritys Inquiry, therefore, it has been necessary to consider events starting at the time when the train on which the fire occurred left the platform in the French terminal to begin its journey to England

Introduction:

1. At 21.58 hrs on 18 November 1996, Heavy Goods Vehicle shuttle No 7539, the incident train, travelling from France to the United Kingdom, stopped in Running Tunnel South, approximately 19 km from the French portal, with a fire on board. The fire emitted large quantities of smoke which rapidly engulfed the Amenity Coach at the front of the train. There were 31 passengers and two crew members in the Amenity Coach, and the train driver was in the front locomotive. The smoke enveloped the train drivers cabin and the Amenity Coach. The passengers and crew members all suffered from smoke inhalation and the presence of smoke made their evacuation to the safety of the Service Tunnel extremely difficult.
2. The evacuation of passengers commenced some 23 minutes after the train had stopped. It concluded about seven minutes later, by which time the Eurotunnel First Line of Response rescue teams had arrived on the scene. The train driver and 26 of the passengers were then evacuated onto a rescue train which had been stopped in Running Tunnel North adjacent to the incident train. The condition of the remaining 7 passengers and crew gave rise to concern, and they were treated on-site in a Service Tunnel ambulance vehicle sent to the scene via the Service Tunnel. They were subsequently evacuated in Service Tunnel Transport System vehicles. All passengers were transferred to local hospitals in France and placed under observation for a short time.
3. Whilst passengers received medical attention, fire-fighting crews began a prolonged and difficult fire-fighting operation. Altogether, in excess of 450 personnel from the French and United Kingdom emergency services were involved in the incident. The fire was finally extinguished towards 05.00 hrs on the 19 November and the Bi-National plan for the Channel Tunnel, triggered at 23.06 hrs on 18 November, was stood-down at 14.50 hrs on 19 November.
4. This was the most serious incident to have occurred in the Channel Tunnel since it opened for commercial services. There were a number of casualties as a result of smoke inhalation and the fire caused considerable damage to a section of the Tunnel (see Chapter IV for details). The Safety Authority instituted a formal Inquiry.
5. The findings of the Inquiry are set out in this two-part report comprising nine chapters. Part I provides a description of the Channel Tunnel and sets out the sequence of events and the aftermath. Chapter I provides a brief description of the Eurotunnel system and its safety features, with particular emphasis on Heavy Goods Vehicle traffic. Chapter II explains the condition of the system immediately before the fire. The precise sequence of events during the incident is described in detail in Chapter III, and Chapter IV details the casualties and damage to the infrastructure, rolling stock and operations. Part II provides analysis, commentary, conclusions and recommendations. Chapter V deals with the fire itself, and Chapters VI, VII and VIII cover the performance of the fixed equipment, the rolling stock and personnel involved in the incident. Chapter IX contains the conclusions and recommendations arising from the Inquiry.

Chapter I: Description of the Eurotunnel System:-

General

1. A detailed explanation of the Eurotunnel system is not appropriate in a report of this nature. The following paragraphs are confined, therefore, to a brief description of those parts of the system which are relevant to the incident and this Inquiry.
2. The Eurotunnel system comprises two running tunnels on either side of a Service Tunnel (see Figure 1). These tunnels are approximately 50km long, of which approximately 37km are under the English Channel. They connect the Channel Tunnel terminals at Coquelles, Pas de Calais region in France, and at Cheriton, Kent, in the United Kingdom.
3. The running tunnels contain the track for the movement of trains. There is a closed circuit track from one terminal to the other used for Eurotunnels shuttle trains, with connections at the French terminal to the SNCF system and in the United Kingdom terminal to that of Railtrack. Running Tunnel North normally handles traffic from the United Kingdom to France, and Running Tunnel South from France to the United Kingdom.
4. The Service Tunnel has three main safety functions:
    - To provide normal ventilation for the running tunnels.
    - To provide a safe haven for passengers and crew members in the event of the need for evacuation.
    - To facilitate the speedy arrival of emergency teams.
5. Four main categories of trains use the Running tunnels:
    - Single and Double Deck tourist shuttles carrying coaches and cars respectively.
    - Heavy Goods Vehicle shuttles carrying lorries and trucks.
    - Passenger trains, currently Eurostar trains which operate between London and Paris and London and Brussels.
    - Freight trains operating between the Fréthun sidings in France and the Dollands Moor sidings in the United Kingdom.

Heavy Goods Vehicle Shuttles

6. The Heavy Goods Vehicle shuttle trains (see photographs 1, 2 and 3) are made up of two rakes of wagons, one Amenity Coach for the carriage of the lorry drivers, with a locomotive at either end of

the train. A rake comprises 14 or 15 carrier wagons with a loader wagon at either end. The crew comprises 3 people: the driver and two crew members in the Amenity Coach. The carrier wagons are of semi-open construction. Their dimensions are as follows: length 20m, width 4.2m and height 5.6m. They are designed to carry Heavy Goods Vehicles up to a maximum weight of 44 tons, and the loader wagons are equipped with props which are lowered onto the rails during loading and unloading, to provide greater stability and avoid excessive wagon movement. The trains can only be driven with the props raised. The position of the props, therefore, has to be monitored. In the event of a fault, a STOP light illuminates in the drivers cabin instructing him to halt the train.

7. The Heavy Goods Vehicle loader wagons are equipped with folding bridge plates and props which are lowered to enable loading and unloading of lorries from and to the platforms. One end of each loader wagon contains two on-board fire detection units, each unit comprising an aspiration tube and a smoke detector. Information on the condition of this system is transmitted directly to the Chef de Trains work station in the Amenity Coach at the same time as it is sent to the drivers cabin.
8. The Amenity Coach is normally situated immediately behind the trains leading locomotive. It can carry a maximum of 52 passengers. Its crew comprises a Chef de Train and a steward, the latter being responsible for serving food and drink to the passengers. The materials used in the construction of the Amenity Coach meet strict fire resistance, smoke emission, toxicity and flammability requirements. The ends of the Amenity Coach have a 30 minute fire resistance. The access doors are equipped with inflatable seals and the Amenity Coach is air-conditioned.
9. The means of communication on board a Heavy Goods Vehicle shuttle include:
    - the track to train radio in the drivers cabin.
    - the concession radio, via a telephone in the drivers cabin and on the Chef de Trains work station.
    - an emergency telephone between the drivers cabin and the Chef de Trains work station.
    - a public address system in the Amenity Coach, operated from the Chef de Trains work station.

Tourist Shuttles

10. The tourist shuttle trains (see photograph 4) are designed to carry passengers in their vehicles. They have a locomotive at either end and are normally made up of two rakes: one rake of single deck and one rake of double deck wagons. A rake of wagons comprises 12 carrier wagons with a loader wagon at each end. The wagons themselves are all entirely closed, with fire barriers of 30 minutes fire resistance on each deck and at each end. They are air-conditioned and each deck is equipped with an automatic fire detection and extinction system.
11. There are eight crew members on board a tourist shuttle: a driver, a Chef de Train, two staff patrolling the single deck rake and four staff patrolling the double deck rake. The Chef de Trains work station situated in the rear locomotive, enables video surveillance and monitoring of the fire detection system on all decks.

Civil Engineering

12. The two running tunnels and the Service Tunnel are lined with reinforced concrete or, in some places, cast iron segments. The nominal diameter of the running tunnels is 7.6 m, and of the Service Tunnel 4.8 m. Each running tunnel contains a walkway on the Service Tunnel side for the evacuation of passengers and crew in the event of an incident. On the opposite side, there is a walkway for maintenance purposes or for the inspection of trains which have broken down (see Photograph 5).
13. The running tunnels are connected to the Service Tunnel by cross-passages at intervals of about 375m (see Figure 2). The running tunnel end of each cross-passage has a fire-resistant cross-passage door which is normally closed (see Photograph 6). Piston Relief Ducts 2m in diameter are found at intervals of about 250m, which connect the two running tunnels in order to balance the air pressure caused by the passage of trains and to reduce aerodynamic resistance (see Figure 2). The Piston Relief Ducts have dampers which are kept open during normal operations.

14. There are two under-sea crossovers (see Photograph 7), and two land crossovers to enable trains to pass from one running tunnel to the other, when part of either tunnel is closed for maintenance. The undersea crossovers are equipped with fire-resistant doors which separate the tracks in the two running tunnels (see Photograph 8). These doors are controlled from the Rail Control Centre. Each tunnel is separated into three intervals approximately 17 km long (see Figure 3).

Fixed Equipment

15. The main and relevant elements of fixed equipment installed in the tunnels are as follows:
    - A fire main running the length of the Service Tunnel and connected to fire hydrants in the running tunnels adjacent to each cross-passage and located every 125m along the running tunnels.
    - A tunnel cooling system made up of pipes circulating cold water.
    - A lighting system operated locally or remotely by the Rail Control Centre.
    - A drainage system to remove infiltrating water.
    - A track to train radio system enabling locomotive drivers to be in constant contact with the Rail Control Centre.
    - A concession radio system enabling any Eurotunnel staff with its portable hand-set to be in contact with the Rail Control Centre.
    - A tactical radio system for the exclusive use of the emergency services.
    - The operational and emergency telephone system connecting, inter alia, all of the cross-passages to the Rail Control Centre.
    - The administrative telephone system providing normal links between the two terminals.
    - A Public Address system in the Service Tunnel adjacent to each Cross Passage.
16. There are, however, two fixed equipment systems which were critical to the incident in question - ventilation and in-tunnel fire detection. The tunnel ventilation system actually comprises two separate systems: the Normal Ventilation System and the Supplementary Ventilation System.

The Normal Ventilation System

17. The Normal Ventilation System is provided to maintain air quality in the tunnel system, and to preserve the Service Tunnel as a safe haven in the event of fire or pollution in one of the running tunnels. It comprises two ventilation plants, one at Shakespeare Cliff in the United Kingdom and the other at Sangatte in France. Each plant has two variable pitch fans which are each capable of supplying air to the tunnel system. It operates by drawing air through ventilation inlets into the Service Tunnel via the air shafts. The air pressure in the Service Tunnel is maintained at a higher level than that of the running tunnels. To maintain this higher pressure there are airlocks at the entrances to the Service Tunnel. The fresh air from the Normal Ventilation System is distributed throughout the full lengths of the running tunnels by means of Air Distribution Units located in 38 of the cross-passages in each running tunnel. The higher air pressure in the Service Tunnel prevents smoke from entering the Service Tunnel and allows a bubble effect to be created. In the case of smoke being present in a running tunnel, the opening of a cross-passage door creates an air flow sufficient to disperse the smoke to a greater or lesser degree in the vicinity of the door.

The Supplementary Ventilation System

18. The Supplementary Ventilation System is used only in abnormal or degraded operating conditions. By configuring the output and the direction of the fans in each plant, it is possible to establish certain air flow conditions in the running tunnels (see figure 4). The main functions of the Supplementary Ventilation System are to:
    - clear smoke away from any area containing passengers or crew in the event of a train with an uncontrolled fire stopping in the tunnel.
    - enable the emergency services to deal with an incident involving fire in the running tunnels.

The Supplementary Ventilation System also has two ventilation plants: one at the Shakespeare Cliff site and the other at Sangatte. These plants are physically and aerodynamically separate from those of the Normal Ventilation System. The plants have two variable speed fans, each of which is capable of supplying the maximum air flow required.

The In-tunnel Fire Detection System

19. The main function of the in-tunnel fire detection system is to detect uncontained fires on moving trains which do not have on-board detection systems, such as the freight trains. The system comprises 33 detection stations in each running tunnel. The 66 stations in both running tunnels are connected in pairs to 33 Local Fire Detection Units located in the cross-passages. These units transmit the alarms to the Fire Equipment Management Centres and the Rail Control Centre. Each detection station comprises:
    - a flame detector with ultra violet and infra red sensors.
    - a smoke detector using optical and ionisation sensors.
    - a carbon monoxide testing system using a carbon monoxide sensor.
    - aspiration tubes around the circumference of the tunnels directing gases to the analysis units.
20. The in-tunnel fire detection system has the necessary redundancy to enable it to continue operating even if a detector fails. In order to avoid disruption of train operations from an excessive number of false alarms, the system operates at two levels - unconfirmed and confirmed alarms. An unconfirmed alarm is triggered by the activation of a single ionisation or optical detector. A confirmed alarm results from the activation of either a flame detector or from both an ionic and an optical detector. All alarms are transmitted simultaneously to the Fire Equipment Management Centres in France and Great Britain which are located at the Emergency Response Centres, from where the First Line of Response teams can be alerted. The Rail Control Centre only receives confirmed alarms.

Rail Equipment

21. Each running tunnel contains a single standard gauge rail track made up of continuously welded rails attached to a concrete trackbed by means of reinforced concrete support blocks (see Photograph 5). The electrical supply to the locomotives is provided by an overhead catenary system energised at 25,000 Vac single phase. Isolators are installed every 1200m enabling, if necessary, electrical isolation of a catenary section over that minimum length.
22. The signalling system in the running tunnels and on the main tracks in the terminals is of the in-cabin type, communicated to the driver by means of an in-cabin display screen. Automatic Train Protection will automatically stop a train in the event of driver error. The signalling system also enables a 4 km protection distance to be maintained behind a Heavy Goods Vehicle shuttle to ensure that the following train does not enter any smoke emitted from a fire on the Heavy Goods Vehicle shuttle.
23. Although the running tunnels work in one direction only during normal operations, the signalling system does allow for each tunnel to be used in either direction. If, for example, maintenance work is being carried out in one interval (see Figure 3), the adjacent interval in the other tunnel can be used in single line working mode. When single line working is in operation, flights of trains pass first in one direction and then the other.

Terminals

24. The French and British terminals provide the necessary connections to the two countries road networks. They enable the entry and exit of road vehicles to the Concession area, and their loading on to, and unloading from, the shuttle trains. The terminals also provide workshops for the maintenance of Eurotunnels rolling stock and other operational areas, including the depot where

works trains are assembled, the administrative buildings, the Rail Control Centres, the Terminal Control Centres for the management of road vehicles and the passengers, and the Incident Co-ordination Centres for the management of emergencies. There are also toll areas, security check areas, passenger amenity areas, pre-loading marshalling areas and loading platforms.

25. On each terminal is located an emergency siding into which trains with serious on-board incidents can be diverted. These sidings contain emergency platforms, blast walls and fire-fighting equipment.

Rail Control Centre

26. The Rail Control Centre is responsible for the central control and monitoring of all rail operations on the main tracks in the Concession area. The main control centre is situated on the British terminal. The stand-by Rail Control Centre is on the French terminal. Each control centre is responsible for local control of stabling and maintenance yards.
27. The Rail Control Centre has radio and telephone contact with all operators. In particular, it has the following two vital systems at its disposal:
    - The Rail Traffic Management system which controls and monitors train movements and is used, in particular, for control of the signalling system.
    - The Equipment Management System which enables the operators to monitor conditions and remotely control all other equipment e.g. ventilation, electrical supply, lighting, cross-passage doors, crossover doors.

Incident Co-ordination Centres

28. The Incident Co-ordination Centres are located in the same building as the other main control centres and are activated in the event of an incident requiring the intervention of the public emergency services. The operational lead is always taken by the country in whose territory the incident has occurred, with support being provided by the other nation. The Incident Co-ordination Centres are able to monitor the fixed equipment, as well as the necessary means for communicating out of, and into, the various Eurotunnel centres and also with the Forward Control Points.

Emergency Centres and Fire Equipment Management Centres

29. The Emergency Centres are buildings located close to the access roads to the Service Tunnel portals. They house the Eurotunnel First Line of Response teams and specialised equipment which those teams and the public emergency services require to deal with incidents in the tunnel. The Fire Equipment Management Centres are situated in those Emergency Centres. They have all the equipment necessary for monitoring the operation of the in-tunnel fire detection systems and the fire extinction systems in the technical rooms. The Fire Equipment Management Centres also co-ordinate and monitor all vehicles authorised to enter the Service Tunnel.

The Channel Tunnel Bi-National Emergency Plan

30. On 25 November 1991, the United Kingdom and French governments signed a Protocol which laid down, inter alia, the principles for co-operation in the fields of public safety and mutual assistance. This Protocol requires that provisions for joint intervention by the public emergency services of both countries be established through emergency procedures drawn up by the competent national authorities. The Channel Tunnel Bi-National Emergency Plan is the response to that requirement.
31. In addition, Article 11 (3) of the Channel Tunnel Treaty provides that, in an emergency, the Chairman of the Channel Tunnel Safety Authority or his agent shall take the measures necessary for the safety of persons or property within the Fixed Link. To fulfil this responsibility, the following persons have been designated as agents of the Chairman:
    - in the United Kingdom, the Chief Constable of the Kent County Constabulary, the Chief Fire Officer of Kent and the Chief Executive of the Kent Ambulance NHS Trust.

- In France, the Préfet of the Pas de Calais region.

Their responsibilities are described in the Channel Tunnel Bi-National Emergency Plan.

32. The following emergency plans also exist:
    - Eurotunnels Emergency Plan,
    - The Pas de Calais Emergency Services Channel Tunnel Specialised Rescue Plan,
    - The emergency plans of the Kent County Constabulary, Kent Fire Brigade and the Kent Ambulance NHS Trust.

    These plans are implemented singly or jointly depending on the nature of the incident. The provisions of the Channel Tunnel Bi-National Emergency Plan are applied when an incident requires greater resources than those available to the host state acting alone.

Eurotunnels Safety Documentation

33. The documents relating to the operating rules, particularly safety, are divided into three levels: the safety arrangements, the operating principles, the operating instructions and procedures. The safety arrangements define the fundamental principles and general parameters which govern operation of the system. They have been approved by the Intergovernmental Commission. The operating principles define the operational basis of the various systems. The procedures set out the actions required of operators in their everyday work.
34. The condition of the different types of fixed equipment such as ventilation, lighting, cross-passage doors and drainage, is monitored. An operating principle entitled Minimum Operating Requirement precisely defines for each sub-system:
    - the normal operating conditions.
    - the minimum conditions for normal commercial operations.
    - the acceptable degraded operating modes, according to the level of residual availability or performance.

Carriage of Dangerous Goods

35. The transport of dangerous goods in the tunnel is subject to greater restrictions than those imposed by international regulations for the transport of these substances by road or by rail. Some substances are, in fact, completely banned others are accepted, under certain conditions, such as a limit on the total quantity carried, or limits on both the quantity transported and its packaging. This policy is applied to both road and rail transport, whether it is on lorries passing through the tunnel on Eurotunnels Heavy Goods Vehicle shuttles or freight trains likely to be carrying dangerous goods.
36. In practice, this policy is applied in two ways. The railway networks send, by fax, on receiving a request from the Eurotunnel Rail Control Centre, all information concerning the presence of dangerous goods on a train. This includes the nature of the goods, quantities and position of the wagon in the train. Eurotunnel has a specific procedure for freight vehicles. Lorries carrying dangerous goods must give their transport manifest to the Eurotunnel Dangerous Goods officer. The officer checks the compatibility of the manifest with the Eurotunnel Dangerous Goods policy. At the same time, he takes the vehicles details and the characteristics of the goods carried. There is an external inspection of the vehicle, to make sure the load is properly contained, which completes the document check. Finally, the position of vehicles carrying dangerous goods on each shuttle is shown on a report given to the Chef de Train and the Dangerous Goods officer.
37. If an incident occurs, these precautions allow for information concerning the type, quantity and location of Dangerous Goods on board a train or a Heavy Goods Vehicle shuttle, to be obtained.

Chapter II: Before the Fire - People, Rolling Stock, Systems and Resources:-

People on Duty

1. The number of people on duty at 21.20 hrs on 18 November 1996, when the loading of the incident Heavy Goods Vehicle shuttle commenced, was as follows:
    - Employees involved in the loading of the shuttle train: two positioners, two marshals, four chockers, one liaison agent and the driver of the bus taking Heavy Goods Vehicle drivers to the Amenity Coach.
    - The crew of the incident train, comprising the driver, the Chef de Train and the catering steward.
    - Nine people on what was to become the evacuation train (this included an extra crew member compared to the normal complement).
    - Six people on duty in a fully staffed Rail Control Centre, with one person on duty in the Standby Rail Control Centre on the French side.
    - Fourteen fire-fighters on the French side and eight on the United Kingdom side[1], making up a fully staffed First Line of Response team.
    - One person on duty in the United Kingdom Fire Equipment Management Centre and one in the French Fire Equipment Management Centre, representing the usual staffing level.
    - An Inspector, a Sergeant and five Constables on duty in the Longport Police Station, the Inspector and four of the Constables making up the team on the communications Service Tunnel Transport System vehicle.
    - Two security guards on duty in a building near the French entrance to the tunnel, a third person on patrol with his dog and a fourth guard monitoring access to the Service Tunnel.

[1] The greater numbers on the French side reflect the fact that French personnel also protect the Terminal, whereas in the UK, fire-fighting outside the tunnel falls to the external services, that is to say, the Kent Fire Brigade.

Trains and Train Movements

2. When the loading of the incident train commenced at 21.20 hrs there were four trains standing at platforms in the United Kingdom terminal: two Heavy Goods Vehicle shuttles and two tourist shuttles. There were seven trains at the platforms in the French terminal: four Heavy Goods Vehicle shuttles and three tourist shuttles. Two trains, one Eurostar and one Heavy Goods Vehicle shuttle were in Running Tunnel North, and two were in Running Tunnel South; one Eurostar and one tourist shuttle.

Fixed Equipment

3. At the shift change at 15.00 hrs on 18 November 1996, the outgoing Equipment Management System controller reported on the status of the fixed equipment, indicating that there was no failure in any system requiring the imposition of operating restrictions. The two undersea crossover doors

which would be closed in normal operating mode, were however, open at the time that the incident train entered the tunnel.

Composition of the Incident Train

4. The incident train was made up of:
    - the leading locomotive.
    - one Amenity Coach.
    - a front rake of fifteen carrier wagons with a loader wagon at each end of the rake.
    - a rear rake of fourteen carrier wagons with a loader wagon at each end of the rake.
    - a rear locomotive.

   The shuttle load identifying the types of cargoes being carried by the Heavy Goods Vehicles is shown in figure 5.

5. The incident train rolling stock had undergone, at the correct dates, all of the normal maintenance operations set out in the maintenance procedures and was not under any operating restrictions. It had been recorded, however, on 15 November 1996, that there was important leakage of air at the top of the windscreen of the driving cab of the leading locomotive and that this caused ear ache when passing the crossovers.

Composition of the Evacuation Train

6. The evacuation train was a tourist shuttle, in normal service with passengers on board, and of standard composition: a front locomotive, a single deck rake, a double deck rake and a rear locomotive. The rolling stock had been subject to normal maintenance at the required dates and all elements were in working order.

Service Tunnel, Emergency Teams and Rescue Vehicles

7. Only one electric maintenance vehicle containing two people was in the Service Tunnel when the fire was discovered. Otherwise, the entire fleet of Service Tunnel Transport System vehicles, four fire vehicles, two ambulance vehicles, and one communications vehicle in each terminal, was fully operational and available at their respective terminals.

Public Emergency Services

8. In Kent, all Police, Fire and Ambulance resources necessary for a predetermined response to an accident in the tunnel, were available. In the Pas de Calais region, the Fire teams were fully staffed and the Emergency Medical Service had five paramedic units available at the stations in Calais, Boulogne, St-Omer and Dunkirk.

Chapter III: The Sequence of Events:-

Railway Operations

Loading and Departure of the Incident Train

1. The 29 Heavy Goods Vehicles loaded on the incident train 7539 passed the toll booths in the French terminal between 19.28 hrs and 20.32 hrs on 18 November 1996. Because of a strike by some Eurotunnel staff, the lorries were held for between 57 and 112 minutes in the lorry park from 19.00 hrs to 21.00 hrs. The allocation of the lorries to the incident train began at 21.19 hrs and was completed by 21.32 hrs. The loading of the lorries onto the Heavy Goods Vehicle shuttle took about 20 minutes from 21.20 hrs to 21.40 hrs.
2. The incident train left the platform at 21.42 hrs, reached a speed of 66kph and then, having travelled some 1500m, stopped in response to signals in order to maintain the required minimum distance from the preceding Heavy Goods Vehicle shuttle train (4km), which had departed at 21.38 hrs. This stop lasted 32 seconds. The incident train then moved off and entered Running Tunnel South at 57kph at 21.48 hrs. Figure 6 shows the position of trains in both running tunnels at that moment.
3. As the incident train passed, two security guards on duty in a building approximately 600m from the tunnel portal, saw a fire beneath a lorry on a wagon somewhere in the middle of the second rake of the incident train. They immediately informed their supervisor, who transmitted the information to the Terminal Control Centre in the French terminal. The Terminal Control Centre in turn informed the Rail Control Centre at 21.49 hrs, more than one minute after the train had entered the tunnel. Two other security guards, a dog handler and a guard at the entrance to the Service Tunnel, also saw the fire.

The Journey in the Tunnel

4. At 21.49 hrs, the in-tunnel fire detection station located at kilometre marker (also known as kilometre point and abbreviated to PK 5913), transmitted an unconfirmed alarm to the Fire Equipment Management Centres. The incident train had then travelled about 2200m into Running Tunnel South. Between 21.50 hrs and 21.52 hrs, four further in-tunnel fire detection stations, of the five which are located between PK 58 and PK 51, sent unconfirmed alarms to the United Kingdom Fire Equipment Management Centre.
5. Meanwhile, at 21.51 hrs, the Rail Control Centre informed the driver of the incident train that there was the possibility of a fire on-board his train, which would be diverted to the emergency siding in the United Kingdom terminal. At the same time, the driver received an unconfirmed alarm on his cab display indicating that there was a fire in the rear locomotive. By this time the incident train was

travelling at 140kph, and the tourist shuttle which was later to form the evacuation train 6518, had entered Running Tunnel North.

6. At 21.52 hrs, train 4899, which was a single locomotive with only the driver on-board, entered Running Tunnel South behind the incident train. At the same time, the Rail Control Centre informed the United Kingdom Fire Equipment Management Centre of the possibility of a fire on the incident train and of the resulting decision to divert it to the emergency siding in the United Kingdom terminal. A few moments later, the driver of train 4899 encountered smoke in the tunnel of sufficient density to make him slow down.
7. At 21.53 hrs, a confirmed alarm appeared at the Chef de Train's work station, indicating that there was a fire on the rear locomotive. Simultaneously, the first confirmed alarm issued by the in-tunnel fire detection station at PK 5015 was received in the Rail Control Centre, by which time the incident train had travelled 10km in Running Tunnel South. On receipt of this alarm, the Rail Control Centre transmitted a general message to all trains in the tunnel to slow down to 100kph and ordered the closure of the Piston Relief Duct dampers. The one at PK 3531 remained open, later allowing smoke to enter Running Tunnel North.
8. Tourist shuttle train 6523 entered Running Tunnel South at 21.54 hrs. The Rail Control Centre instructed the driver of train 4899 to make a controlled stop, i.e. using normal braking, adjacent to a cross-passage door. The speed limit in Interval 2 of Running Tunnel North was reduced to 100kph (see figure 3). This action reduced the speed limit displayed in the drivers' cabs of all trains travelling in that interval, and led to emergency braking on the evacuation train 6518 through the action of the Automatic Train Protection. At that time the evacuation train was travelling at 139kph. The incident train was still travelling at 140kph. The Rail Control Centre switched on the main lighting in Running Tunnel South and the Service Tunnel.
9. At 21.55 hrs, train 4899 stopped at PK 5685. The Rail Control Centre prevented the entry of any further trains into the tunnels and set the speed limit at 100kph in intervals 4 and 6. The incident train slowed to 100kph and, at 21.56 hrs, its driver saw a warning light on his cab display indicating the opening of the principal circuit breaker in the train's rear locomotive. At this point the incident train was approximately 1km beyond the French crossover. A few moments later, an empty Heavy Goods Vehicle shuttle 752 returning to France via Running Tunnel North passed this crossover, the doors of which were still open. The train encountered thick smoke which entered the Amenity Coach. The speed limit of 100kph had been implemented in Intervals 1 and 3.
10. The Rail Control Centre activated the closure of the United Kingdom crossover doors at 21.57 hrs. At the same time, the Chef de Train of the incident train received a major alarm on his display indicating a fault with the props or the bridging plates, together with indication of other system failures. Simultaneously, the stop lamp was illuminated on the driver's cab display. The Rail Control Centre sent a general message informing all trains of the fire and requesting that they keep any dialogue with the Rail Control Centre to a minimum.

After the Incident Train Stopped

11. The incident train made a controlled stop at 21.58 hrs adjacent to the cross-passage at PK 4131. Figure 6 shows the position of all trains in the tunnel at that time. The driver of the incident train was unable to see the number of the cross-passage door because of the thick smoke which had almost immediately enveloped the front locomotive. The power supply from the catenary was lost four seconds after the train stopped. The Chef de Train informed the Rail Control Centre of the alarms he had received and confirmed that the incident train had stopped.
12. At 21.59 hrs, the Rail Control Centre requested train 7533, immediately ahead of the incident train, to reduce speed to 30kph. At that point train 7533 was adjacent to the United Kingdom crossover. Tourist shuttle train 6527 and Eurostar 9059, which were ahead of train 7533 and close to the United Kingdom portal, continued their journeys at 100kph. The driver of the incident train informed the Rail Control Centre that he had stopped and lost power. Tourist shuttle train 6523 stopped 2km behind train 4899 in response to the signalling system.
13. The driver of the incident train then attempted to leave his cab but was prevented by thick smoke. At 22.01 hrs, he informed the Rail Control Centre that he was unable to leave his cab to organise the

evacuation of passengers because the smoke was too dense. A second attempt by the driver to leave the cab, this time using his respirator, also failed. Smoke began to enter the Amenity Coach. The Chef de Train then opened the rear door of the Amenity Coach in an attempt to locate the cross-passage. This resulted in a significant amount of smoke entering the Amenity Coach and, unable to find the evacuation route, the Chef de Train immediately closed the door and decided to keep everyone on-board the incident train until the arrival of the emergency services.

14. Because of the fire, the administrative telephone network between the United Kingdom and France failed at 22.02 hrs. The concession radio was still available but was overloaded with traffic. The Rail Control Centre ordered the driver of train 6523 to go to the rear locomotive of his train and prepare to reverse out of the tunnel. The driver of the incident train informed the French Fire Equipment Management Centre at 22.03 hrs via the concession radio that he was in his cab, that there was too much smoke outside to leave, that the passengers were in the Amenity Coach and that he did not know exactly where he had stopped.
15. At 22.04 hrs the Rail Control Centre activated the closure of the French crossover doors which Heavy Goods Vehicle shuttle 7532 had just passed. This train encountered dense smoke which entered the Amenity Coach. At the same time, Eurostar 9059 left Running Tunnel South. Train 752 left Running Tunnel North two minutes later. At approximately the same time, the driver of train 6518 indicated the presence of smoke at about the mid-point of Running Tunnel North and at 22.08 hrs, train 6527 left Running Tunnel South. At 22.09 hrs, the driver of the incident train spoke to the Rail Control Centre again in order to find out where the rescue teams were. The Rail Control Centre received a confirmed fire alarm from the in-tunnel fire detection station at PK 4746 in Running Tunnel North, together with a 'command not executed' alarm for the French crossover doors. The Rail Control Centre activated the closure of Air Distribution Units serving Running Tunnel North.
16. The Rail Control Centre instructed the driver of train 4899 to evacuate to the Service Tunnel at 22.10 hrs. The driver of train 6523 informed the Rail Control Centre that he was in his rear locomotive, that the signals in the cab authorised a speed limit of 100kph and that there was no traction power.
17. At 22.11 hrs, the Rail Control Centre remotely activated the opening of the cross-passage doors situated at PKs 5689 and 5651 in order to evacuate the driver of train 4899 to the Service Tunnel. The Rail Control Centre activated the Supplementary Ventilation System in Running Tunnel South in the United Kingdom to France direction at 22.13 hrs, but the fan blades were left at zero pitch. As a result, the Supplementary Ventilation System had no effect on the movement of smoke in the running tunnel. Train 7532 left Running Tunnel North, and at 22.15 hrs the Rail Control Centre instructed the driver of train 6518 to make a controlled stop adjacent to the cross-passage at PK 4132 so that his train could be used as an evacuation train. The Rail Control Centre remotely closed cross-passage doors 5689 and 5651, and reactivated the catenary in interval 5. At 22.16 hrs the Rail Control Centre closed the Air Distribution Units in the area of the incident in Running Tunnel South between PKs 3687 and 5539, and at 22.17 hrs it disconnected the catenary power in interval 5.
18. The Rail Control Centre reconfigured the Supplementary Ventilation System at 22.20 hrs, putting the fans to the predetermined setting blowing from the United Kingdom to France. At 22.21 hrs the Rail Control Centre opened cross-passage doors 4101 and 4131 and then instructed train 6523 to reverse out of the tunnel as soon as traction power was re-established. By looking through the window of the Amenity Coach, the Chef de Train on the incident train was able to see the arrow pointing towards the cross-passage door and the lights in the tunnel. He decided, in conjunction with the catering steward, to take advantage of the 'bubble effect' and evacuate the passengers. The Supplementary Ventilation System was functioning normally at 22.22 hrs and had started moving the smoke along Running Tunnel South towards France. At 22.32 hrs, train 7533 left Running Tunnel South and arrived at the United Kingdom terminal at 22.39. Train 6523 left Running Tunnel South and reversed to the French terminal. At this point there were, therefore, only three trains left in the tunnel, the incident train, the evacuation train and the single locomotive 4899 which was 4 km from the French portal in Running Tunnel South.

Evacuation

19. The driver of the incident train and 26 passengers were boarded on wagon 3 of the evacuation train at 22.42 hrs, the side door of the wagon being closed at 22.52 hrs. The driver reported an acrid smell of smoke in Running Tunnel North. The Chef de Train noted smoke puffing from a Piston Relief Duct. Following verbal authorisation from the Rail Control Centre, the evacuation train moved off at 23.04 hrs. At 23.11 hrs, the driver reported thick smoke to the point of zero visibility, and that he could smell smoke in his cabin as he passed the French crossover. Some smoke entered the front loader wagon adjacent to the wagon where a number of the evacuated passengers were located. This activated the fire alarm and led the crew of the evacuation train to speed up the longitudinal evacuation from wagon 3 to the next wagon. The evacuation train arrived at platform 7 in the French terminal at 23.24 hrs.

Fire-fighting and Rescue Operations

Alerting Actions and Initial Responses

20. At 21.50 hours the French Terminal Control Centre notified the Fire Equipment Management Centre in the French terminal that a fire had been seen on the last train to enter the Running Tunnel South. The United Kingdom Fire Equipment Management Centre was given similar information at 21.52 hrs by the Rail Control Centre, and was advised that the incident train would be diverted into the emergency siding in the United Kingdom terminal, the French Fire Equipment Management Centre being advised of this at 21.53 hrs.
21. Eurotunnel's First Line of Response was notified of the incident by the Fire Equipment Management Centre, and in France the duty officer ordered crews to go to the mid-point of the tunnel. Here, they would be best positioned, should the incident train have to make an emergency stop. A team of eight fire-fighters, commanded by a Sub-Officer, left the French Emergency Centre at 21.56 hrs in two of the Service Tunnel Transport System vehicles.
22. In the United Kingdom Fire Equipment Management Centre, fire alarm monitoring equipment indicated the activation of several consecutive in-tunnel fire detection stations from the French portal towards the United Kingdom. The First Line of Response team was not initially mobilised on the United Kingdom side because it was believed that the standard procedure would be carried out and the fire dealt with by crews from the Kent Fire Brigade in the emergency siding. Following a discussion between the United Kingdom Fire Equipment Management Centre operator and the Rail Control Centre about the number of alarms activated however, it was decided that the United Kingdom First Line of Response should also mobilise to the mid-point. This team, comprising eight fire-fighters under the command of a temporary Sub-Officer, entered the Service Tunnel at 22.03 hrs.
23. At 22.02 hrs, the French First Line of Response team, which had only just entered the Service Tunnel because of a 1 km journey from the Emergency Centre to the Portal and some delay caused by the requirement for each fire-fighter to swipe a card through a security system, was redirected by the Rail Control Centre to Cross-passage 4101 in the belief that this was the cross-passage door nearest to the front locomotive of the incident train. This information was reconfirmed by the Rail Control Centre at 22.08 hrs, and again at 22.16 hrs.
24. As part of Eurotunnel's standard procedures, the United Kingdom Fire Equipment Management Centre operator sent a facsimile message to the United Kingdom Terminal Control Centre and to the French Fire Equipment Management Centre detailing the alerting and mobilisation actions to be taken. The United Kingdom Fire Equipment Management Centre operator then telephoned the United Kingdom Terminal Control Centre at 22.12 hrs to countermand the final line which had instructed the Terminal Control Centre to call in the United Kingdom Second Line of Response.
25. At 21.57 hrs the French Fire Equipment Management Centre informed the French Immigration Department (the Immigration Police), the French Emergency Medical Service (the Ambulance Service) and French Fire Command (Fire Service) of the incident. This alerting included the senior fire officer responsible for the French Emergency Centre and he requested activation of the Pas-de-

Calais Emergency Services' Channel Tunnel Plan at 22.05 hrs. This activated a pre-determined level of attendance by the Pas-de-Calais Fire Brigade, the regional medical services and the French Police. The decision was notified to the United Kingdom Fire Equipment Management Centre at 22.06 hrs.

26. The French First Line of Response team was informed of the presumed location of the stationary incident by radio messages from the Fire Equipment Management Centre and the Rail Control Centre. The United Kingdom First Line of Response team had difficulty contacting the Rail Control Centre and had to rely on messages relayed by the United Kingdom Fire Equipment Management Centre operator. Similar difficulties were experienced by the French First Line of Response team during their journey through the Service Tunnel and following their arrival at the incident scene.
27. On reaching cross-passage 4201, three cross-passages and some 1125m from cross-passage 4101 at 22.17 hrs, the members of the French First Line of Response team on the second of its vehicles noticed swirling smoke within the cross-passage. They stopped and asked the Rail Control Centre whether they should continue. The Rail Control Centre confirmed that at 22.18 hrs. they should proceed to cross-passage 4101. Immediately upon their arrival at 22.20 hrs, cross-passage door 4101 was opened by remote control and revealed only smoke, not the incident train.
28. At 22.24 hrs, the Rail Control Centre sent a radio message to the French First Line of Response team directing them back to cross-passage 4201. At 22.25 hrs, the Rail Control Centre corrected that instruction and directed the French First Line of Response team to cross-passage door 4131. This instruction was confirmed by the Railway Control Centre at 22.27 hrs.

Location of the Casualties

29. At 22.28 hrs, on arrival at cross-passage 4131, the French First Line of Response team found people in the Service Tunnel and advised the Rail Control Centre of the evacuation of the incident train. Acting on information from one of the Heavy Goods Vehicle drivers, the leader of the First Line of Response team also informed the Rail Control Centre that the incident train might have contained a lorry loaded with polystyrene compound. He also reported his intention to enter Running Tunnel South to search for the incident train's driver, who had not yet evacuated to the Service Tunnel. They found him in his cab and led him to safety at 22.29 hrs. At 22.30 hrs, having carried out a search of the front locomotive and the Amenity Coach, the French First Line of Response leader informed the Fire Equipment Management Centre that nobody had been left on-board the incident train. With all involved then in the safety of the Service Tunnel, at 22.34 hrs cross-passage door 4131 was closed locally by the French First Line of Response team.
30. All efforts were then directed to the passengers and crew from the incident train, many of whom were suffering from shock and the effects of the smoke. The French First Line of Response team concentrated on supplying oxygen to those suffering worst from breathing difficulties. They were aided in this by the arrival of the United Kingdom First Line of Response team at 22.30 hrs.
31. Before leaving for the incident, the French Fire Commander had asked the Rail Control Centre to ensure that the Supplementary Ventilation System was configured to direct the air flow over the front locomotive and the Amenity Coach, towards France. At 22.25 hrs he reported on the situation to the Sous-Préfet of Calais.
32. The responses to the initial mobilising arrangements in France had enabled a medical team from the Calais Medical Emergency Service: one doctor, one nurse and one driver in a Service Tunnel Transport System ambulance, to enter the Service Tunnel at 22.40 hrs. At 22.42 hrs the less affected passengers and crew boarded the evacuation train.
33. At about 22.45 hrs, following an apparent delay of five or six minutes awaiting the arrival of the Immigration Police, three more Service Tunnel Transport System vehicles (two fire and one communications) left the French Emergency Centre carrying 22 fire-fighters, including three officers, under the command of a Fire Commander.
34. The evacuation train left for France at 23.04 hrs. The seven most serious casualties remained in the Service Tunnel where the French team continued with first aid treatment. It was decided that the United Kingdom First Line of Response would be responsible for managing fire-fighting and ventilation operations.

First Sight of the Fire

35. Information was requested by the Commander of the French First Line of Response about the configuration of the ventilation system and the catenary, and it was decided by the United Kingdom First Line of Response Commander that a reconnaissance would be carried out in order to determine the exact location and extent of the fire on the incident train. Two members of the United Kingdom First Line of Response team, using breathing apparatus and taking a fire-fighting hose and a thermal imaging camera, entered Running Tunnel South through cross-passage door 4131 at about 22.53 hrs. They moved first to the right where they found the front of the Amenity Coach and the front locomotive engulfed in heavy smoke. They then proceeded towards the rear of the incident train where clearer air after cross-passage door 4131 initially enabled good progress to be made. However, after passing cross-passage door 4163 they became aware of increased noise and damage to fixed equipment was readily apparent. Approximately 100m further on, the fire could be seen roughly in the vicinity of cross-passage door 4201.
36. The reconnaissance team judged that about five wagons were involved in the fire at the rear of the incident train. They were by then out of communication contact and the fire was beyond the reach of their hose. The team therefore returned to cross-passage door 4131 to report their findings to the team leader. Before leaving Running Tunnel South they carried out a further precautionary search of the Amenity Coach, but were prevented from searching the front locomotive cab because it had been locked. The cab was searched by a second United Kingdom First Line of Response team shortly afterwards and was found to be empty.
37. At the same time as the reconnaissance team had entered Running Tunnel South, the United Kingdom First Line of Response team leader requested attendance of the United Kingdom Second Line of Response which he believed would be ready at the United Kingdom portal. This message was received by the United Kingdom Fire Equipment Management Centre at 23.00 hrs and was relayed to the United Kingdom Terminal Control Centre. The request was transmitted to the Kent Fire Brigade Control Room at 23.02 hrs, which was the first notification of the incident received by the Kent Fire Brigade.
38. Having conferred with his crew leaders, the United Kingdom First Line of Response team leader in the Service Tunnel decided to mount an attack on the fire on the incident train from cross-passage door 4163. Before this was effected, the French Second Line of Response team arrived at the scene at about 23.07 hrs. The French Fire Commander thereafter took command of the incident.

Fire-fighting and Related Activities

39. The French Fire Commander organised his resources to take care of the remaining casualties and to provide a further two reconnaissance teams to enter Running Tunnel South from cross-passage doors 4163 and 4201. The team sent at cross-passage door 4201 was unable to enter the tunnel because of the fierceness of the fire at that point, but the team at cross-passage door 4163, after some difficulty in opening it, was able to make progress and reported that explosions had been heard and that a significant fire, described as 'a lot of flames', had been seen in the direction of France. This information was passed to the French Incident Co-ordination Centre and Fire Equipment Management Centre at 23.29 hrs.
40. At 23.39 hrs the remaining seven casualties left for France in the two ambulance Service Tunnel Transport System vehicles. The French Medical Emergency Service doctors were later replaced by two Fire Brigade doctors. By 23.39 hrs, the French Fire Commander was able to report the results of the second reconnaissance in Running Tunnel South to the French Incident Co-ordination Centre. He confirmed that the fire was between cross-passage doors 4163 and 4201 and that although the front of the fire could be seen, its extent in the direction of France could only be estimated. He then ordered French fire-fighting teams to take three fire-fighting hoses into Running Tunnel South via cross-passage door 4163 and one large diameter hose via cross-passage door 4201, the aim being to extinguish the fire between these two doors.
41. At 23.45 hrs, the French Fire Commander reported to the French Incident Co-ordination Centre that 'the fire is situated between cross-passage doors 4163 and 4201. The origin may be a lorry carrying

25 tonnes of polystyrene. Five lorries can be seen on fire by the fire-fighting team at cross-passage door 4163. Service Tunnel Transport System vehicles A12 and A14 have left with five casualties for the French Emergency Centre'. At about the same time, the United Kingdom Police arrived at the scene in the United Kingdom Service Tunnel Communications Vehicle and made contact with the French Fire Commander.

42. Two Service Tunnel Transport System Fire Appliances, with 24 Kent Fire Brigade fire-fighters on-board under the command of a Senior Divisional Officer, entered the Service Tunnel at 23.19 hrs and 23.21 hrs. They arrived at the incident scene at approximately 23.52 hrs.
43. The Kent Ambulance NHS Trust was notified of the incident by the Kent Fire Brigade at 23.20 hrs and thereafter mobilised ambulances and officers to pre-determined locations. An ambulance Service Tunnel Transport System vehicle with a crew of two paramedics and two technicians, entered the Service Tunnel at 23.51 hrs.
44. On his arrival at the incident scene, the United Kingdom Fire Commander and the French Incident Commander jointly assessed the fire-fighting activity being conducted from cross-passage door 4163 in Running Tunnel South,. and agreed that the Incident Commander would direct operations from cross-passage door 4163 and the United Kingdom Commander from cross-passage door 4201 in order to extinguish the fire between these two cross-passages (see Figure 7.)
45. At this stage, the United Kingdom communications and ambulance vehicles, the latter having just arrived, were moved to cross-passage door 4201 in support of United Kingdom operations. The crew of the communications vehicle prepared their equipment to act as a Forward Control Point for the United Kingdom emergency services by providing tactical radio and telephone communications from the incident site to the Incident Co-ordination Centre. The ambulance was on hand and ready to receive personnel in the area for any accident or injury.
46. The two fire-fighting teams initially deployed five fire-fighting jets. Explosions continued to be heard and severe damage to the running tunnel was observed. This led the French Fire Commander to request the assistance of a civil engineering expert.
47. For approximately the next five hours, the fire was attacked by teams of fire-fighters working in relays. The conditions were very cramped, and the limited access was made additionally hazardous by fallen debris and damaged fixed equipment. Footholds were precarious, and the space between the side of the incident train and the tunnel wall was only one metre wide and covered in rubble. Access was possible only to one side of the incident train. Having dealt with the worst of the fire between the two cross-passage doors, the fire-fighters concentrated their jets on the rear wagons and locomotive. The centre of the fire was extinguished by about 05.00 hrs. Minor fires were extinguished during the early morning, but smouldering debris continued to be dealt with until 03.00 hrs on 20 November 1996.
48. For a period, the fire-fighters were hampered in their efforts by an uncertain and inadequate water supply resulting from a rupture in the water main and leaking from flanges at joints in the vicinity of the fire. In the early stages of attacking the fire, this required the number of jets to be reduced to two until the arrival of a Eurotunnel engineer, who then reconfigured the water flow to avoid the worst of the damaged area.
49. The French and United Kingdom Police provided operational assistance during the incident by securing traffic routes and providing communications links between the scene underground and the Incident Co-ordination Centre. In France, the Magistrate was advised of the incident at 00.48 hrs on 19 November 1996, and a representative of the Judicial Department was on-site at 02.45 hrs on that date.

Supporting Operations

50. The emergency teams in the tunnel were supported by strategic and tactical command structures established under the Channel Tunnel Bi-National Emergency Plan (see Chapter I, paragraphs 30-32). The lead nation, France, took responsibility for the overall management of the operation, requesting such assistance as it considered necessary from the support nation, in this incident, the United Kingdom.

51. In France, representatives of all the main emergency services under the direction of the Sous-Préfet on duty, who on the night of 18 November 1996 was the Sous-Préfet of Calais, went to the French Incident Co-ordination Centre in the French terminal. Here, they managed the tactical response to the incident by establishing communications with the emergency services below ground, local emergency centres, the Regional Administrative Centre (Arras), Eurotunnel management centres, and the Incident Co-ordination Centre in the United Kingdom terminal. The French Incident Co-ordination Centre was opened at 22.13 hrs, and by 23.00 hrs was in a position to decide the operational strategy necessary to deal with the casualties and the fire and to deal with any requests for logistical assistance from the Fire Commander in the tunnel. The Head of Public Protection arrived from Arras at about 23.55 hrs to act as Director of the Préfet's cabinet, and the Director of the Ambulance Service arrived at 00.20 hrs. The Chief Fire Officer of Kent was coincidentally in Calais at the time of the incident, and was therefore able to act as liaison officer for the United Kingdom emergency services between 00.55 hrs and 03.35 hrs.
52. At the United Kingdom Incident Co-ordination Centre, senior Police, Fire and Ambulance Commanders came together to direct United Kingdom operations in conjunction with Eurotunnel's on-call Co-ordinator and an Equipment Management System operator. Their task was to provide the resources requested by the French authorities, and to maintain support for United Kingdom personnel committed to the incident through additional resources and equipment. The Kent Police and Eurotunnel representatives were at the Incident Co-ordination Centre first, but were joined later by teams from Kent Fire Brigade and the Kent Ambulance NHS Trust shortly afterwards. The Incident Co-ordination Centre was opened at about 22.00 hrs on 18 November 1996 and was fully operational by 23.45 hrs. Due to the failure of the administration telephone lines, difficulties were experienced in making contact with the French Incident Co-ordination Centre. In fact the Rail Control Centre knew at an early stage that the internal telephone system had failed but this information was not given to the Incident Co-ordination Centre until much later. Contact was eventually made at 00:06 hrs on 19 November 1996 and again at 00.48 hrs, when the French Incident Co-ordination Centre advised that no additional United Kingdom resources were required. Full communications were established by 01.00 hrs. The United Kingdom Incident Co-ordination Centre was unable to obtain information from the Fixed Equipment Management System monitor.
53. Strategic Command Centres were established by the Lead Nation at the Pas-de-Calais Prefecture in Arras and by the Support Nation at Kent Police Headquarters in Maidstone, known as Gold Command. The Poste de Commandement Fixe, under the leadership of the Deputy Director of the Préfet's Cabinet, was responsible for keeping the national authorities and ministers informed of progress and developments and for providing information to the public and the media.
54. By 00.30 hrs on 19 November 1996, the fire-fighting resources available in the United Kingdom terminal comprised 10 fire appliances and 40 fire-fighters, including 4 senior officers. By 00.49 hrs, four fire appliances and two ambulances were being loaded on-board a rescue train provided by Eurotunnel in readiness for transportation to the incident via Running Tunnel North. As there was no acknowledgement from the French Incident Co-ordination Centre that these resources could be committed, the Senior Fire Officer in the United Kingdom Incident Co-ordination Centre decided at 00.49 hrs that they should be unloaded from the rescue train and transferred to the Emergency Centre. Other vehicles had already been mobilised in the Emergency Centre to carry personnel, smaller items of equipment and refreshments to the incident via the Service Tunnel, and the 16 United Kingdom fire-fighters and two Officers, with supplies and equipment, entered the Service Tunnel at 02.05 hrs in electric cars and lightweight maintenance Service Tunnel Transport System vehicles. They arrived at the incident at 02.51 hrs.
55. At 01.52 hrs the United Kingdom Incident Co-ordination Centre was notified by its French counterpart that the rescue train could proceed. The train was therefore reloaded and departed at 02.48 hrs, carrying 6 fire appliances and 24 fire-fighters. It suffered from electrical power pick-up problems during the journey, and only arrived at the scene of the incident at 03.42 hrs. It was unloaded some time later. In France, approximately 37 additional fire-fighters went into the tunnel between 02.30 hrs and 05.30 hrs on 19 November 1996, to relieve the crews who had first attended.

Resource Commitment

56. Over the entire duration of the incident, some 233 French emergency services' personnel were mobilised from 31 rescue centres. The United Kingdom commitment, as Support Nation, was also considerable with a total of 209 Fire Brigade Personnel, 24 Ambulance personnel and 50 Police Officers involved.

Chapter IV: After the Fire - Casualties and Damage:-

Casualties

Consequences for the System

Civil Engineering

Railway and Fixed Equipment

Rolling Stock

Operational

Casualties

1. For some 20 minutes, the passengers and crew of the incident train inhaled fumes, of increasing toxicity, which entered the Amenity Coach and the drivers cabin. They also suffered considerable anxiety whilst awaiting evacuation and the arrival of assistance. Some of them were nauseous.
2. On arrival of the First Line of Response emergency teams, seven of the passengers and crew received intensive oxygen therapy at the scene, and were then evacuated from the Service Tunnel on an ambulance Service Tunnel Transport System vehicle. The other 27 were evacuated on the evacuation train. Having left the tunnel, most of the passengers and crew from the incident train were transferred by road to various hospitals in the Calais region; two who were considered to be more seriously ill were transported by helicopter to the hospital in Lille. The periods spent in hospital were short. The person in the most serious condition was discharged from Lille hospital at 22:50 hrs on 19 November 1996.

Consequences for the System

Civil Engineering

(see Photograph 9)

3. For the purposes of this report, civil engineering is regarded as the lining of the tunnel, the cross-passages and Piston Relief Ducts, the walkways and the concrete trackbed. The train on fire stopped in Running Tunnel South, about 19 km from the French portal. In addition to the pollution due to smoke and soot deposits over several kilometres of tunnel, the fire caused considerable damage over approximately 480m.
4. Most of the tunnel is lined with reinforced concrete segments 40cm in depth. The area most severely damaged by the fire is approximately 50m in length. In this area, in many places, the depth of the concrete is reduced to an average of 17cm. In a few places, only 2 cm of concrete remains, and all the steel reinforcing is visible. Neither the concrete grouting which was injected during construction, nor the rock itself has been damaged. The monitoring devices put in place after the fire have not revealed any ground movement, but metal supports have been installed as a precaution. The whole section has been reinforced and rebuilt.
5. On either side of this zone, over a distance of approximately 70m towards the United Kingdom and 170m towards France, the tunnel lining has also been damaged. The concrete has spalled in many places to a depth of between 5 and 20cm. leaving the first layer of metal reinforcement visible. In this zone, the lining can be repaired without replacing the steel reinforcements. On either side of this zone, a total of approximately 190m has been slightly affected by the fire. Superficial damage to the concrete can be seen in places, but the steel reinforcing has not been exposed.
6. Concerning the other civil engineering elements, the structure of the cross-passages and Piston Relief Ducts closest to the fire suffered very little. Similarly, the walkways and the

concrete trackbed were largely undamaged, having been unaffected directly by the fire and protected either by the concrete debris falling from the crown of the tunnel or by the floor of the wagons.

Railway and Fixed Equipment

7. The fire caused serious damage to the fixed equipment in the tunnel, which has required major repair work. The main damage was as follows:
    - 1500m of electrical supply cables (21kV, 3.3kV and 0.4kV) needed to be replaced, together with the push-buttons, junction boxes and light boxes for the lighting system over some 800m;
    - The aspiration tube and four detectors in the in-tunnel fire detection station nearest to where the incident train stopped needed to be replaced;
    - In the control and communications system, 2100m of leaky feeder for the track to train radio and 3900m of fibre optic cables needed to be replaced;
    - In the signalling system, track circuits, markers and information transmitters particularly required replacement over about 1500m;
    - The track needed to be rebuilt over 500 m and the catenary over 800m;
    - The electromechanical equipment for the four cross-passages and five Piston Relief Ducts needed to be replaced, together with 800m of cooling pipes.

Rolling Stock

8. The front locomotive and the Amenity Coach on the incident train were not damaged, but required thorough cleaning as a result of sooty deposits from the fire. The electronic systems on the locomotive and the Amenity Coach had to be removed for decontamination. The front rake overall was very little affected, with only a few minor repairs and thorough cleaning required. However, the rear rake was very severely damaged (see Photograph 10), as follows:
    - The front loader wagon and the first carrier wagon appeared salvageable after some repair work;
    - The following three carrier wagons were seriously damaged, their repair depending on the outcome of the assessment being carried out by Eurotunnel and the constructor, Breda-Fiat;
    - The following 10 carrier wagons and the rear loading wagon were irreparable, the chassis and superstructures having been deformed to the point that it was impossible to repair them; some bogies might be salvageable for workshop use;
    - The rear locomotive suffered severe damage; but the second drivers cabin adjacent to the rear loader wagon suffered less damage than the main cabin at the other end of the rear locomotive furthest from the fire.

Operational

9. All commercial services through the Channel Tunnel were stopped immediately following the incident. Eurotunnel subsequently made technical submissions, setting out details of the temporary measures necessary during the reconstruction work in interval 3 (see figure 3), and requested approval to restart freight train, tourist shuttle and Eurostar services. Following detailed examination of the proposals and, for the Eurostar service, completion of an evacuation exercise in interval 4 of the tunnel (see figure 3), the Channel Tunnel Safety

Authority considered that the general level of safety would permit the resumption of commercial services. Freight train services were resumed during the evening of 29 November 1996, the Eurostar service was reopened on 4 December 1996, and tourist shuttles restarted operations on 10 December for cars and on 6 January 1997 for coaches.

10. The need to use interval 4 of the tunnel for single line working in both directions while the repair operations have been carried out in interval 3 has significantly reduced the tunnels capacity from twelve trains per hour in each direction, to six. As a result, there have been reductions in the daily number of return Eurostar journeys from fourteen to thirteen between London and Paris, and from eight to seven between London and Brussels. Similarly, the frequency of the tourist shuttle service has been halved.

Chapter V: The Fire:-

Propagation and Development

Immediate Development after Ignition

1. It has not proved possible with the evidence available to identify the precise original source of the fire on the incident train. Witness statements have identified the wagon of origin as either wagon 7 or wagon 10 of the rear rake (see Figure 5). The failure of a motorised catenary switch above wagons 7 and 8 could point to one of these wagons as the source of the fire, but this only indicates that a significant fire had spread to these wagons by the time the incident train stopped. The lack of major fire damage to the Heavy Goods Vehicles on wagons 1 to 4 inclusive, does suggest that the origin of the fire was on wagons 5, 6 or 7, since it is unlikely that there would have been significant forward fire spread while the train was moving.

Early Development Prior to Tunnel Entry

2. Witness statements from the security guards indicate that flames about 2m wide by 2m high were seen just before the incident train entered the tunnel at the French portal. The smoke was reported to have been in sufficient quantity to be higher than the road bridge carrying the Route Nationale 1 over the Beussingues trench. This suggests that a fire of between 1 and 1.5MW had developed by this point. Taking account of the stop the incident train made at signals just before entering the tunnel (see paragraph 2 of Chapter III), the fire had grown to this size in about 6 minutes from the time the train left the platform.

In-Tunnel Development and Growth Prior to Confirmed Alarm

3. The incident train clearly entered the tunnel on fire, and in-tunnel ionisation detectors were triggered from entry. However, the driver of the following train 4899 reported that he did not see any smoke until he was about 2-3km into the tunnel near PK 5685, at which point he hit a wall of smoke. The failure of the in-tunnel optical smoke and flame detectors to react at this stage raises two possibilities:
    - that the size of the fire was below the various detector thresholds,
    - that the detector characteristics were not sufficiently sensitive to that type of fire or smoke.
4. Other than some soot deposits, there was no damage to the tunnel during this phase of the fire. The train speed was at least 100kph, and the tunnels fixtures and fittings had only a very brief exposure to heat. It is unlikely that the fire was greater than 4MW at this stage, otherwise it would almost certainly have registered as a confirmed alarm.

From Confirmed Detection Until the Train Stopped

5. Once there had been confirmed flame detection at 21.53 hrs, it may be assumed that the fire was at least 1.5MW and possibly higher. Since there was little damage to the tunnel while the train was moving, it is possible to estimate the maximum fire size that would have left low melting point items such as polyethylene fixtures undamaged. At 50kph only a fire in excess of 200MW would have resulted in any effect on such fittings. Immediately prior to stopping, at a very slow speed, however, a fire of between 5 and 10 MW might have caused some damage. Such damage to low melting point items did occur as far back as cross-passage 4239, but it is not possible to determine whether it occurred while the incident train was stopping or later after the Supplementary Ventilation System was activated. A precise estimate of fire size at this stage in the incident is not possible because the wagon of origin and its load, and the effect of the aerodynamic regime on the development of the fire, are all unknown. It is reasonable, however, to assume that the fire was developing during this phase. It is evident that the fire had grown to a size that had an immediate impact on the tunnel infrastructure once the incident train stopped, and was producing significant quantities of smoke.

Growth on the Stationary Train

6. As the incident train slowed and stopped, the inertia of the moving air resulted in smoke flowing forward and engulfing the front of the train. This development was very rapid. From the time the driver stopped at the cross-passage marker and looked for the cross-passage door number, all visibility was lost. The smoke had therefore already developed from a substantial fire by the time the incident train came to a halt; it was not the result of a fire that only grew once the train had stopped. The driver reported smoke so thick that he could not see the walkway 1.5m away, and, after smoke entered the Amenity Coach, conditions continued to get worse, with visibility as low as 0.5m or less. From his and other witness accounts it is possible to conclude that the fire was growing, although there were few references to the smoke being hot.
7. The most severe damage to the Heavy Goods Vehicles, the wagons and the tunnel was rearwards of wagon 8 of the rear rake, which was carrying a Heavy Goods Vehicle loaded with frozen fat. Forward of that wagon the damage to the tunnel lining was concentrated in two bands down each side of the tunnel (see photograph 9). This suggests that, prior to the activation of the Supplementary Ventilation System, the fire was sufficiently well contained that flames were impinging on the tunnel lining only from the side openings on the carrier wagons i.e. there was no flow of flames above or around the wagons. Since the evidence shows that the most severe heating occurred around wagon 8 , it follows that the frozen fat did not become significantly involved in the fire until after the Supplementary Ventilation System had taken effect.
8. During this phase of growth of the fire on the stationary train prior to activation of the Supplementary Ventilation System, the fire involved at least the Heavy Goods Vehicles on carrier wagons 5, 6 and 7 of the rear rake. The loads on wagons 5 and 6, pineapples, do not appear to have contributed significantly to the fire, but the structures of the refrigerated trailers did. Other Heavy Goods Vehicles, further back on the rake, may also have been burning during this phase but without the involvement of the frozen fat. Forward of wagon 5 there was probably some burning of Heavy Goods Vehicle structures such as soft sides, glass-fibre and plywood, but most of the damage was due to heat and this diminished as the hot gases from the fire moved towards the front of the incident train. However, the aluminium roof of the Heavy Goods Vehicle trailer on wagon 4 did partially melt at about 660ºC despite its load and cab being only slightly damaged. This indicates that the flow of heat forward of wagon 7 was substantial at a high level.
9. It is possible to estimate the size of the fire from estimates of the density and temperature of smoke that engulfed the Amenity Coach. This suggests that at this stage the fire was at least 10MW and possibly as large as 50MW. A fire of this size would probably not have been limited by the oxygen available in the tunnel. It is not possible to derive a more accurate value without knowing the material on fire at that time, or the aerodynamics of the airflow around the fire.

Growth After Activation of the Supplementary Ventilation System

10. Once the Supplementary Ventilation System was activated the fire became much larger. The most severe damage to the tunnel was around the incident train itself, in particular around wagons 9 and 10 on the rear rake. It seems most likely therefore that the fire spread rearwards from wagon 8 and then involved the other wagons. As fire damage to the tunnel extended some 150m beyond the rear locomotive, and there is little to burn in the rear locomotive and loader wagon, it follows that substantial flame lengths were developed from the burning Heavy Goods Vehicles. The fire size would, however, have been limited by the air supply provided by the Supplementary Ventilation System.
11. The Heavy Goods Vehicle cabs and their fuel would have been burning. Although few of the loads were particularly combustible, the trailers themselves would have contributed to the fire. Only the frozen fat and clothing loads provided significant combustible material, with the 20 tonnes of frozen fat probably providing the major source of heat. During the period of burning during this phase, over 3 hours, the fire did not spread substantially forward of wagon 7 of the rear rake.
12. Assuming that all the oxygen from the Supplementary Ventilation System was being consumed during the fire, then the Supplementary Ventilation System could have supported a fire of up to about 350MW. It is unlikely, however, that heat release was sustained at that level for very long. The most severe damage to the tunnel was mostly around the stationary train, with less damage beyond the rear locomotive. This indicates that flame lengths did not exceed 200m, in excess of 350MW for very long. It is also possible to estimate the average rate of heat release from the available fuel and known duration of the fire. Assuming that the fire burned for 3 hours, the average rate of heat release would have been about 150MW. It is therefore plausible to postulate that the maximum value of 350MW was achieved at some stage during the fire.
13. As the tunnel and its contents became hotter during the fire, the production of volatiles from the combustible material available would have exceeded the available air. The excess would have been carried away unburned in the gas stream instead of contributing to the flames. Once the gases from the fire had cooled, these unburned volatiles were deposited as soot or lost in the atmosphere. Overall temperatures in the tunnel during the fire appear to have been about 800ºC, but there were localised areas around the Heavy Goods Vehicle loaded with frozen fat where temperatures were up to 1300ºC. Elsewhere, softening of copper pipes and cables suggests that temperatures of about 1100ºC were reached. The explosive spalling of the concrete lining of the tunnel would have taken place at temperatures approaching 800ºC but the damage to the segments was probably due to the overall size of the fire and the effects of containment in the tunnel.

Smoke Movement

(see figure 8 and figure 9)

Running Tunnel South

14. As stated earlier in this chapter, the incident train was evidently on fire when it entered the tunnel. While ionisation smoke alarms were triggered from entry, the driver of the following train 4899 did not report seeing smoke until he was about 2-3km into the tunnel. This may indicate that the smoke from the fire at entry was carried with the incident train a short way into the tunnel by the air movement around the train. The driver of train 4899 stated that he hit a wall of smoke at about PK 5685. The smoke cleared partially, and he was able to make his own way to the nearest cross-passage door 5689. His train had just passed the ventilation fan station at the Sangatte shaft, between PKs 5705 and 5744 and it is possible that the smoke was venting from the Supplementary Ventilation System shaft, in which soot deposits were found.
15. After the incident train had stopped in Running Tunnel South, smoke from the fire continued to move forward at least 6 km towards the United Kingdom until it was reversed by the operation of

the Supplementary Ventilation System. The smoke then presumably vented at the Sangatte shaft and the French portal, but there have been no reports of this to date.

Running Tunnel North

16. The main route for smoke penetration into Running Tunnel North appears to have been via the open French crossover doors. Other routes include the Piston Relief Ducts prior to and after closure of their dampers. Once closed, the French crossover door did not seal properly, nor did all the Piston Relief Duct dampers close or seal properly on command. Smoke was seen puffing-out of the Piston Relief Duct near cross-passage door 4132, by the Chef de Train on the evacuation train.
17. It was possible to smell smoke in the region of the evacuation train while evacuated passengers and crew from the incident train were being boarded. Since there were no reports of smoke in the cross-passages or the Service Tunnel in this area at PK 4132, this smell almost certainly must have originated from the smoke which came via the Piston Relief Duct mentioned in paragraph 16 above. figure 8 and 9 illustrate the movement of smoke at different times during the incident, based upon the carbon monoxide detection readings. The diagrams do not show all of the leakages of smoke from the Running Tunnel South to Running Tunnel North through Piston Relief Ducts.

Service Tunnel

18. The only report of smoke entering the Service Tunnel was from the French First Line of Response which reported seeing smoke in cross-passage 4201. Video taken during the fire-fighting operations however, clearly showed the Normal Ventilation System holding the smoke back effectively, close to the seat of the fire.

Chapter VI: Fixed Equipment:-

In-Tunnel Fire Detection System

Smoke Detection System

Carbon Monoxide Detection

Flame Detection

Detection Sequences and Response of the System

Other Fixed Equipment

In-tunnel Fire Detection System

Smoke Detection System

1. This comprises a custom made air-sampling system which draws air from a sampling tube in the form of an arc mounted in the upper third of the running tunnel, designed to allow sufficient mixing of smoke and air to take place for the smoke to reach the sampling system as the train travels through the tunnel. The sampled air is drawn through a filter and then passes optical and ionisation chamber point type smoke detectors and a carbon monoxide sensor. The optical and ionisation smoke detectors are fixed threshold devices calibrated to EN 54 smoke detector sensitivity test standard. The ionisation detectors are particularly sensitive to small, almost invisible particles, such as those typically produced by clean burning fires. The optical detectors are particularly sensitive to larger, preferably light coloured, smoke particles produced by smoky or smouldering fires.
2. The triggering of either type of detector will produce an indication of an unconfirmed alarm in the Fire Equipment Management Centre. The triggering of both types of detector is required to produce a confirmed alarm in the Fire Equipment Management Centre which is subsequently automatically relayed as a confirmed alarm to the Rail Control Centre. A sufficiently broad spectrum of smoke particle sizes therefore needs to be detected before a confirmed alarm is transmitted.

Carbon Monoxide Detection

3. The carbon monoxide sensors were originally installed to monitor the toxicity of the air in the tunnels during construction. Analogue signals are transmitted to the Fire Equipment Management Centres and are displayed at 50ppm (parts per million) and 100ppm thresholds of carbon monoxide levels but do not specifically trigger the fire alarm system.

Flame Detection

4. Custom made flame detection units are mounted as twin sets of back-to-back pairs either side of the running tunnels and orientated so as to have a horizontal longitudinal view approximately 2.5 metres above the walkways. Line-of-sight ultra-violet and infra-red sensors are used in combination. The decision making logic requires that the infra-red sensors must be triggered and then the ultra-violet sensor must detect sufficient ultra-violet radiation within a 0.5 second time window in order for an alarm to be raised. This system produces confirmed alarms. The infra-red sensors are pyro-electric devices which only respond to rate-of-change. They cannot detect a non-moving or non-growing fire in their field of vision, and their sensitivity depends both on fire size and the speed with which the fire is travelling into their field of vision.
5. Tests carried out in France at the Centre National de Prévention et de Protection, using a stationary fire and moving detectors indicated that they could readily detect the required fire size of 5MW and could also reliably detect fire sizes of 500KW. It was not possible to carry out dynamic full-scale tests in the tunnel. A functionality test procedure has been devised which also tests sensitivity to some extent. A small assembly is mounted on the front of the detectors which momentarily exposes

a standard size of gas flame. Fire Research Station experts have estimated that this could be equivalent to a fire size of 500KW, viewed at 10 metres.

6. Both ultra-violet and infra-red radiations are considerably obscured and attenuated by their passage through smoke. Consequently, the flame detectors are much more responsive to a clean fire which is producing sufficient infra-red radiation from, for example, hot metal, than they are to fires producing large quantities of smoke which obscures the flame.

Detection Sequences and Response of the System

7. The fire dimensions suggested by the witnesses who saw it before the shuttle entered the tunnel indicates that it was at least 1 to 1.5MW in size. The ionisation smoke detectors responded quickly to the fire with the exception of detection station 57. The first response is noted approximately one minute after the train entered the tunnel. This simply resulted, however, in a series of five or more unconfirmed alarms being received at the Fire Equipment Management Centre, over a period of four minutes. The first confirmed alarm and hence the first alarm to be received at the Rail Control Centre, was a confirmed flame alarm at 21.53 hrs. This was followed by other confirmed flame alarms and a confirmed fire alarm at cross-passage 4856 at 21.53 hrs.
8. Although individual detectors in the fixed installation began to respond within a minute of the train entering the tunnel, the system configuration and decision making logic needs are such that confirmed alarms were not received until approximately five minutes had passed. That the system detected smoke is not in doubt, but better decision-making logic needs to be evolved which will automatically register the output from all of the existing in-tunnel fire detectors including unconfirmed alarms and high carbon monoxide levels. A fire alarm could then be raised by the activation of any detector.
   Recommendation 1: *Eurotunnel must review the decision making logic of the In-Tunnel Fire Detection System, and abandon the concept of an unconfirmed alarm, so that the fire detection system can be used to give the earliest possible warning to the Rail Control Centre.*

Other Fixed Equipment

9. The performance of much of the fixed equipment in the tunnel during the incident appears to have been generally satisfactory. The main exceptions were the French crossover doors, certain Piston Relief Duct dampers and the catenary. There were also some failures of the fixed equipment as a result of actions by the operators; these are analysed in Chapter VIII.
10. The crossover doors should normally be kept in the closed position and be able to be operated remotely. Due however to the lack of reliability in the opening and closing mechanisms for both undersea crossover doors, Eurotunnel had been operating for some time with these doors open. It is clear, however, that during the incident on 18 November 1996, incorrect application of procedures did result in an incomplete closure of the French crossover door, with serious consequences.
    Recommendation 2: *Eurotunnel must resolve the technical problems associated with the crossover doors, ensure that these are fully closed during normal operations and ensure that they are capable of immediate closure by remote operation in the event of an emergency at other times. Any locally confirmed fault of a crossover door in the open position must lead to suspension of the Heavy Goods Vehicle service.*
11. The Rail Control Centre ordered the closure of the Piston Relief Duct dampers at 21.53 hrs. The damper in the Piston Relief Duct at PK 3531 remained open, thereby enabling smoke from the fire on the incident train to enter Running Tunnel North. The Chef de Train of the evacuation train had also noticed that some smoke was escaping from the Piston Relief Duct located by the rear locomotive. In addition, analysis of the printouts from the Equipment Management System shows that, in the minutes following the closure command from the Rail Control Centre, 177 of the 196 dampers were indicated as closed. For the remaining 19 dampers, probably because the cycle of closure had not been completed, the information showed that either the command had not been executed or that the damper was faulty. This resulted in a flood of alarms appearing on the operators visual display unit screen.

Recommendation 3: *Eurotunnel must review the maintenance of Piston Relief Duct dampers and the means of their closure so that all dampers are capable of immediate closure in the event of an emergency.*

12. The catenary tripped only a few seconds after the incident train stopped in the tunnel, thereby cutting off traction power supply to Running Tunnel South between the tunnel mid-point and the French portal. The exact cause of this tripping is not known, but it is likely to have resulted from arcing following either ionisation of the air in the smoke produced by the fire, or failure of a soldered catenary connection. This may have led to the cable short-circuiting against one of the Heavy Goods Vehicle shuttle wagons or the tunnel lining. One of the most serious consequences of the loss of the catenary was that the front locomotive and the Amenity Coach could not be uncoupled from the rest of the incident train and driven away from the fire.
    Recommendation 4: *Eurotunnel must examine the feasibility of reducing the chances of the catenary tripping, and in fire scenarios abandon the procedures relating to Heavy Goods Vehicle shuttles concerning uncoupling the Amenity Coach and bringing it out of the tunnel with the adjacent locomotive.*
13. The performance of the communications systems during the incident also gives rise to concern. Many people have since complained of poor reception quality, and particular concerns have been raised about the saturation of the concession radio during the early phases of the incident.
    Recommendation 5: *Eurotunnel must improve the quality of its radio communications and give additional training to users. Particular emphasis must be given to radio discipline, use of standard messages and use of the emergency call button. The number of users of concession radio should also be restricted.*
14. During the incident the emergency telephone network performed satisfactorily. However, the fire damaged fibre optic cables in the Running Tunnel South, caused the loss of two of the four communication lines between the terminals and, consequently, the loss of the administrative telephone between France and the United Kingdom, at approximately 22.00 hrs. The system was not reconfigured automatically as it should have been using the fibre optic cables in the Running Tunnel North. This complicated the task of the Rail Control Centre operators who had difficulties keeping in contact with the French Terminal Control Centre.
    Recommendation 6: *Eurotunnel must review the performance of the tunnels entire hard-wired, telephone and radio links and upgrade them as necessary in order 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.*
15. The fire main in the vicinity of the fire was damaged by the intense heat and developed leaks in places; as a result there was an inadequate supply of water to fire-fighters until the system was reconfigured.
    Recommendation 7: *Eurotunnel must examine the loss of performance caused by damage to the fire main and ensure that any necessary steps are taken to minimise the impact of fire in the tunnel on this essential equipment.*

Chapter VII: Rolling Stock:-

The Incident Train

On-Board Fire Detection System

Locomotive Fire Detection

Props and Bridging Plate Control Circuit

Brake Pipes

Amenity Coach

Other Issues

Evacuation Train

The Incident train

On-board Fire Detection System

1. The on-board fire detection system draws air from two sampling tubes mounted externally around the cabs of the loader wagons. Each sampling tube then feeds air through filters to remove larger dust particles and passes the air through two high-sensitivity optically based particle detector counters. These use a xenon flash to illuminate and count the smoke particles. Two detection units, each with two sensor heads, are used to ensure that there is some level of redundancy but also to enhance the reliability of detection and reduce the number of false alarms. The sensing heads in the on-board fire detection system are widely used in buildings around the world as highly sensitive early fire development smoke sensors. They are analogue devices and use a pre-set, though variable, threshold which is easy to adjust. The systems are normally tuned to the environment in which they are used
2. Sensitivity and response time of the system depends on the threshold setting, the length of time the threshold must be exceeded and the airflow rate through the sampling pipes. Tests witnessed, using cold smoke and analogue values from the sensors, indicated that when using mist or fog smoke from a carrier at the front of a rake, the response time was typically thirty seconds between the smoke being released and the sensor activating. Although sensors are optical devices, tests carried out at the Fire Research Station indicate that the sensors do not discriminate between smoke types as much as single point optical detectors, but nevertheless, can be more responsive to clean smoke than ionisation detectors
3. The alarm from the on-board detection system registers in the Chef de Trains cab in the Amenity Coach. There is a continuous buzzer and one lamp for each loader which has detected smoke. It is estimated that the on-board detection system indicated a fire alarm on the rear loader on the Chef de Trains desk at 21.53 hrs, approximately four minutes after the first unconfirmed ionisation detector alarm.
   Recommendation 8: *In order to ensure an 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 tests conducted in the Channel Tunnel.*

Locomotive Fire Detection

4. The locomotive fire detection system is installed primarily to protect the driver and the rolling stock and activate the halon extinguishing systems within the technical compartments. Ionisation detectors are fitted in the cab and vestibule of the locomotive, and heat detectors are fitted in the technical compartments. A fire alarm from the rear locomotive fire detection system registers on a dedicated display in the front locomotive. The detectors are wired in two loops, so that one or more detectors triggered on one loop will produce an unconfirmed alarm and if detection occurs on both loops then a confirmed alarm is indicated. The locomotive will then shut down and the halon system will be activated.

5. The locomotive fire detectors are not part of the on-board fire detection system, but nevertheless on 18 November 1996, produced the first indication of fire on the incident train, at 21:51 hrs when an orange lamp lit up in the drivers cab of the front locomotive indicating an unconfirmed fire in the rear locomotive. The origin of this alarm cannot be established with any certainty because of the severity of the damage to the rear locomotive. It may have been triggered either by heat in the traction control compartments or by smoke detection in the drivers cab or vestibule, although the latter spaces are reasonably well sealed from the ingress of smoke, suggesting that activation of a heat detector caused the alarm.
   Recommendation 9: *In order to ensure an early warning of fire, Eurotunnel must revise responses to the locomotive fire alarms which must be treated in the same way as any other fire alarm.*
6. Five minutes later, the main circuit breaker opened in the rear locomotive thereby shutting it down. Again, because of the severity of the damage it has not been possible to confirm whether this protective measure activated as a consequence of the fire or of a random failure.

Props and Bridging Plates Control Circuit

7. The severe damage to the rear loader wagon of the second rake of the incident train has made it difficult to establish the exact cause for the activation of the stop signal in the drivers cab in the front locomotive. It may have been the result of either:
   - a random failure in the control circuits of the props and bridging plates, such as had been observed in the months immediately preceding the incident, or
   - failure of a props and bridging plate control circuit as a result of the fire.

   Recommendation 10: *Eurotunnel must improve the reliability of the control circuits for the props and bridging plates in the loader wagons, to avoid unnecessary stopping of trains in the tunnel.*

Brake Pipes

8. The driver of the incident train, some 10 to 15 minutes after stopping, observed a drop in pressure from 9 bars to 0, in the air line which feeds the brakes and other auxiliary systems. It is most likely that one of the flexible couplings between the wagons had failed at that stage.
   Recommendation 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 plates control circuit,*
   - *failure of a brake line,*
   - *failure of the catenary,*
   - *the risk to people on the following trains from smoke,*
   - *the risk to people on the incident train due to the size of the fire at the time of any eventual stop (planned or unplanned).*

Amenity coach

9. It has not been possible to make any examination of the Amenity Coach because it has been impounded for the French Judicial Inquiry. However, statements from the passengers and crew have confirmed that smoke entered the Amenity Coach only after the train stopped and from places other than the rear door which the Chef de Train opened briefly in an attempt to locate the cross-passage.
   Recommendation 12: *Eurotunnel must carry out thorough tests on all Amenity Coaches and locomotives, and correct any faults discovered during these tests to ensure that they will prevent the ingress of smoke during an incident. All new rolling stock of this type must meet the same criteria to prevent the ingress of smoke before they are brought into service.*

Other Issues

10. Examination of the most severely damaged rolling stock (see paragraph 8 of chapter IV) shows that the equipment located beneath the underframe, in particular equipment boxes, bogies and couplings, resisted the fire more than the superstructures of the wagons. It is noteworthy that all the wagons and locomotives making up the incident train were towed to the workshop yard in the French terminal on their own bogies. This shows the effectiveness of the fire resistant decks.

Evacuation Train

11. The driver of the evacuation train 6518 saw smoke in the tunnel at about PK 3531, which was where a damper in the Piston Relief Duct remained open. He pressed the fire in tunnel button which commands the closure of the ventilation dampers in the tourist shuttle wagons. According to the Chef de Trains display, the closure of the dampers in wagons 3, 8 and 21 was not confirmed. The Chef de Train therefore ordered a local check to be carried out, which revealed that the dampers in wagons 3 and 21 were open. As a precaution, the Chef de Train ordered a longitudinal evacuation of these wagons.
    Recommendation 13: *Eurotunnel must review maintenance procedures for the ventilation dampers in the tourist wagons in order to ensure that they function effectively.*
12. To assist the single deck rake crew with the reception of passengers from the incident train, the Chef de Train asked a crew member from the double deck rake, who had some knowledge of first aid, to go to the front rake of the shuttle. The loader wagon end door, which allows internal passage to the front rake, could not be opened and the crew member had to leave the train and use the walkways.
    Recommendation 14: *Eurotunnel must review the maintenance procedures for the doors at the ends of the tourist loader wagons in order to ensure that they function effectively.*

Chapter VIII: Performance of Staff:-

Alerting and Responses

General

1. The various emergency plans (see paragraphs 31 and 32 of Chapter I) for dealing with incidents in the Channel Tunnel make provision for a variety of alerting procedures. Although these procedures contain some variations to meet the needs of different administrative arrangements in the United Kingdom and France, they are all designed to ensure speedy mobilisation of sufficient resources to deal with any emergency that occurs, whether national or bi-national.
2. The key to the alerting process is Eurotunnel, who have responsibility for informing the relevant external emergency services about incidents. Eurotunnel have developed various procedures and instructions for all their key staff involved in the alerting process. These include the Fire Equipment Management Centre, Terminal Control Centre and Rail Control Centre operators. The alerting procedures which Eurotunnel used at the time of the incident were deficient. The procedures had failed to be fully or properly implemented on a number of occasions before; these had been brought to the attention of Eurotunnel. Alerting difficulties had also occurred at the major Bi-National exercise, eight days earlier. As a result of Eurotunnel's alerting arrangements, the French First Line of Response was delayed by 11 minutes, the French Second Line of Response was delayed by 2 minutes and the United Kingdom Second Line of Response by approximately 67 minutes.

Alerting Responses in France

3. The message giving the initial alert of the incident on 18 November 1996, was made quickly. One of the security guards who saw flames coming from the incident train before it entered the tunnel radioed this information to his supervisor, who in turn passed it to the Control Security Officer. From there it was passed to the French Terminal Control Centre, where it was received at 21.48 hrs. By 21.49 hrs, the Rail Control Centre had been made aware of the incident, and by 21.50 hrs the information, having been passed on four times, reached the French Fire Equipment Management Centre where the First Line of Response team was despatched, arriving at the correct cross-passage door, 4131, at 22.28 hrs. The United Kingdom Fire Equipment Management Centre was alerted at 21.52 hrs.

4. During the 55 minutes following the alert to French Fire Services Operational Control Centre, the number of fire-fighters mobilised was sufficient to crew the specialised fire vehicles used by the Second Line of Response in the Service Tunnel.
5. The first French Ambulance Service personnel entered the tunnel 43 minutes after the initial alert, with a second Service Tunnel Transport System ambulance following 27 minutes later. Three more medical teams arrived at the French terminal within the following 20 minutes and a medivac helicopter was present by 23.56 hrs.
6. The French Immigration Police, having organised traffic control and terminal access arrangements, arrived at the departure point at 22.45 hrs. This led the French Commander to delay the departure of the Second Line of Response team for some five or six minutes. Most of the Second Line of Response teams arrived at the incident scene at 23.07 hrs.

Alerting Responses in the United Kingdom

7. The initial alert to the United Kingdom Fire Equipment Management Centre originated from the Engineering Management System operator in the Rail Control Centre at 21.52 hrs. This was some two minutes after the French Fire Equipment Management Centre had been informed. Significantly, the initial alerting message to the United Kingdom Fire Equipment Management Centre included the additional information that the incident train would be diverted to the emergency siding in the United Kingdom terminal. Had the 'drive through' policy worked, there would have been no role for the United Kingdom First Line of Response in the incident. In the circumstances, the United Kingdom Fire Equipment Management Centre operator followed Eurotunnel's standing instruction to keep the United Kingdom First Line of Response team on stand-by, that is, ready to respond. Matters then developed quickly, and by approximately 21.54 hrs the Rail Control Centre had agreed with the United Kingdom Fire Equipment Management Centre operator that the United Kingdom First Line of Response team should be mobilised. They entered the Service Tunnel at 22.03 hrs and arrived at the incident scene at 22.30 hrs
8. The alerting procedure requires that the United Kingdom Fire Equipment Management Centre operator informs the Terminal Control Centre of the action he has taken, and which public emergency services in the United Kingdom should be alerted. The incident on 18 November 1996 demonstrated that the instructions were deficient, and they have subsequently been replaced, on 29 November 1996 following representations from the Emergency Planning Committee.
9. The United Kingdom Terminal Control Centre supervisor telephoned the Longport Police Station to indicate that there was a possible fire on a train in Running Tunnel South on the French side. The Longport Control Room immediately passed this information to the Kent Police Operations Centre in Maidstone, where it was received at 22.10 hrs. At 22.36 hrs the Longport Control Room received another message from the Terminal Control Centre indicating that there was a fire on a train in the tunnel and that the passengers were being evacuated. A further message at 22.53 hrs informed the police that this was a major incident on the French side. The Duty Inspector in the Operations Centre decided that a full emergency response from the United Kingdom was not required. He did not become fully aware of the seriousness of the incident until the BINAT GO message was received at 23.19 hrs.
10. The Police at the United Kingdom terminal mobilised and by 22.38 hrs, an inspector and four constables were on-board the Service Tunnel Transport System communications vehicle and entering the Service Tunnel. A police sergeant and a civilian employee went to the Incident Co-ordination Centre. Other resources were put in place to control traffic and to receive emergency vehicles.
11. At 23.00 hrs, the United Kingdom Fire Equipment Management Centre received a confirmed request for reinforcements from the United Kingdom First Line of Response leader. This was passed directly to the Terminal Control Centre, which informed the Kent Fire Brigade at 23.02 hrs. The Kent Fire Brigade mobilised seven major appliances, six senior officers and support vehicles. The Divisional Fire Commander entered the tunnel at 23.19 hrs, and the second Service Tunnel Transport System fire appliance left some two minutes later with a further 12 fire-fighters. The Kent Ambulance NHS Trust received notification of the incident at 23.20 hrs. Two ambulances and four

senior officers responded to the call. The Service Tunnel Transport System ambulance entered the Service Tunnel at 23.51 hrs.

Bi-National Alerting

12. The fire developed into a Bi-National incident. The lead nation was France, and the responsibility for declaring the incident a Bi-National emergency, lay with the Préfet.
13. The duty Sous-Préfet on behalf of the Préfet, declared the incident as BINAT GO at 23.06 hrs. This message was sent to the Poste de Commandement Fixe in Arras and then by facsimile to the Kent Police, who received it at 23.19 hrs. Kent Police passed it to Eurotunnel at 23.20 hrs. 13 minutes were therefore taken up in passing this important emergency alerting measure.
    Recommendation 15: *Eurotunnel, with the assistance of the Emergency Planning Committee, must review the priority and procedures for alerting the external emergency services.*

Actions of the Public Emergency Services

General

14. Seven Emergency Response Organisations were involved in the incident: Eurotunnel First Line of Response, the Pas de Calais Fire Service, the Kent Fire Brigade, the French Ambulance Service, The French Immigration Police, the Kent Police and the Kent Ambulance NHS Trust. A number of other organisations and people contributed to the overall management of the incident. Others were put on immediate standby, including Accident and Emergency Hospitals, the Royal Air Force, the Sécurité Civile and the Gendarmerie. All the necessary resources were available to those responsible for managing the incident.

Conduct of Operations

15. The Eurotunnel First Line of Response Teams managed, with the train crew, the evacuation of the casualties into the safety of the Service Tunnel, provided first aid to the casualties and loaded them into the evacuation train. They then carried out a search and located the fire, and notified the Rail Control Centre and Fire Equipment Management Centres of their actions.
16. The sequence of events of the Emergency Response Organisations are detailed in Chapter III and have been the subject of a detailed operational analysis which can be used by Eurotunnel and external public emergency services for training purposes and in the development of operational tactics.
    Recommendation 16: *Eurotunnel must amend the procedure for the entry of the First Line of Response into the Service Tunnel at the French terminal. Procedures concerning the transportation of the Second Line of Response to incidents should be reviewed to enable as speedy a response as possible. Eurotunnel and the Emergency Planning Committee must review the joint training of the First Line of Response and the Second Line of Response in relation to incident management, breathing apparatus control and related operational issues.*
17. The fire-fighting tactics employed by the combined forces of the French and United Kingdom Second Line of Response teams were competent and effective. The two Commanders worked together and they amended their strategies to cope with developments and the severe limitations of the tunnel environment. Attacking the fire from cross-passage doors 4163 and 4201 was the appropriate way of ensuring the safety of the fire-fighters and of tackling the fire.
18. The fire-fighting operation was characterised by resoluteness and high personal commitment of the fire-fighters particularly those from both countries operating from cross-passage 4201. Here they gained and maintained entry into Running Tunnel South between two flame fronts, one of which was being driven towards them by the Supplementary Ventilation System. They continued to attack the fire despite uncertain footholds, intense heat, fluctuating water supplies and cramped conditions, and brought it under control comparatively quickly. The fact that no fire-fighters suffered serious

injury in dealing with the fire, was a credit to them and to the tactics employed. Overall the performance of crews was very creditable in the circumstances.

Support Operations

19. The lack of training or experience of Eurotunnel staff in the management of emergencies, was apparent. For some key personnel this was their first experience of a major emergency. As a consequence, not only was there delay in the transmission of important information, but at various times the Emergency Services experienced difficulty in obtaining information concerning the incident.
    Recommendation 17: *Eurotunnel must improve the training of all of their staff in relation to the management of emergencies and develop a structured and practically based training programme.*
20. The two Incident Co-ordination Centres appear to have functioned well, but the overriding requirement for sound communications collapsed at an early stage in the incident. By 22.02 hrs, Eurotunnel staff were informed of the loss of the administrative telephone links between the United Kingdom and France. The public emergency services' principal officers in the two Incident Co-ordination Centres were not made immediately aware of this, and for an hour, unsuccessful attempts were made to establish the important link between the two command posts. The design of the standard communications links should have been such that damage to one set would result in the cable feeds being switched automatically to an alternate route.. The "hot line" between the United Kingdom and French Command Centres also failed, although it was later reinstated. System failures, coupled with reliance on manually kept records, have made detailed analysis of aspects of the command and control function very difficult.
    Recommendation 18: *Eurotunnel must introduce the recording of all radio and telephone communications to and from the Control Centres: Rail Control Centre, Terminal Control Centre, Fire Equipment Management Centre, and the two Incident Co-ordination Centres in France and the United Kingdom, including the hot-line.*
21. Supplies on the Service Tunnel Transport System vehicles for the rest and refreshment of those dealing with the incident in the tunnel were soon exhausted. Breathing apparatus, in particular, was used up very quickly and, without it, fire-fighting in the tunnel would not have been possible. The United Kingdom re-supply route was 31km long and needed careful management. Fire-fighting equipment supplies were maintained, but not without difficulty. At the same time, there is some evidence that the huge resources devoted to this incident did cause some congestion, although this is not thought to have been detrimental to the actual fire-fighting.

Actions of Eurotunnel Staff

Security Guards

22. The four security guards (see paragraph 3 of Chapter III) who saw the fire on the incident train shortly before it entered the tunnel, acted correctly by transmitting this information immediately to their Chef de Poste. It is important to note however that the security guards have neither responsibility for assessing the condition of trains entering the tunnel, nor the means of stopping them. Their place of work is also very close to the tunnel portal. The Chef de Poste correctly transmitted the information about the fire to the French Terminal Control Centre, which promptly and correctly informed the Rail Control Centre. Almost two minutes passed between the first sighting of the fire and the receipt of the information in the Rail Control Centre. Early warning of an incident like the fire on 18 November 1996 is fundamental to its containment.
    Recommendation 19: *Members of staff, who because of their function are likely to observe fires or smoke on a train before it enters the tunnel, should be equipped with a means of direct communication with the Rail Control Centre. Such information must be treated in the same way as any other fire alarm. Appropriate procedures for such members of staff must be put in place.*

Incident Train Crew

23. Overall, the performance of the incident train's crew was good. In particular, the calmness of the Chef de Train and catering steward helped to prevent the passengers from panicking in the Amenity Coach, under very difficult circumstances. Their statements do demonstrate, however, that they were not sufficiently prepared to deal with this kind of situation.
    Recommendation 20: *The train crews of Eurotunnel and all other railway operators who use the tunnel must receive additional training on the handling of emergencies. This 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 in the presence of smoke and crews should be trained in this environment.*
24. In accordance with procedures, after activation of the stop signal on his cab display, the driver of the incident train made a controlled stop just behind the diamond-shaped marker. This positioned the right hand door of the Amenity Coach directly opposite a cross-passage. The number of the cross-passage, though displayed immediately below the marker, was obscured by smoke as soon as the train stopped.
    Recommendation 21: *Eurotunnel must improve the visibility of the reflective position marker panels and ensure that they are kept as clean as possible.*
25. In accordance with the procedures, the driver tried to leave his train to prepare the evacuation and open the cross-passage door. In his first attempt, he did not use his breathing apparatus because he considered it impractical. The presence of dense, opaque smoke, which irritated his eyes and throat and, in his view, reduced visibility to 50cm, prevented him from carrying out this operation. His attempt to pass through the locomotive via an internal passageway to take breathing apparatus to a pregnant woman passenger also failed.
    Recommendation 22: *The training programme for Eurotunnel train crews must include familiarisation with the breathing apparatus which they may be called upon to use. Eurotunnel must also improve lighting by the cross-passage doors, and ensure that train crew are equipped with high quality hand lamps.*
26. Shortly after the incident train stopped, the Chef de Train opened the right hand side rear door of the Amenity Coach in an attempt to find the cross-passage. Finding thick smoke surrounding the Amenity Coach he immediately closed the door. During the short time that the doors were open, a considerable quantity of smoke entered the Amenity Coach.
    Recommendation 23: *The evacuation procedures for the Amenity Coach must be revised, and stipulate that the evacuation doors should only be opened if the Chef de Train has had visual contact with the driver or has previously been able to ascertain that there is sufficient visibility on the walkways and has located the cross-passage.*
27. The Chef de Train stated that he had difficulty contacting the Rail Control Centre by radio, but he did not use the emergency button on his concession radio. (See Recommendation 5).
28. The statements taken from the Heavy Goods Vehicle drivers show that all the passengers felt that they received insufficient information, both at departure and during the incident. Regular users of the tunnel have also pointed out this regular deficiency and that it is rare to receive information during an incident, such as a sudden halt.

Evacuation Train Crew

29. The evacuation train crew responded well to a difficult situation. The presence of a first-aider in the crew was particularly useful. The crew had some difficulties in reassuring the train passengers, however, as no pre-recorded messages adapted to this situation were available.
    Recommendation 24: *Eurotunnel must revise the procedures and the training of its staff regarding safety announcements to passengers. In addition, the passengers must receive safety instructions before, or immediately after, the train's departure.*
    Recommendation 25: *Eurotunnel and all operators who use the tunnel, must ensure that prepared messages for broadcasting to passengers are updated in relation to emergencies. The possibility of the train being used as an evacuation train should also be considered.*

Recommendation 26: *Eurotunnel must review its first aid training policy. Eurotunnel must ensure that Railway Operators who use the tunnel for carrying passengers and Eurotunnel's own train staff have a sufficient level of competence to ensure that basic life preserving measures can be taken in emergencies. Eurotunnel must incorporate first aid training into the crew training within six months:*

- *in relation to Heavy Goods Vehicles shuttles, the Chef de Train must be qualified in first aid.*
- *in relation to tourist shuttles, at least one member of the crew, other than the driver, must be qualified in first aid.*

Rail Control Centre Staff

30. The handling of the incident on 18 November 1996 by the Rail Control Centre was not satisfactory. Numerous mistakes were made. It must be acknowledged, however, that the staff in the Rail Control Centre were confronted by an extremely complex situation which, although covered by emergency procedures, required them to make a rapid series of actions in a short period of time. Several complicating factors need to be highlighted:
    - Training was deficient or ill-adapted for incidents of this type.
    - Operating procedures were complex.
    - There was a multiplicity of possible scenarios for operators to consider, requiring preliminary checks to be carried out by the operators before giving commands, which delayed immediate action.
    - Some fixed equipment suffered from technical malfunction or incomplete functioning.
31. Decisions taken at the beginning of an incident are crucial. If those decisions are inappropriate, an incident, even one of little importance, can soon degenerate into a major emergency. Great attention, therefore, needs to be paid to the errors identified in the following paragraphs.
    Recommendation 27: *The feed-back system, through which operational incidents can be analysed and discussed by managers, together with modifications to operating procedures, must be strengthened.*

Application of Procedures

32. The errors analysed in this section have been included in this report because they concern essential instructions within the relevant emergency procedures. During the incident on 18 November 1996, those instructions were either forgotten, incorrectly applied, applied too late or applied in a different order to that prescribed. These errors had or could have had serious consequences for the course of the incident, leading to an increase in risk.
33. As soon as the Rail Control Centre received notification that the incident train had stopped in Running Tunnel South, it should have ordered all trains forward of the incident train to stop. The Rail Control Centre should also have stopped the trains in Running Tunnel North because the French crossover doors were still open. This failure to stop the trains in the tunnel accelerated the movement of smoke towards the front of the incident train in Running Tunnel South, and later enabled the penetration and diffusion of smoke in Running Tunnel North.
34. The Supplementary Ventilation System was activated too late, approximately 15 minutes after the incident train had stopped. In addition, for another seven minutes, the fan blades were set at zero pitch, which prevented any movement of air. Taken together with the failure to stop the trains in front, the front locomotive and Amenity Coach on the incident train were engulfed in smoke for approximately one hour. Correct application of both procedures should have ensured that this period was considerably reduced.
35. The order to close the crossover doors was also given too late. This was due to the fact that, in the face of repeated failures of these doors, a normal practice had been developed of first sending a technician to the relevant door before they were operated. In addition, during the incident, the manoeuvre was not carried out in accordance with procedures. These stated that an order should be sent to all trains moving within 1500m of the doors to slow down to 30kph. Failure to apply this

procedure led to incomplete closure of one leaf of the French crossover door and, after the Supplementary Ventilation System was activated, to the penetration of smoke into interval 6 of Running Tunnel North.
Recommendation 28: *The Rail Control Centre operators' training must be revised and improved. The additional training programmes must include training for emergency situations and on-site visits. Training should be acknowledged with a certificate which confirms the level of competency attained. Refresher training must take place periodically. Any member of staff failing a competence assessment should be removed from duty, re-trained and retested.*

36. The Rail Control Centre set the speed limit for trains in interval 2 of the tunnel at 100kph, one minute after the general message on the track to train radio. As a result, the Automatic Train Protection caused emergency braking on the evacuation train 6518, whose driver had not acknowledged receipt of the message. Had the Rail Control Centre operator started by ordering the reduced speed limit in the interval in which the incident train was moving, the incident train would have encountered an uncontrolled stop which would have had even more serious consequences.
Recommendation 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.*
37. After giving the order to close the Piston Relief Duct dampers, the operator in charge should have ensured that they had actually closed. This was not done, because when this order was given, the operator received a status report via the computer. If the movement of some of the dampers from open to closed position had been too slow, the system would have sent back a report reading 'status unknown' or 'command ignored' which in turn would have activated an alarm. The operator stated that he cancelled more than a dozen alarms during the incident and then, busy with other tasks, forgot to carry out the necessary checks to ensure that the relevant dampers were, in fact, closed.
Recommendation 30: *The Engineering Management System must be modified so that the operator is not faced with an unmanageable increase in workload during an emergency. Eurotunnel must also develop and install an Alarm Management System.*
38. Another cause for concern is that the Engineering Management System operator encountered difficulties in reconfiguring and isolating the catenary. The operator should have isolated the interval where the incident train had stopped and re-supplied the remainder of Running Tunnel South to facilitate the other trains leaving the tunnel.
Recommendation 31: *The software controlling the Engineering Management System must be modified so that the operator may easily identify the damaged zones of, and reconfigure the catenary.*
39. The evacuation train 6518 should have been returned to the United Kingdom terminal, not the French Terminal. The procedures state that if a fire occurs less than 5km from an undersea crossover, that crossover should not be passed by a train with passengers on-board. In addition, the presence of thick smoke at the French crossover in Running Tunnel North had been observed by the drivers of trains 752 and 7532. However, because they were respecting radio discipline during the incident, the drivers of these trains did not report this to the Rail Control Centre.
Recommendation 32: *The procedures for the passing of information in an emergency between trains and the Rail Control Centre must be reviewed.*

Complicating Factors

40. This incident has shown that the training of the Rail Control Centre operators places little emphasis on the management of emergency situations. There is a tendency for training in infrequent events to be based on reference to written procedures. As indicated in the following Recommendation, these laborious procedures are not well adapted to such situations.
Recommendation 33: *The training received by the Rail Control Centre operators must therefore be reviewed so that they may acquire, "by heart", knowledge of standard responses necessary, for situations which are uncommon, but potentially dangerous, so that the safety of people and the system can be assured without referring to written documents. Periodic exercises must take place in order to maintain levels of competence.*

41. The procedures which the Rail Control Centre operators had to apply during the incident were difficult to use, were too complicated, too numerous and badly presented. The excessive use of logigrams and too many options such as Heavy Goods Vehicle shuttle train or not, crossover doors open or closed, Amenity Coach at the front or rear of the train and the incident train moving or stopped, made immediate action by the operators difficult.
    Recommendation 34: *Eurotunnel must fully review Rail Control Centre procedures with a view to clarifying and simplifying the procedures and to make them more user-friendly. Eurotunnel must allocate sufficient qualified personnel, in order to complete this task and commit itself to a time-scale. Eurotunnel must also carry out an analysis of the tasks of each operator in the Rail Control Centre to ensure that their tasks can be carried out effectively in all circumstances.*
42. There were further factors which complicated the tasks of the Rail Control Centre operators during the incident:
    - The Rail Control Centre had insufficient time to correctly carry out all the necessary procedures because four minutes were lost between the first unconfirmed alarm and the first confirmed alarm. (see Recommendation 1).
    - The presence of two trains in Running Tunnel South behind the incident train, could have been avoided by earlier reaction to the in-tunnel fire detection system alarms. The first unconfirmed alarm was triggered at 21.49 hrs, and train 4899 entered the tunnel at 21.52 hrs.
    - The inability of the driver of the incident train to identify its precise location by reading the cross-passage door marker number because of the dense smoke. As a result, 23 minutes were lost before it was known which cross-passage door should be opened and incorrect information was given to the First Line of Response team.
    - The fact that the crossover doors were open complicated the operators' task. (see Recommendation 2.)
    - The workload of the operators during the first minutes of the incident was excessive.

    Recommendation 35: *The procedures relative to controlled stops must be improved to state that, except in a 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.*
    Recommendation 36: *Eurotunnel must increase staffing by provision of a fourth operator in the Rail Control Centre who should be qualified in the use of the fixed equipment and rail traffic management. In an emergency this operator would provide assistance to one or other of the normal operators, who would nonetheless remain solely responsible for these tasks. At other times the fourth operator would replace one or other of the operators during training sessions or relief breaks.*

Chapter IX: Conclusions and Recommendations:-

CONCLUSIONS

The History of the Shuttle Design

1. The history of the design of Heavy Goods Vehicle shuttles has been one of concern about fire containment set against the engineering difficulties of building enclosed wagons which could carry lorries up to 44 tons in weight. Eurotunnel finally asserted their determination to develop a convincing fire safety regime in which the semi-open design could be used.
2. The Channel Tunnel Safety Authority considered Eurotunnel's proposals and, in 1992, confirmed that the overall objectives of the system must be to enable the passengers in the Amenity Coach to be safely evacuated in the presence of a developing fire anywhere in the Heavy Goods Vehicle shuttle and to ensure the protection of passengers on other trains. The concerns of the Channel Tunnel Safety Authority were:
    - the size of the fire at the time of detection,
    - the rate of fire development and spread,
    - the size of the fire able to overcome the Supplementary Ventilation System,
    - and the conditions concerning temperature, visibility, and toxicity which would allow safe evacuation from the Amenity Coach.
3. Eurotunnel put forward an extensive programme of experiments and tests, the results of which were reported to the Channel Tunnel Safety Authority. The key points of evidence considered were developments of the Channel Tunnel Safety Authority's original concerns from 1992; they included:
    - the ability of the fire detection systems to detect a fire early enough for evacuation to proceed safely;
    - the rate of fire development in a Heavy Goods Vehicle;
    - the ability of the Tunnel ventilation systems to control the air flow in the vicinity of a fire;
    - the effectiveness of the procedures for dealing with any emergency in the Tunnel, including the evacuation of the incident train and the movement of other trains out of the Tunnel;
    - and the ability of the Rail Traffic Management System to maintain, in all circumstances, the necessary minimum separation distance between Heavy Goods Vehicle shuttles and other trains.
4. In May 1994, the Channel Tunnel Safety Authority was of the opinion that the equipment and procedures proposed by Eurotunnel were such that they should always allow passengers in the Amenity Coach to be safely evacuated and passengers in other trains to be protected, providing procedures were properly implemented by adequately trained staff. In the event of a fire occurring, trains would, in the first instance, attempt to exit the tunnel so that the fire could be dealt with in one of the emergency sidings. Should this not be possible, the train would be stopped and the locomotive and Amenity Coach would be uncoupled and driven out leaving the rest of the train behind. In the event that uncoupling was not possible, the Supplementary Ventilation System would be used to

drive smoke away from the Amenity Coach in order that passengers could be safely evacuated to the Service Tunnel.

5. As a consequence, on 14 May 1994, Eurotunnel received authorisation from the Intergovernmental Commission for the Heavy Goods Vehicle shuttle service to start.

Key Safety Criteria

6. Each of the points of evidence set out in paragraph 3 above may be regarded, in fact, as safety criteria. An examination of the performance of the Eurotunnel system on the night of 18 November 1996, is set out below:

Fire Detection Systems

7. Four security guards saw flames of 1 to 2 metres in height on a Heavy Goods Vehicle wagon before the train entered the Tunnel. Five of the first six in-tunnel fire detectors only gave unconfirmed alarms and the on-board fire detectors on the rear loader wagon did not give an early alarm. Given the drive through strategy used by Eurotunnel, any extra delay in alerting the Rail Control Centre has most impact on the following trains. In this particular fire, four minutes were lost before the first actions were taken to configure the tunnel systems for dealing with an emergency.
8. The fire on 18 November illustrated however, that not only are there technical issues relating to fire detection system logic and calibration of detectors to be corrected, there is a need overall for re-appraisal of the policy in respect of fire alarm signals. Concerns about the potential level of false alarms and the consequences of these, led Eurotunnel to develop the current philosophy of unconfirmed and confirmed fire alarms. The objective of detecting a fire as early as possible can therefore be seen to have been impeded in two ways. The fire detection system reacted, but not sufficiently to give an immediate warning of what was a significant developing fire; and the existing procedures would have entitled Rail Control Centre operators to regard the unconfirmed alarm as either a false alarm or a small fire. Clearly future arrangements must embody the spirit of an immediate response to any fire alarm, whatever the source, in order for the early warning safety criterion to be met.

Rate of Fire Development and Spread

9. The drive-through strategy was followed and the fire developed substantially while the train was still moving. After the train stopped fire development rapidly accelerated, first towards the front of the train and then towards the rear after the Supplementary Ventilation System had been activated. In effect, nearly half of the train, the rear locomotive and the cargo of Heavy Goods Vehicles, was severely damaged or destroyed. The drive-through strategy failed for at least two reasons; on the balance of probability, fire damage to safety critical equipment caused an alarm which led the driver to make a controlled stop. The catenary tripped out within seconds of the train stopping, making uncoupling and drive-out by the lead locomotive and Amenity Coach impossible. This may have been due to hot smoke and ionisation causing catenary flashover, possibly in a manner unforeseen during design, or by failure of the catenary such as the loss of a soldered connection when the catenary was subject to the effects of the stationary fire.
10. The extent of the fire spread also raises questions as to what the effects would have been if the Heavy Goods Vehicle in the leading wagon of the front rake had been the one to catch fire, a point which is developed in paragraph 16 below. The fire also raises questions as to what the effects would have been if the Amenity Coach had been at the rear of the train, as it would have been in "en tiroir" operations which are carried out in high wind conditions.
11. The damage to the tunnel structure and fixed equipment was extensive and provides clear evidence of the ultimate size and intensity of the fire. The ensuing fire-fighting operation placed enormous demands on the public emergency services of both France and the United Kingdom.

The Ventilation System

12. Once a Heavy Goods Vehicle shuttle is stopped with an uncontained fire, Eurotunnel's strategy requires use of the Supplementary Ventilation System to direct smoke and fumes away from the Amenity Coach so that people can reach the cross-passage door to escape to the Service Tunnel. In the fire on 18 November 1996, the Supplementary Ventilation System was not operated soon enough. However, the overpressure in the Service Tunnel and correct, if late, opening of the cross-passage door achieved the expected bubble effect which allowed the escape.
13. The ability of the Supplementary Ventilation System to reverse and control air flows was clearly demonstrated as witnessed by fire-fighters at the scene and in subsequent technical analysis.

Effectiveness of Emergency Procedures Including Rail Traffic Management

14. As soon as the Rail Control Centre knew that there was a confirmed fire, controllers should have halted the following trains to prevent them running into smoke. Once the incident train had come to a halt, the Rail Control Centre should have halted any preceding trains in order to lessen the forward movement of smoke and fumes over the Amenity Coach. The procedures may be correct but they were not properly implemented; the effects were aggravated by the delay in operating the Supplementary Ventilation System.
15. Rail Control Centre operators, during the first few minutes of the incident, did not have time to implement all the required actions and were submerged in an overload of information and alarms. The number and complexity of the existing procedures and insufficient training of the Rail Control Centre operators led to errors and delays in the implementation of necessary actions. The number of people involved in the incident and lax radio discipline led to overloading of the concession radio; considerable difficulties in communications were further aggravated by the loss of the internal administrative telephone between the United Kingdom and French terminals. Only an increase in qualified operators for the Rail Control Centre will ensure that a sufficient number are available to enable effective training to take place. Although it had previously been identified that there were insufficient controllers to enable a full programme of continuous training, no increase in the number had been sanctioned at the time of the incident.
16. The density of the smoke was such that the Chef de Train was unable to see the cross-passage door and identify it so that the Rail Control Centre could be sure of remotely operating the correct door. The Chef de Train opened the door of the Amenity Coach to assess the situation and significant quantities of smoke entered causing considerable physical discomfort and anxiety among the passengers. According to passengers in the Amenity Coach, smoke also entered by other means. Had the fire been on the front rake, the effect of the combustion products would have been much greater and the penetration of the Amenity Coach by smoke could have had the gravest of consequences.
17. The driver correctly stopped on a marker, so that the Amenity Coach was adjacent to a cross passage. If he had not been able to do so, it is clear that in the circumstances of the incident, the train crew and passengers would have been exposed to even greater risk. In circumstances where the Supplementary Ventilation System had not taken effect, it is possible that passengers could have had to walk perhaps as much as 150m in thick smoke to locate an exit.
18. Normally the crossover doors should be kept closed but at the time of the incident, they were open. They were closed later than they should have been by the Rail Control Centre staff and the French crossover door did not fully engage. This resulted in smoke entering the north running tunnel which complicated the task for the evacuation train crew.
19. The 4 km separation distance behind a Heavy Goods Vehicle shuttle has been established in practice and is maintained by the Rail Traffic Management computer and the signalling system. The adequacy of this separation distance needs to be confirmed. The evidence of the spread of smoke and the difficulties the operator had in managing the incident emphasise the importance of this safety feature.

20. Overall therefore the performance of the Eurotunnel system, set against the key safety criteria, illustrates both the unavoidable complexity of its interrelated elements and the absolute importance of the actions of operators. While we consider that the existing design of the HGV shuttles can be utilised in a way that secures the safety of people, all designs may be capable of improvement as technology develops. In the future Eurotunnel should not neglect to explore other options.

The Actions of People

21. The train crews of the incident train and the evacuation train were faced with a very difficult situation which overall they handled well. An incident such as this would have severely tested any crew member, and notwithstanding the lack of preparedness which some of the crew felt, some notable individual actions characterised by calmness and professionalism were evident.
22. The Eurotunnel First Line of Response Teams responded promptly, managed, with the train crew, the evacuation of the casualties, secured the safety of the Service Tunnel, provided first aid to the casualties, carried out a search and located the fire, and notified the Rail Control Centre and Fire Equipment Management Centres of their actions. Overall the performance of crews was very creditable in the circumstances and reflected their professional training and discipline.
23. The fire-fighting tactics employed by the combined forces of the French and United Kingdom Second Line of Response teams were competent and effective. The two Commanders worked together and they amended their strategies to cope with developments and the severe limitations of the tunnel environment. The fire-fighting operation was characterised by resoluteness and high personal commitment of the fire-fighters particularly those from both countries operating from cross-passage 4201 who gained and maintained entry into the Running Tunnel South inevitably creating two flame fronts, one of which was being driven towards them by the Supplementary Ventilation System. The fact that no fire-fighters suffered serious injury in dealing with the fire, was a credit to them and to the tactics employed. The Commanding Officers of both nations deserve commendation for their performance of duty at this difficult fire.

The Management of Safety in Eurotunnel

24. It is not possible in this Inquiry to fully encompass the question of the management of safety within Eurotunnel or to debate the nature of the safety culture in the organisation. The fundamental weaknesses exposed by the fire of 18 November need to be recognised and corrected by Eurotunnel at the highest levels however, because they have an impact on the framework of safety arrangements overall, they are not just the failures on the day of specific people or equipment. The staff on duty were unable to carry out the emergency procedures which were too complex and demanding, and for which they had not been adequately trained. Greater attention to rehearsing these procedures would have shown up earlier the undue demands imposed on the control room staff.
25. Eurotunnel is probably unique in its evolution as a transportation systems company. Its tunnels, equipment and rolling stock are highly complex and its staff derive from diverse backgrounds as well as railway disciplines. After lengthy commissioning and the management of high volumes of traffic, operating experience has undoubtedly been gained by staff but Eurotunnel is still a young organisation. The management of emergencies remains characterised by the limited experience of many staff and the intrinsic difficulties posed by the complexity of the Eurotunnel operation overall and the nature of operating procedures and engineering systems which have been developed. In addition, the bi-national nature of the company and the need to work in two languages present their own challenges.
26. The Eurotunnel Health, Safety and Quality Directorate systematically audits performance of staff in all disciplines and had audited the Rail Control Centre in July 1996. The findings of the Directorate illustrate particularly well the difficulties which the company faces. Eurotunnel may be an emergent company with the inherent need to mature in terms of operational culture, but it also has the continuity and operating difficulties of any company in relation to refresher training and staff turnover issues to address in the Rail Control Centre and elsewhere. The audit Report highlighted many areas of concern and detailed the corrective actions which needed to be taken. Overall the

audit exposed the underlying weaknesses in the Rail Control Centre which were so plainly evident on the night of 18 November. It is regrettable that, by this date, Eurotunnel's senior managers had still not taken the necessary corrective actions.

27. It could be argued, superficially at least, that the safety equipment, staff and procedures worked well enough overall to achieve the main safety objective of ensuring no serious harm to people. But a closer analysis of the performance of key staff, emergency procedures and safety equipment raises serious questions as to the safety of the system in these and similar circumstances. We set out below the recommendations of this Inquiry which, if implemented, will improve important elements of the safety systems.

RECOMMENDATIONS

28. The following recommendations must be addressed by Eurotunnel. The Safety Authority considers that they should be taken into account at the highest level and implemented at all levels of decision making and execution.

Chapter VI - Fixed Equipment

Recommendation 1: *Eurotunnel must review the decision making logic of the In-Tunnel Fire Detection System, and abandon the concept of an unconfirmed alarm, so that the fire detection system can be used to give the earliest possible warning to the Rail Control Centre.*
Recommendation 2: *Eurotunnel must resolve the technical problems associated with the crossover doors, ensure that these are fully closed during normal operations and ensure that they are capable of immediate closure by remote operation in the event of an emergency at other times. Any locally confirmed fault of a cross passage door in the open position must lead to suspension of the Heavy Goods Vehicle service.*
Recommendation 3: *Eurotunnel must review the maintenance of Piston Relief Duct dampers and the means of their closure, so that all dampers are capable of immediate closure in the event of an emergency.*
Recommendation 4: *Eurotunnel must examine the feasibility of reducing the chances of the catenary tripping, and in fire scenarios abandon the procedures relating to Heavy Goods Vehicle shuttles concerning uncoupling the Amenity Coach and bringing it out of the tunnel with the adjacent locomotive.*
Recommendation 5: *Eurotunnel must improve the quality of its radio communications and give additional training to users. Particular emphasis must be given to radio discipline, use of standard messages and use of the emergency call button. The number of users of Concession Radio should also be restricted.*
Recommendation 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.*
Recommendation 7: *Eurotunnel must examine the loss of performance caused by damage to the fire main and ensure that any necessary steps are taken to minimise the impact of fire in the tunnel on this essential equipment.*

Chapter VII - Rolling Stock

Recommendation 8: *In order to ensure an 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 tests conducted in the Channel Tunnel.*
Recommendation 9: *To ensure an early warning of fire, Eurotunnel must revise responses to the locomotive fire alarms which must be treated in the same way as any other fire alarm.*
Recommendation 10: *Eurotunnel must improve the reliability of circuit breakers and the control*

circuits for the props and bridging plates in the loader wagons, to avoid unnecessary stopping of trains in the tunnel.
Recommendation 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 plates 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 due to the size of the fire at the time of any eventual stop (planned or unplanned).*

Recommendation 12: *Eurotunnel must carry out thorough tests on all Amenity Coaches and locomotives, and correct any faults discovered during these tests to ensure that they will prevent the ingress of smoke during an incident. All new rolling stock of this type must meet the same criteria to prevent the ingress of smoke before they are brought into service.*
Recommendation 13: *Eurotunnel must review maintenance procedures for the ventilation dampers in the tourist wagons in order to ensure that they function effectively.*
Recommendation 14: *Eurotunnel must review the maintenance procedures for the doors at the ends of the tourist loader wagons in order to ensure that they function effectively.*

Chapter VIII - Performance of staff

Recommendation 15: *Eurotunnel, with the assistance of the Emergency Planning Committee must review priorities and procedures for alerting the external emergency services.*
Recommendation 16: *Eurotunnel must amend the procedure for the entry of the First Line of Response into the Service Tunnel at the French terminal. Procedures concerning the transportation of the Second Line of Response to incidents should be reviewed to enable as speedy a response as possible. Eurotunnel and the Emergency Planning Committee must review the joint training of the First Line of Response and the Second Line of Response in relation to incident management, breathing apparatus control and related operational issues.*
Recommendation 17: *Eurotunnel must improve the training of all of their staff in relation to the management of emergencies and develop a structured and practically based training programme to cover these needs.*
Recommendation 18: *Eurotunnel must introduce the recording of all radio and telephone communications to and from the control centres: Rail Control Centre, Terminal Control Centre, Fire Equipment Management Centre, and the two Incident Co-ordination Centres in France and the United Kingdom, including "hot-lines".*
Recommendation 19: *Members of staff who because of their functions are likely to observe fires or smoke on a train before it enters the tunnel, should be equipped with a means of direct communication with the Rail Control Centre. Such information must be treated in the same way as any other fire alarm. Appropriate procedures for such members of staff must be put in place.*
Recommendation 20: *The train crews of Eurotunnel and all other Railway operators who use the tunnel must receive additional training on the handling of emergencies. This 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 this environment.*
Recommendation 21: *Eurotunnel must improve the visibility of the reflective position marker panels and ensure that they are kept as clean as possible.*
Recommendation 22: *The training programme for Eurotunnel train crews must include familiarisation with the breathing apparatus which they may be called upon to use. Eurotunnel must also improve lighting by the cross-passage doors, and ensure that train crew are equipped with high quality hand lamps.*

Recommendation 23: *The evacuation procedures for the Amenity Coach must be revised, and stipulate that the evacuation doors should only be opened if the chef de train has had visual contact with the driver or has previously been able to ascertain that there is sufficient visibility on the walkways and has located the cross-passage.*
Recommendation 24: *Eurotunnel must revise the procedures and the training of its staff regarding safety announcements to passengers. In addition, the passengers must receive safety instructions before or immediately after the train's departure.*
Recommendation 25: *Eurotunnel and all operators who use the Tunnel must ensure that prepared messages for broadcasting to passengers are updated in relation to emergencies. The possibility of the train being used as an evacuation train should also be considered.*
Recommendation 26: *Eurotunnel must review its first aid training policy. Eurotunnel must ensure that Railway Operators who use the tunnel for carrying passengers and Eurotunnel's train staff have a sufficient level of competence to ensure that basic life preserving measures can be taken in emergencies. Eurotunnel must incorporate first aid training into the crew training within the first six months:*

- *in relation to Heavy Goods Vehicles shuttles, the Chef de Train must be qualified in first aid.*
- *in relation to tourist shuttles, at least one member of the crew, other than the driver, must be qualified in first aid.*

Recommendation 27: *The feed-back system, through which operational incidents can be analysed and discussed by managers, together with modifications to operating procedures, must be strengthened.*
Recommendation 28: *The Rail Control Centre operators' training must be revised and improved. The additional training programmes must include training for emergency situations and on-site visits. Training should be acknowledged with a certificate which confirms the level of competency attained. Refresher training must take place periodically. Any member of staff failing a competence assessment should be removed from duty, re-trained and retested.*
Recommendation 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.*
Recommendation 30: *The Engineering Management System must be modified so that the operator is not faced with an unmanageable increase in workload during an emergency. Eurotunnel must also develop and install an Alarm Management System.*
Recommendation 31: *The software controlling the Engineering Management System must be modified so that the operator may easily identify the damaged zones of, and reconfigure the catenary.*
Recommendation 32: *The procedures for the passing of information in an emergency between trains and the Rail Control Centre must be reviewed.*
Recommendation 33: *Training received by the Rail Control Centre operators must be reviewed so that they may acquire, "by heart", knowledge of standard responses necessary for situations which are uncommon but potentially dangerous, so that the safety of people and the system can be assured without referring to written documents. Periodic exercises must take place in order to maintain levels of competence.*
Recommendation 34: *Eurotunnel must fully review Rail Control Centre procedures with a view to clarifying and simplifying the procedures to make them more user-friendly. Eurotunnel must allocate sufficient qualified personnel, in order to complete this task and commit itself to a time-scale. Eurotunnel must also carry out an analysis of the tasks of each operator in the Rail Control Centre to ensure that their tasks can be carried out effectively in all circumstances.*
Recommendation 35: *The procedures relative to controlled stops must be improved to state that, except in a 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.*

Recommendation 36: *Eurotunnel must increase staffing by provision of a fourth operator in the Rail Control Centre who should be qualified in the use of the fixed equipment and rail traffic management. In an emergency this operator would provide assistance to one or other of the normal operators, who would nonetheless remain solely responsible for these tasks. At other times the fourth operator would replace one or other of the operators during training sessions or relief breaks.*

Annex:- Members of the Channel Tunnel Safety Authority

UK Delegation

Roderick Allison
Head of Delegation April 1997 onwards.
Former member of the Health and Safety Executive and recently retired as Chief Executive, Offshore Safety Division.

Edward Ryder, CB
Former Head of the UK Delegation (July 1992-March 1997). Formerly HM Chief Inspector of Nuclear Installations, Health and Safety Executive.

Sandra Caldwell
Head of Safety Policy Division A, Health and Safety Executive.

Jeremy Beech, CBE QFSM
County Fire Officer of Kent.

Peter Moss
Former Head of Channel Tunnel Division, Department of Transport.

Victor Coleman
HM Deputy Chief Inspector of Railways, HM Railways Inspectorate, Health and Safety Executive.

Liste des Membres du Comite de Securite

French Delegation

Roger Lejuez
Chef de la Délégation
Inspecteur Général du Transport et des Travaux Publics - Haut Fonctionnaire de l Equipement et des Transports pour lEurope - Conseiller du Directeur des Affaires Economiques et Internationales pour les Affaires communautaires - Ministère de lEquipement, des Transports et du Tourisme.

François Barthelemy
Ingénieur Général des Mines - Chef de la Mission du Transport des Matières Dangereuses - Ministère de lEquipement, des Transports et du Tourisme.

Jean-Pascal Cogez
Sous-Préfet de Calais - Ministère de lIntérieur

Claude Charmeil
Ingénieur Général des Ponts et Chaussées - Direction des Transports Terrestres - Ministère de lEquipement, des Transports et du Tourisme

Pierre Desfray
Ingénieur Divisionnaire des Travaux Publics de lEtat - Secrétariat Général au Tunnel sous la Manche - Ministère de lEquipement, des Transports et du Tourisme

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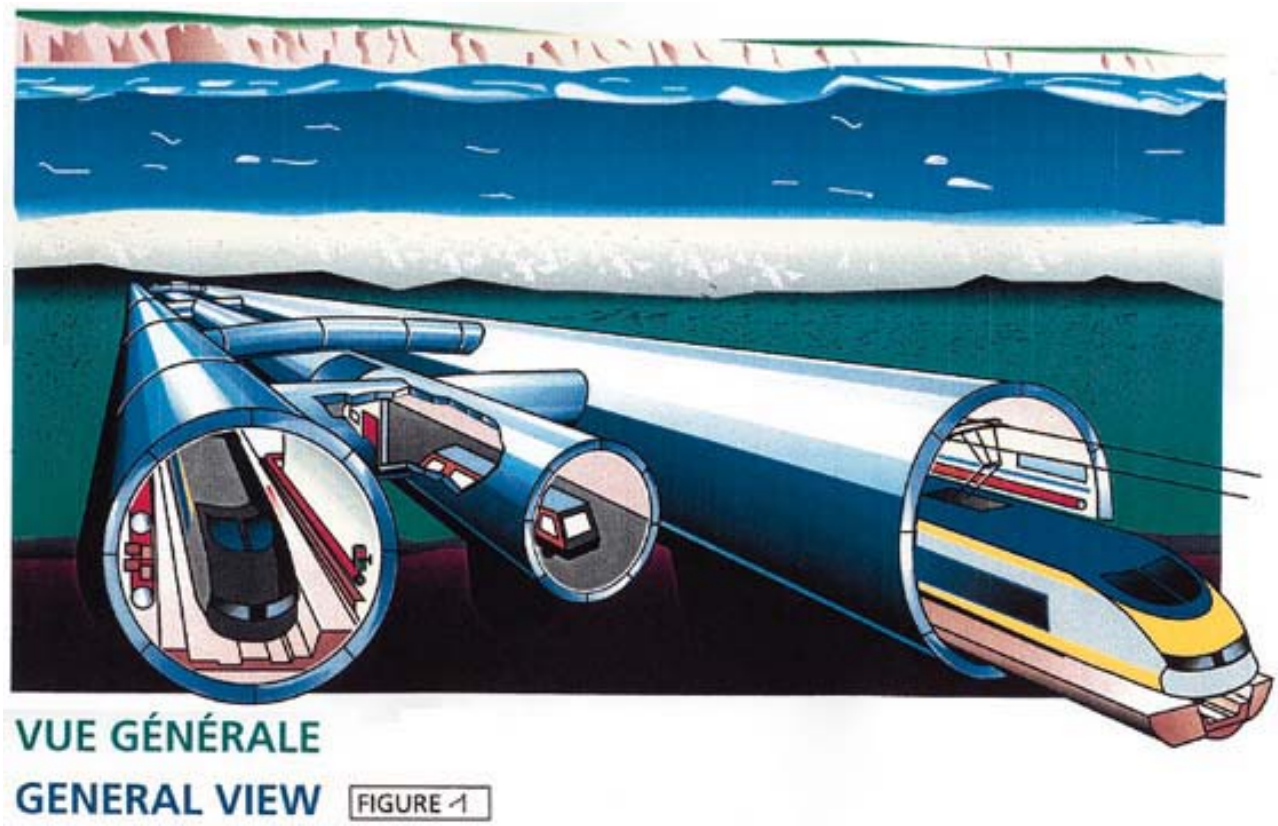
Figure 1:- General View of the Tunnel System



(c) Eurotunnel

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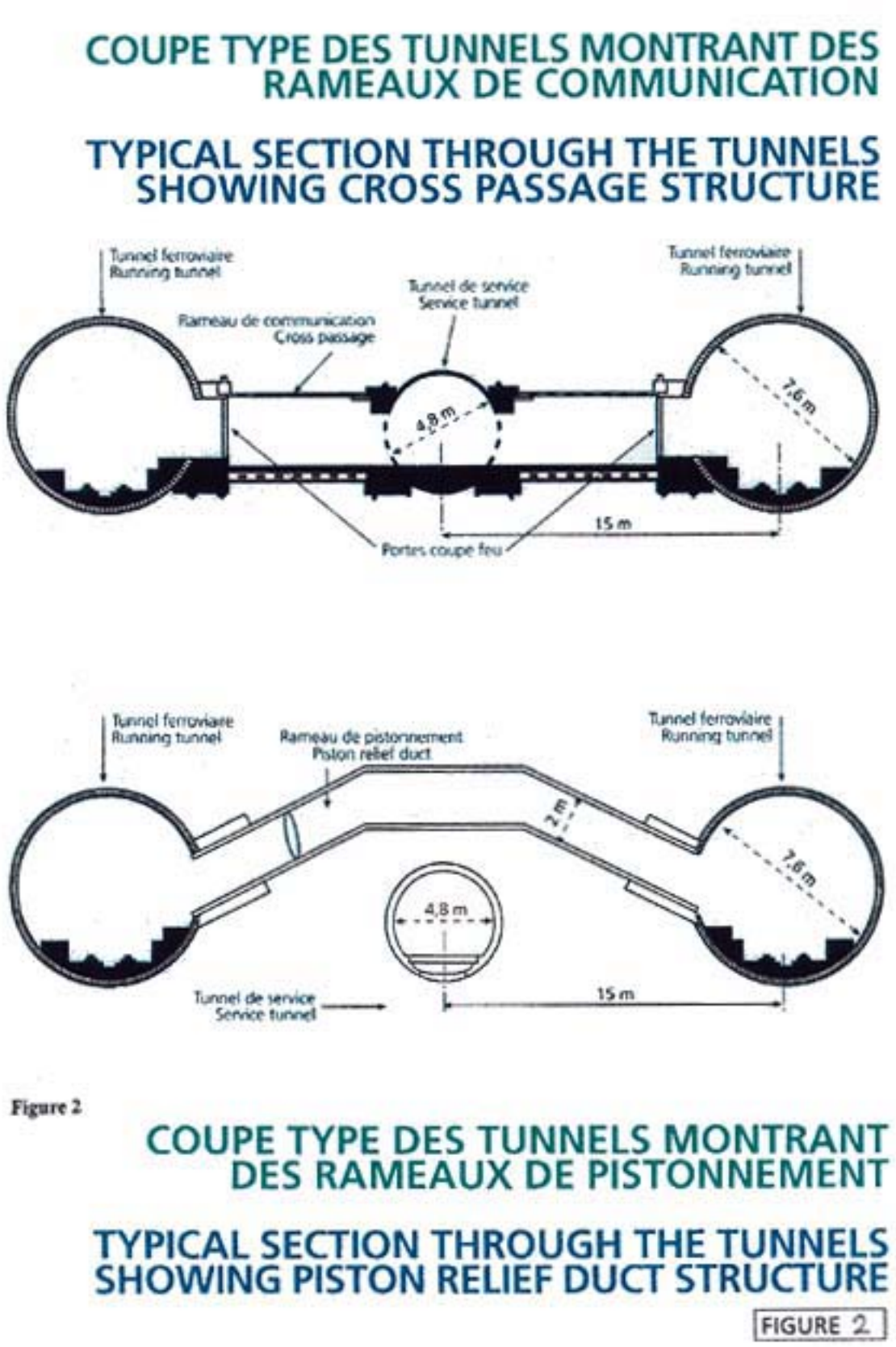

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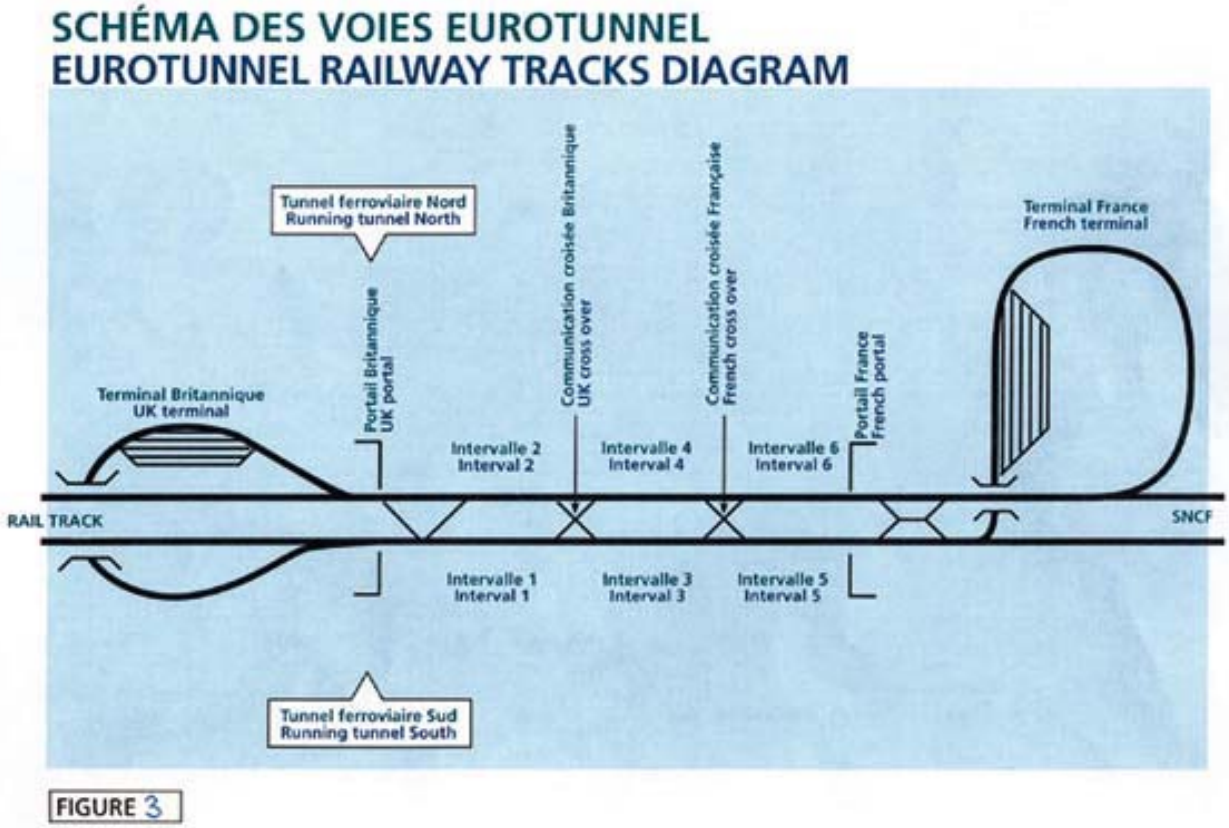

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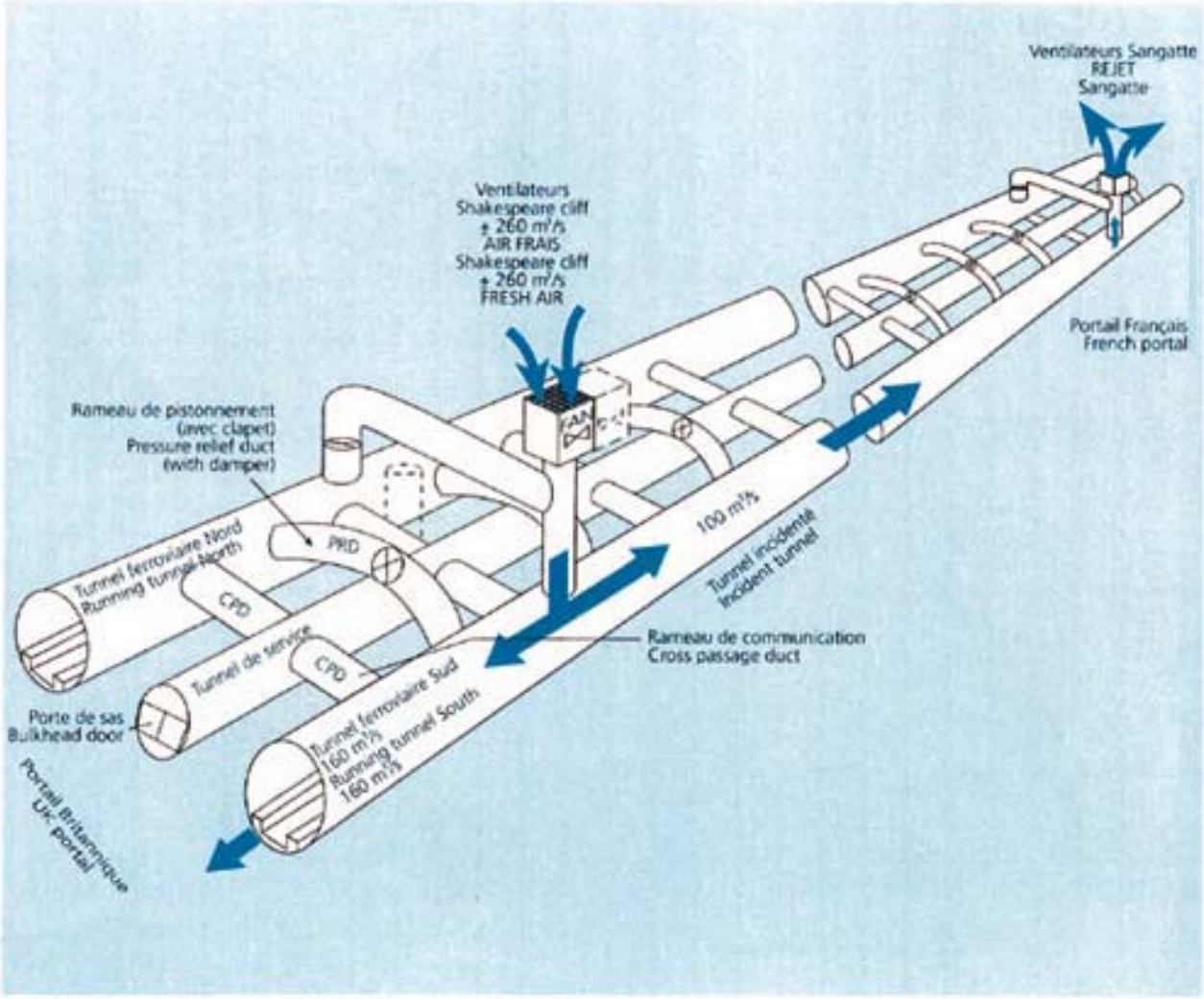

SYSTÈME VENTILATION SUPPLÉMENTAIRE
Figure schématique

SUPPLEMENTARY VENTILATION SYSTEM
schematic diagram

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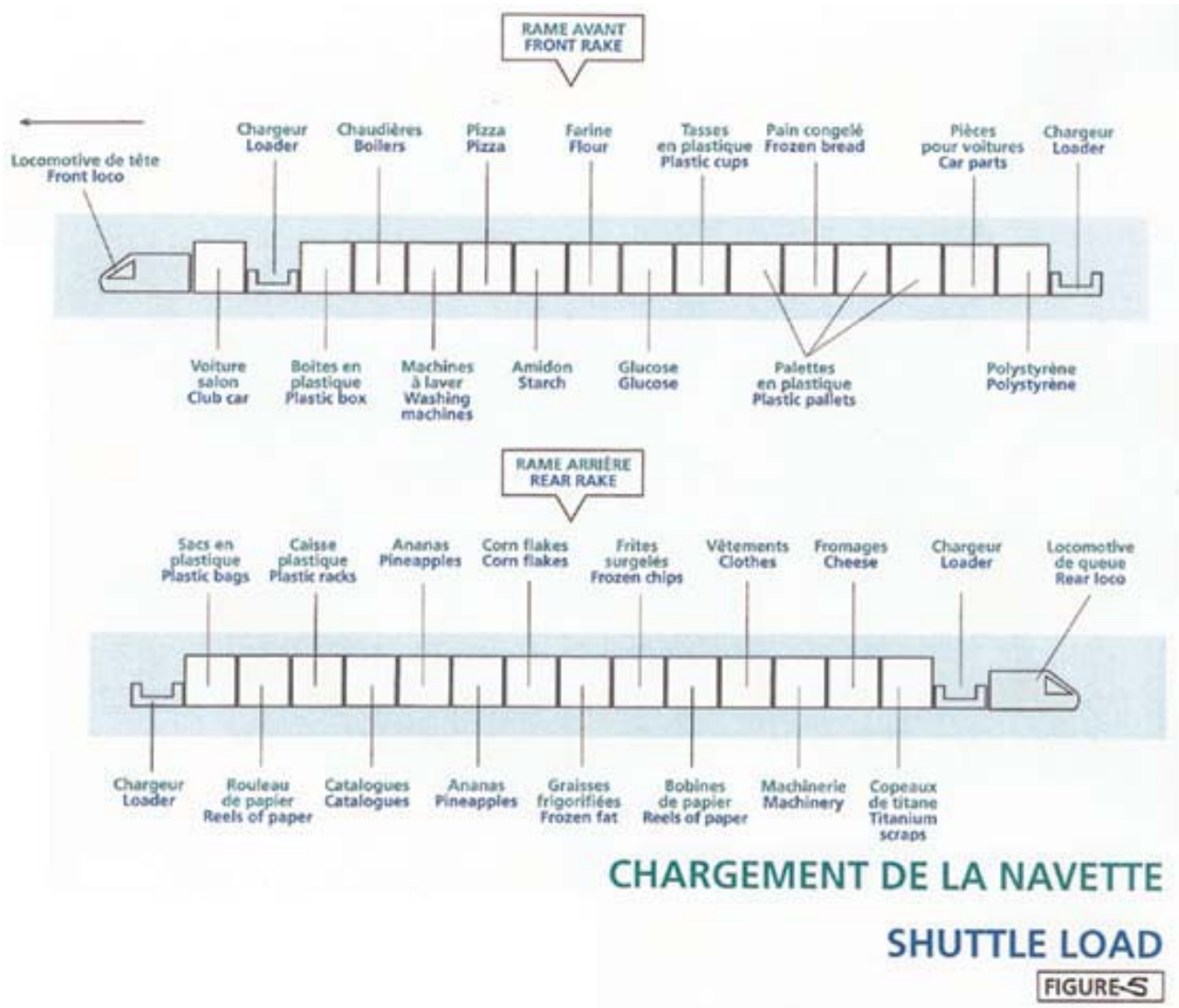

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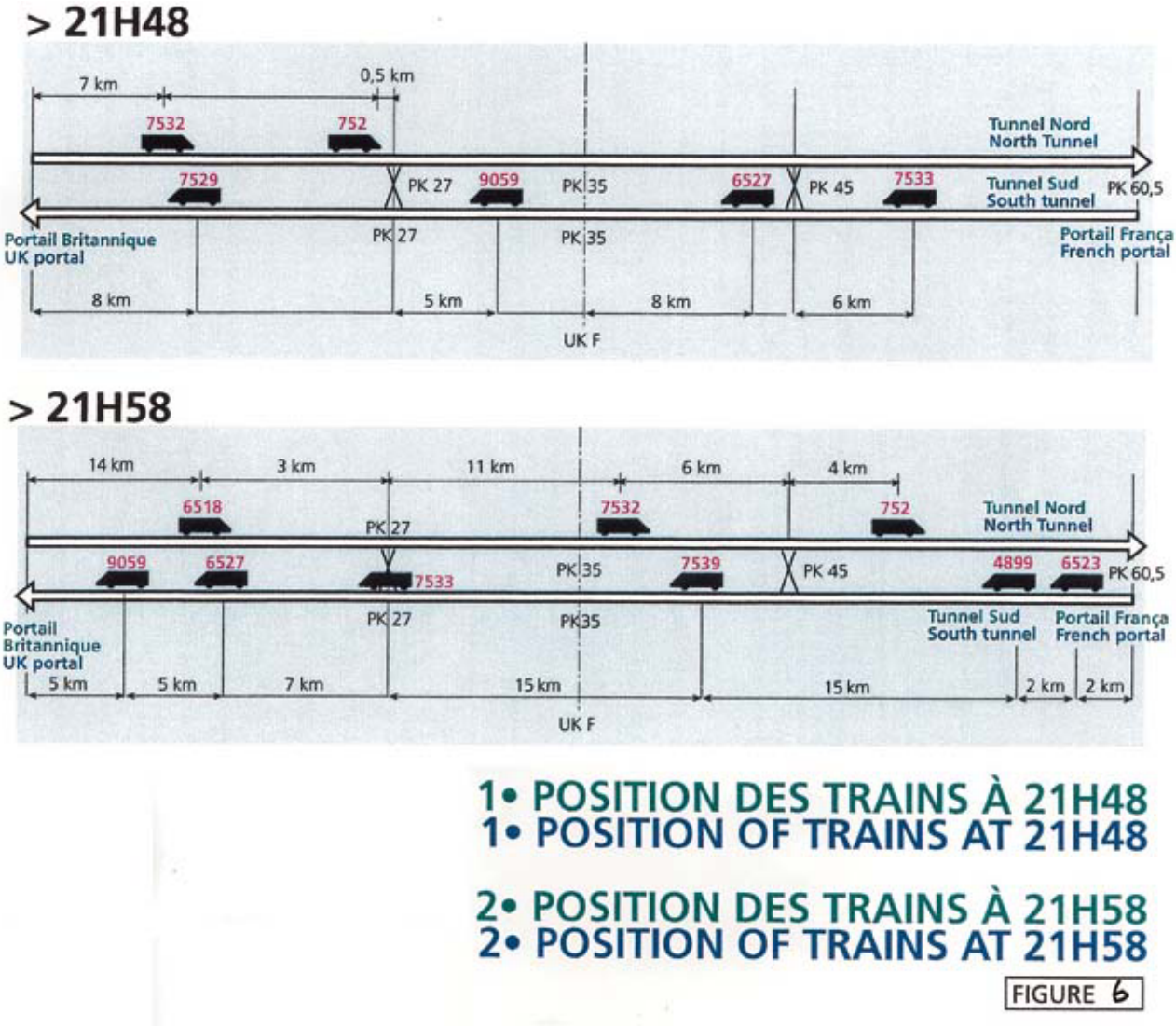

1• POSITION DES TRAINS À 21H48
1• POSITION OF TRAINS AT 21H48

2• POSITION DES TRAINS À 21H58
2• POSITION OF TRAINS AT 21H58

FIGURE 6

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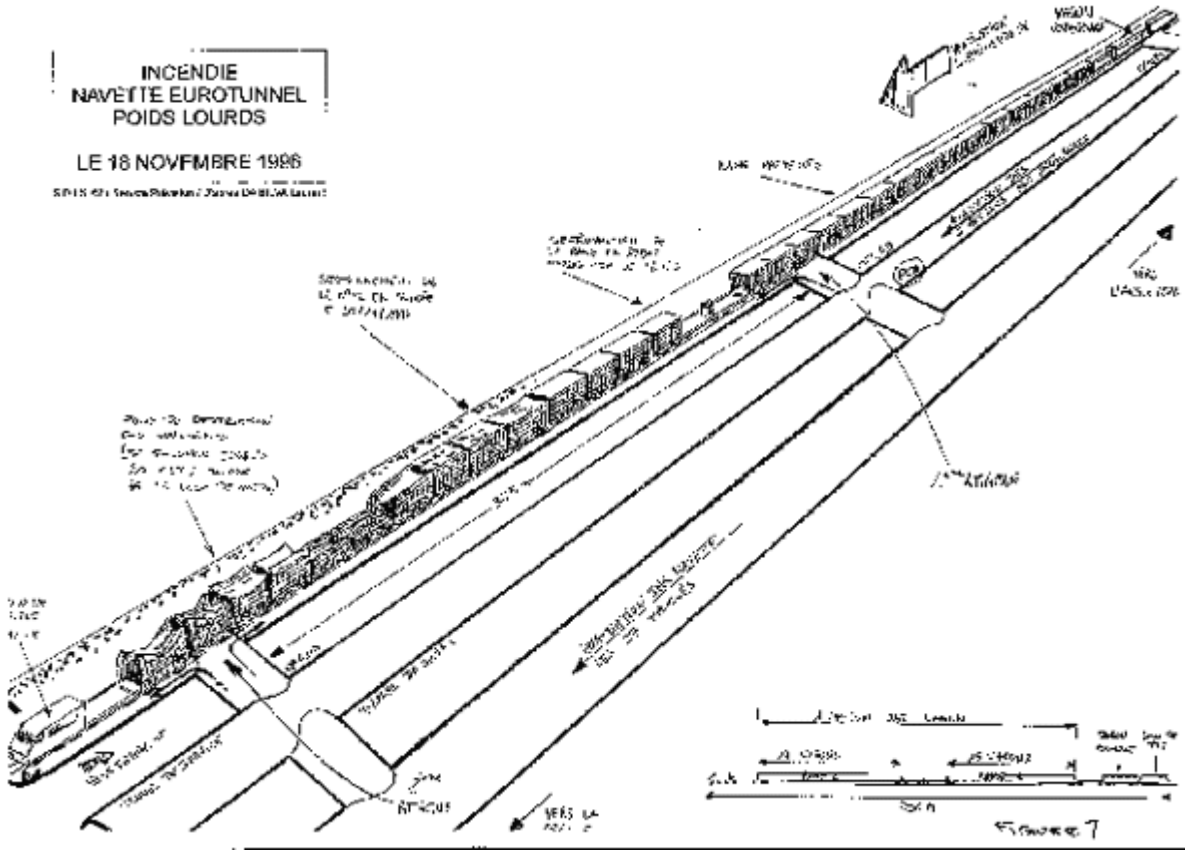

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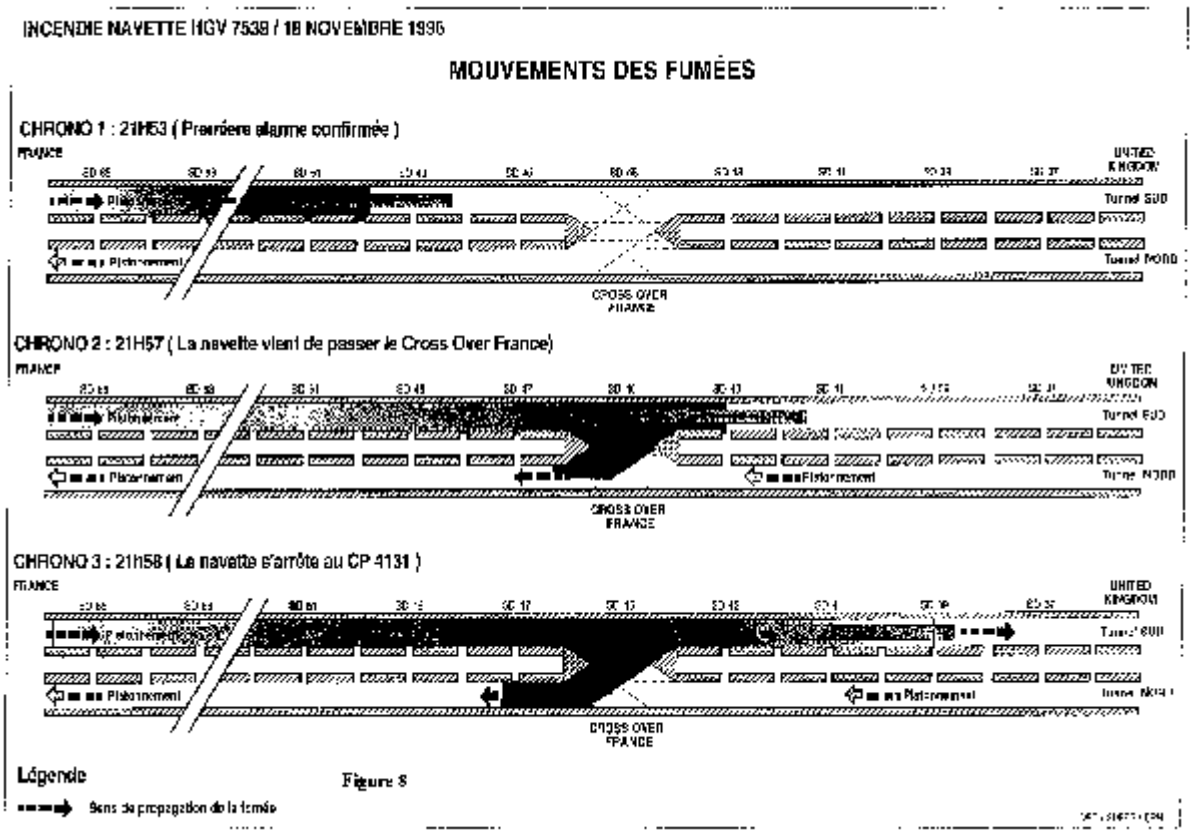

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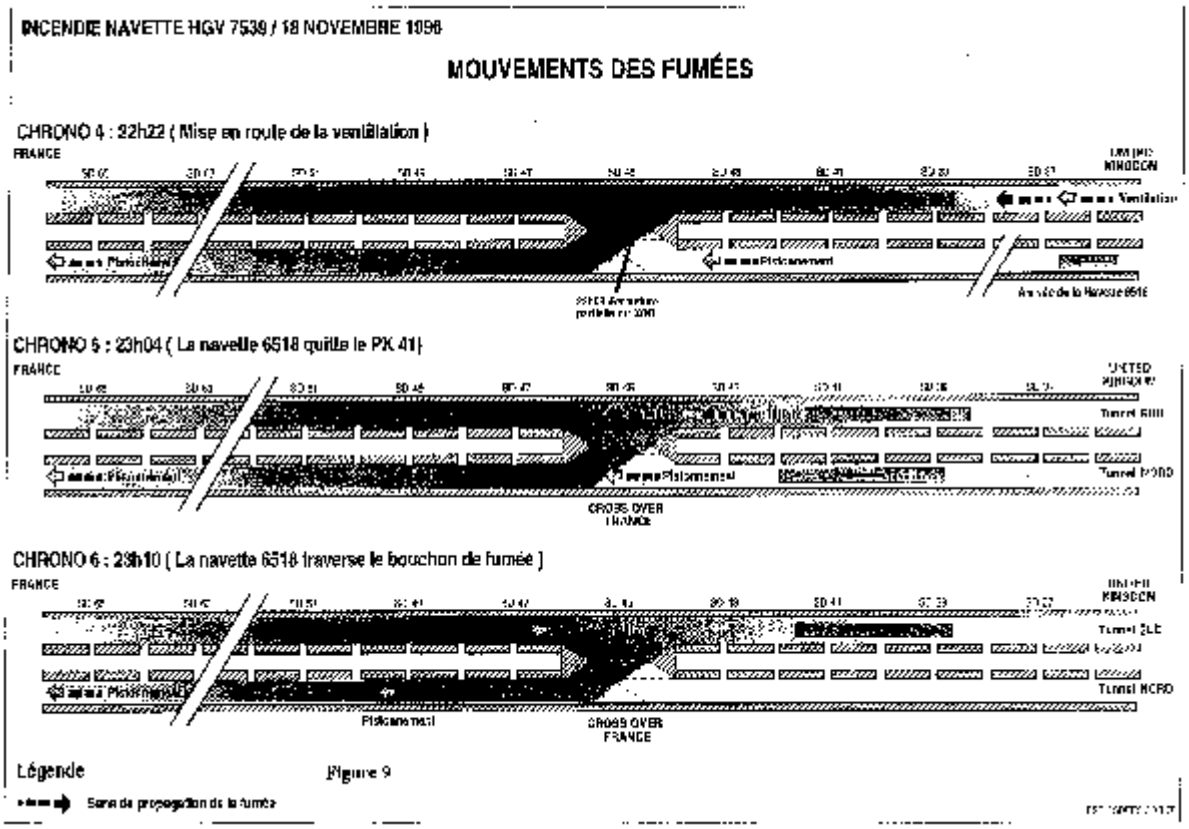

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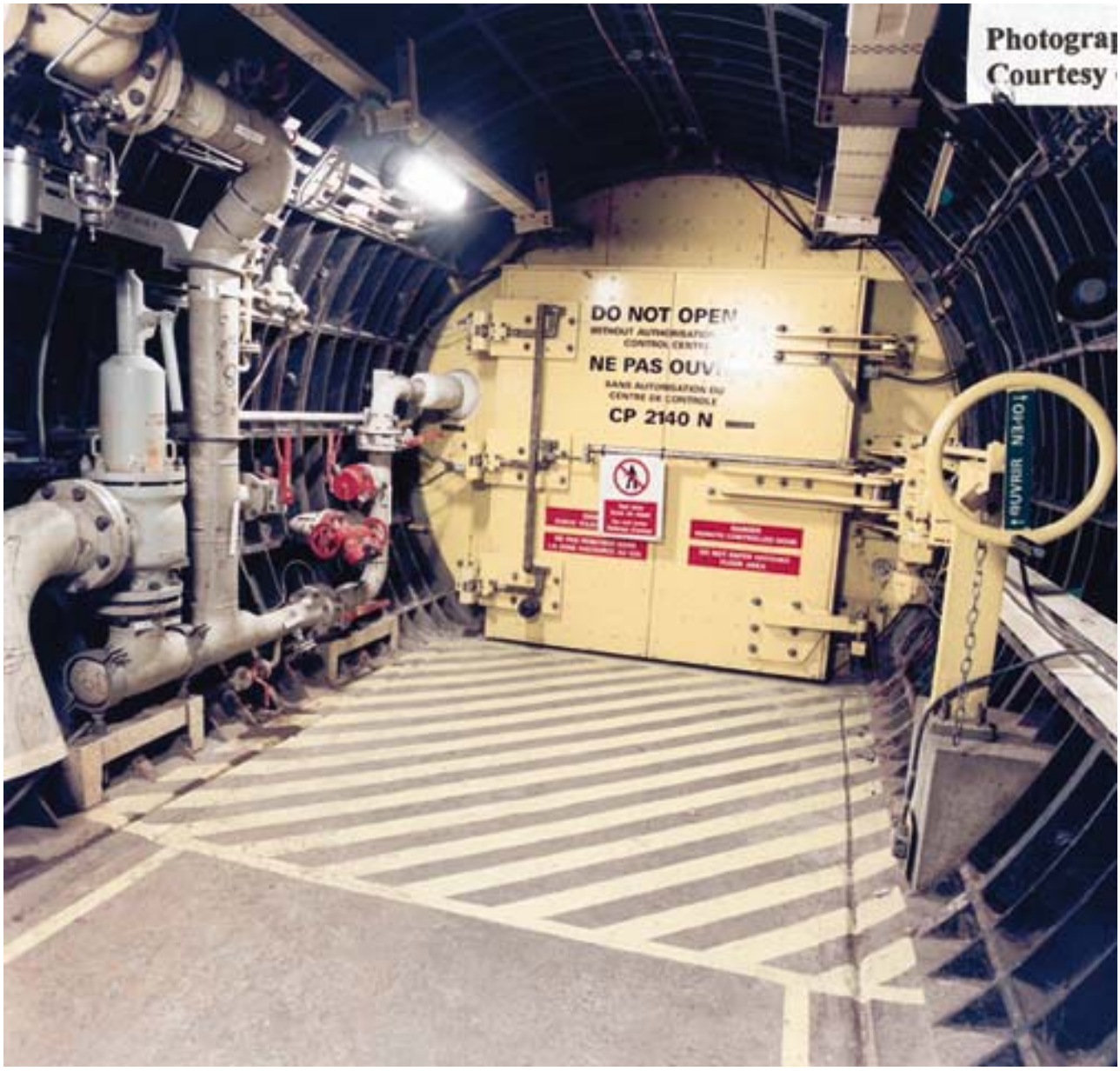

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Glossary of terms

Air Distribution Unit (ADU)	One-way grill, allowing fresh air to pass from the Service Tunnel to the Running Tunnels, located at selected cross-passages.
Airlock	Area at each end of the Service Tunnel separated by two sets of doors; one set of doors only can be open at any time to ensure that the Service Tunnel remains over-pressurised.
Amenity Coach (AMC)	In an HGV shuttle, the wagon located behind the front locomotive for transporting lorry drivers.
BINAT GO	Expression used to activate the Emergency Response Organisations of both nations as required by the BINAT plan.
Bubble Effect	Zone of clear air created by the opening of a cross-passage door; air from the pressurised Service Tunnel is forced into the Running Tunnel, creating a bubble of clean air in the vicinity of the doorway.
Catenary	Overhead electrical power cable providing traction current to the locomotives passing through the Tunnel.
Chef de Train (CDT)	A member of the shuttle train crew responsible for the safety aboard; on an HGV shuttle, the Chef de Train is located in the Amenity Coach; on a Tourist shuttle, he or she is located in the rear locomotive.
CODIS 62	Co-ordinating body for the Rescue Services, based in Arras,France.
Concession Radio (CR)	Radio facility for use by Eurotunnel personnel; it can also be used by the Rescue Services and train drivers if their Track-to Train radio fails.
Controlled Stop	Used to describe when a driver stops his train at a predetermined location near a cross-passage to facilitate a safe evacuation.
Crossover	Allows trains to change from one Running Tunnel to the other; there are two in the tunnel situated 17km from each portal.
Cross-passage	Pedestrian passageway between the Service Tunnel and the Running Tunnels, situated at 375m intervals; each passage has an airtight and fire resistant door.
DDCILEC	French police
Equipment Management System (EMS)	A computer controlling the status of fixed equipment located in the Rail Control Centre.
Emergency Centre	Building located near the portals accommodating FLOR personnel.
Emergency Planning Committee	A sub-committee of the Rescue and Public Safety Working Group. It is composed of personnel from the Emergency Services and includes the Emergency Response Manager of Eurotunnel.
Emergency Sidings	An area surrounded by concrete blast walls or bunds to which trains are directed in event of an emergency.

En-tiroir	A French expression used to describe the disposition of rolling-stock usually used during high wind speeds on the terminals.
Fire Equipment Management Centre (FEMC)	Manned computer terminals located at the Emergency Centres where fire or smoke alarms recorded in the tunnels are recorded.
First Line of Response (FLOR)	Eurotunnel emergency personnel on secondment from Kent Fire Brigade and Pas de Calais fire services.
Incident Co-ordination Centre (ICC)	Operations centre located on the UK terminal activated during major incidents and manned by Eurotunnel and Emergency Services personnel.
Loader Wagon	Wagon at either end of a rake allowing lorries to drive from the platforms to the HGV shuttles.
Normal Ventilation System (NVS)	Used to supply air to the Service Tunnel and, through the ADUs, to the Running Tunnels.
Poste de Commandement Avancé (PCO)	Operations centre located on the French terminal activated during major incidents and manned by Eurotunnel and Emergency Services personnel.
Piston Relief Duct (PRD)	Ducts between the two Running Tunnels which help to reduce air pressure in front of fast moving trains or shuttles.
Rail Control Centre (RCC)	Operations centre responsible for the control and monitoring of rail traffic and the fixed equipment required for rail operation and safety.
Rake	Eurotunnel rolling stock composed of one loading wagon, 12 carrier wagons for tourist shuttles or 14 for HGV shuttles, and an unloading wagon.
Second Line Of Response (SLOR)	Public emergency services called to the tunnel for any major incident, providing a back-up to FLOR.
Service Tunnel Transport System (STTS)	Vehicles used for carrying maintenance or Emergency Services personnel in the Service Tunnel.
Supplementary Ventilation System (SVS)	Used to control movements of air or smoke in the Running Tunnels. Fans are located at Sangatte and Shakespeare Cliff and can blow air in or draw air out.
Tourist Shuttle	Eurotunnel rolling stock carrying cars and small vans, usually composed of two locomotives, one single-deck rake and one double-deck rake.
Track to Train Radio	Allows communications between train drivers and the RCC

Acknowledgements

Building Research Establishment (Fire Research Station)
Centres de Contrôle Routier
Centre dEtude des Tunnels
Chief and Assistant Chief Fire Officers Association
Direction du Contrôle de lImmigration et de la Lutte contre lEmploi des Clandestins
Direction Départementale des Services dIncendie et de Secours 62
Direction de la Sécturité Civile
Direction Départementale de lEquipment des Alpes Maritime
Eurostar plc
Eurotunnel staff:
Rail Control Centre, Emergency Centres, Train Crews, Management,
Fire Equipment Management Centres, Incident Co-ordination Centres,
Terminal Control Centre
Fire Brigades Union
Health & Safety Executive
Her Majestys Inspectorate of Fire Services
Institut National de Recherche et dEtude sur les Transports et leur Sécurité
Kent Ambulance NHS Trust
Kent County Constabulary
Kent Fire Brigade
Members of the Public of Both Nations Who Offered Advice
Le Tribunal de Grande Instance de Boulogne
Monsieur le Directeur de la Protection Civile
Monsieur le Procureur de la République (Boulogne)
Passengers from the Incident Train
Sapeurs-Pompiers du Pas-de-Calais
Service dAide Médicale Urgente
Service Médical dUrgence et de Réanimation de Calais
Sous-Préfecture du Pas-de-Calais
Sussex Ambulance Service