BEATT

Bureau d'Enquêtes sur les Accidents de Transport Terrestre

RAIB

Rail Accident Investigation Branch

TECHNICAL INVESTIGATION REPORT

Concerning the fire on Eurotunnel freight shuttle 7340 on 17 January 2015

April 2016

This document is a translation of the original French report

Bureau d'Enquêtes sur les Accidents de Transport Terrestre

Rail Accident Investigation Branch

Affaire n° BEATT-2015-001

Technical investigation report Concerning the fire on Eurotunnel freight shuttle 7340 on 17 January 2015

(Translation of French original)

BEA-TT – Bureau d'enquêtes sur les accidents de transport terrestre

Tour Pascal B - 92055 La Défense cedex
Tel: +33 1 40 81 21 83

mél: bea-tt@developpement-durable.gouv.fr

www.beat-tt.developpement-durable.gouv.fr

RAIB – Rail Accident Investigation Branch

The Wharf - Stores Road - Derby - DE21 4BA
Tel: +44 1332 253300

Email: enquiries@raib.gov.uk

www.gov.uk/raib

Document notes

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Notice

The technical investigation which is the subject of this report was undertaken by the French and UK organisations in charge of railway accidents investigations, working together in cooperation.

In France, the investigation was performed by the Bureau d'Enquêtes sur les Accidents de Transport Terrestre (BEATT) within the framework laid down within articles L. 1621-1 to 1622-2 and R. 1621-1 to 1621-26 of the Transport Code, which relate in particular to technical investigations following a land transport accident or incident. In the United Kingdom, the investigation was performed by the Rail Accident Investigation Branch (RAIB) within the framework laid down within the Railways and Transport Safety Act 2003 and the Railways (Accident Investigation and Reporting Regulations) 2005.

In accordance with French and UK legislation, the sole purpose of this investigation is to prevent future accidents by determining the circumstances and causes of the event in question and by creating appropriate safety recommendations. It is not intended to determine responsibility.

As a result, the use of this report for any purposes other than accident prevention could lead to its incorrect interpretation.

TABLE OF CONTENTS

Glossary

- BEA-TT : Bureau d'Enquêtes sur les Accidents de Transport Terrestre - Land Transport Accident Investigation Bureau
- BINAT : Bi-national emergency plan
- BINAT GO : Message warning of the impending implementation of the BINAT plan
- CP : Cross-passage
- CTSA : Channel Tunnel Safety Authority
- IGC : Inter-Governmental Commission
- DOS : Directeur des Operations de Secours - Director of Emergency Operations
- EMS : Engineering Management System
- ET : Eurotunnel
- FD : Fire Detection
- FEMC: Fire Equipment Management Centre
- FLOR : First Line of Response
- ISIS : Integrated Staff Information System
- KFRS : Kent Fire and Rescue Service
- NVS : Normal Ventilation System
- PK : Point Kilométrique - Kilometre marker
- PRD : Piston Relief Duct
- RAIB : Rail Accident Investigation Branch
- RCC : Rail Control Centre
- RTM : Rail Traffic Management
- SAFE : Station d'Attaque du FEu - Fire Containment Station
- SDIS : Service Départemental d'Incendie et de Secours - French Fire and Rescue Service
- SEL : Elementary Section of Electric Traction
- SLOR : Second Line of Response
- STTS : Service Tunnel Transport System
- SVS : Supplementary Ventilation System
- TCC : Terminal Control Centre

Summary

At 11:57 hrs on 17 January 2015, Eurotunnel freight shuttle 7340, loaded with 30 vehicles leaves the English terminal of Folkestone. This is an Arbel shuttle for which the wagons of the front rake do not have any roof structure (pagoda).

At 12:00 hrs as it is entering the tunnel, the shuttle experiences an electrical arc with the overhead power line which causes it to stop. At 12:03 hrs, once the power is re-established, it sets off again. At 12:23 hrs, when it is about one kilometre from the fire suppression station (SAFE 4F), a fire is detected on board the shuttle.

Shortly after 12:26 hrs the train is brought to a controlled stop beyond SAFE 4F with its leading locomotive at PK 44.2, so that its amenity coach is located in line with cross passage CP 4418 about 16 km from the exit on the French side.

At 12:37 hrs the evacuation of passengers and train staff towards the service tunnel is complete and has been uneventful.

None of the 42 people present on the train has been injured during the event.

The two lorries situated on wagons 14 and 15 of the front rake have completely burnt.

The running tunnel North has been damaged. In addition to the overhead power line and electric cabling which are beyond repair, the reinforced concrete ceiling has been damaged by the fire. The tunnel lining has become detached exposing the reinforcing bars over a length of approximately sixty metres.

A limited service resumes in the running tunnel South on 18 January at 03:45 hrs.

Normal service in both tunnels re-starts on 23 January at 12:00 hrs.

The fire was caused by an electrical arc between the overhead power line and a CB aerial which had not been detected by the aerial detection system and which was mounted on a lorry which had been loaded onto an Arbel wagon without pagoda.

Causal analysis led to three recommendations being made to address the causal factors. These relate to:

- Processes and systems for detecting aerials and small objects;
- Pagodas or other physical barriers between the vehicles and the overhead power line;
- Fire detection systems;
- RCC procedures in the event of fire and simultaneous power trips.

Examination of the underlying causes led to the drafting of three recommendations to improve Eurotunnel's change management process.

Furthermore, the review of the emergency operations and the firefighting activities has led to a recommendation being made, which is linked to the timescales for despatching firefighters inside the tunnel.

1 - Immediate findings and opening of the investigation.

1.1 - Circumstances of the fire

At 11:57 hrs on 17 January 2015, Eurotunnel freight shuttle 7340, loaded with 30 vehicles leaves the English terminal of Folkestone. This is an Arbel shuttle for which the wagons of the front rake do not have any roof structure (pagoda). The amenity coach, in which the lorry drivers and the chef de train are travelling, is in its normal position, immediately behind the leading locomotive.

At 12:00 hrs as it is entering the tunnel, the shuttle experiences an electrical arc with the overhead power line which causes it to stop. Once the power is re-established, it sets off again at 12:03 hrs and travels in the running tunnel North which is normally allocated to traffic from England to France. Around 12:23 hrs when it is about one kilometre from the fire suppression station (SAFE 4F), a fire is detected on board the shuttle.

Shortly after 12:26 hrs the train is brought to a controlled stop beyond SAFE 4F with its leading locomotive at PK 44.2, so that its amenity coach is located in line with cross passage CP 4418, about 16 km from the exit on the French side.

At 12:37 hrs the evacuation of passengers and train staff towards the service tunnel is complete and has been uneventful.

1.2 - Loss of human life, injuries and damage to equipment

None of the 42 people on the train has been injured during the event.

The two lorries loaded on wagons 14 and 15 of the front rake have completely burnt.

Figure 1: Lorries loaded on wagons 14 (left) and 15 (right)

Vehicles loaded forward of the two burnt out lorries have not sustained any obvious signs of damage other than traces of smoke.

The first three vehicles situated behind the burnt out lorries have sustained significant heat damage but they have not burnt. The subsequent vehicles have not sustained any obvious damage other than traces of smoke.

Figure 2: Van on wagon 13 and first lorry on the rear rake

The two wagons on which the burnt out lorries are located have sustained major damage but their running gear and brakes appear to remain in a good state of repair. The other wagons have not sustained any obvious damage.

The running tunnel North has been damaged. In addition to the overhead power line and electric cabling which are beyond repair, the reinforced concrete ceiling has been damaged by the fire. The tunnel lining has become detached exposing the reinforcing bars over a length of approximately sixty metres.

Figure 3: Damage to the tunnel above the burnt out lorries

1.3 - Traffic measures taken after the fire

At the time of the detection of the fire (12:23 hrs), no train has entered the running tunnel North behind shuttle 7340. The “passenger” shuttle 6350 has left the loading terminal but it is stopped before entering the tunnel. The previous train (“passenger” shuttle 6340) has exited the tunnel on the French side at 12:16 hrs.

Two other trains have entered the running tunnel South. Once the safety measures required by operating instructions have been implemented, these two trains continue on their journey to England.

The traffic is then completely stopped in both directions of travel.

A limited service resumes in the running tunnel South on 18 January at 03:45 hrs.

Normal service in both tunnels re-starts on 23 January at 12:00 hrs.

1.4 - Determining the origin of the fire

From the observations made on site immediately after the event, it appeared, as stated in paragraph 1.2, that only the two lorries located on wagons 14 and 15 at the front of the train had completely burnt out.

During the investigations made by Eurotunnel and the French judicial authorities shortly after the incident, the examination of the CCTV footage at the tunnel portal on the British side showed that at 12:00:08 hrs an electrical arcing occured between the overhead power line and the lorry loaded on wagon 15 of the front rake, just before the wagon entered the tunnel.

Subsequently the camera situated in the tunnel at CP 1114 showed that at 12:04:10 hrs that the cab of this lorry appeared to be full of smoke.

Figure 4: View of lorry B139CAL at CP 1114

It therefore quickly became obvious that the fire originated from the lorry, registration number B139CAL which was situated on the 15th and penultimate wagon of the front rake, and that the fire was caused by an electrical arc between the overhead power line and a part of this lorry.

This lorry will be referred to as the incident lorry in the rest of this report.

1.5 - Opening of the investigation

The decision to carry out a technical investigation was taken on the French side by the Director of the Bureau d'Enquêtes sur les Accidents de Transport Terrestre (BEA-TT) on 20 January 2015 (see Annex 1).

On the British side, the decision to participate in a joint investigation with the BEA-TT was taken by Chief Inspector of the Rail Accident Investigation Branch on 26 January 2015.

This investigation is one that is mandated under EC directive 2004-49, as the amount of damage appeared to be higher than two million euros at the time the investigation was started.

2 - Organisation of the investigation

2.1 - Cooperation between BEA-TT and RAIB

Both investigation organisations, the French BEA-TT and the British RAIB started an investigation in their own country.

They collaborated in producing a joint investigation report in accordance with the conditions specified in the agreement previously produced).

In application of this agreement:

- the investigation and the report have been completed jointly;
- the organisations jointly decided on the scope of the investigation and the methods to be used, how duties would be shared out and how the work would be organised. They consulted each other on reports and communications produced;
- as the shuttle had stopped in French territory, the BEA-TT was responsible for leading the investigation, summarising the information produced by the two investigations and compiling the joint report;
- during the investigation, the two organisations regularly exchanged information obtained within the limits of national regulations.

2.2 - Investigations carried out

Each organisation carried out its investigations in the areas agreed, with or without the assistance of an investigator from the other organisation, depending on requirements and availability.

A non-permanent technical investigator was appointed and commissioned by the French ministry of transport in an order dated 18 February 2015 to assist the BEA-TT throughout the investigation.

The investigators worked mainly on the basis of:

- interview reports from the judicial authorities;
- interviews they conducted themselves;
- working documents used by staff on the day of the fire;
- meetings with managers and other Eurotunnel members involved;
- regulations and technical documents applicable on the day of the fire.

They have exchanged information that they obtained as well as studies that they carried out.

2.3 - Preparation of the report

In accordance with the cooperation agreement, the BEA-TT prepared compiled the entire report using its own template. The contents were drawn up during exchanges and joint meetings, and then validated in its final form by the two investigating organisations.

3 - Background to the accident

3.1 - General context

3.1.1 - *Eurotunnel concession*

Eurotunnel is the concessionaire responsible for the operations of the Channel Tunnel installation and associated facilities.

The concession includes the following installations:

- the two rail tunnels and the service tunnel,
- the surface and underground installations,
- the Folkestone and Coquelles terminals,
- the connections to the French and British rail networks.

Eurotunnel has been operating and maintaining the Channel Tunnel installations since its opening in 1994. Eurotunnel is therefore:

- the infrastructure manager within the meaning of European Directive 91-440;
- a railway operator in respect of its own trains (freight and passenger shuttles).

3.1.2 - *The Folkestone – Coquelles section of the line*

The length of the railway line is 63 km.

The tunnel itself is 50.6 km long of which 37 km is under the Channel. Figure 5 shows the layout of the Channel tunnel and its main technical facilities.

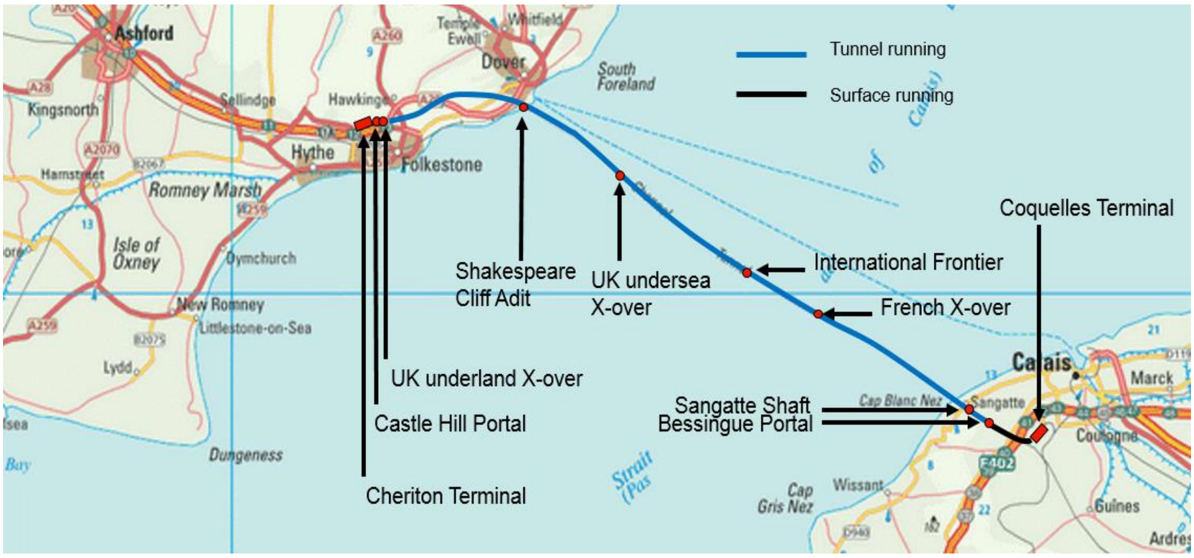

Figure 5: Layout of the Channel Tunnel

The layout comprises two identical tracks. In normal operations, the trains run along the left track but the equipment allows for running in the opposite direction at a speed limited to 100 km/h.

The rail network is electrified with an alternating current of 25 kV fed to the trains through an overhead power line system. The trains are fitted with an in-cab signalling system (TVM – Transmission Voie Machine).

Rail traffic is managed by rail control centres (RCC) located in each terminal. Only one of the two operates at a given time and manages all the facilities, in real time.

3.1.3 - The Channel Tunnel

The layout comprises two rail tunnels:

- The running tunnel North where the trains normally travel in the direction Great Britain – France;
- The running tunnel South where the trains normally travel in the direction France – Great Britain.

Each rail tunnel is 7.6 m in diameter (see Figure 6) and comprises a single track.

A third tunnel located between the two rail tunnels, except at the crossovers, acts as the service tunnel. It measures 4.80 m in diameter. It provides access to underground technical equipment, enables light maintenance of the rail tunnels and allows an emergency team to patrol and provide assistance in the event of an incident or accident involving the railway. Specialist tyred vehicles, referred to as the Service Tunnel Transport System (STTS) travel in this tunnel, as do service cars (Agila).

Approximately every 375 metres, cross-passages (CP) connect the service tunnel to the rail tunnels. In normal conditions, these cross-passages are isolated from the rail tunnels by sealed, fire-resistant doors. These doors are normally controlled remotely from the rail control centre (RCC). They can also be operated in situ by two electrical or manual control devices.

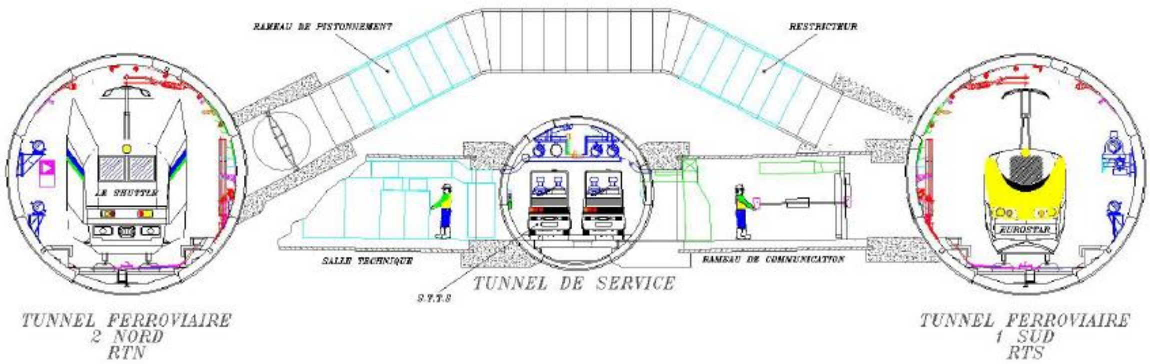

Figure 6: Standard section of the layout

Each tunnel is divided into 3 intervals. There are three crossovers enabling the trains to cross from one tunnel to the other in the event of an incident which renders an interval unavailable.

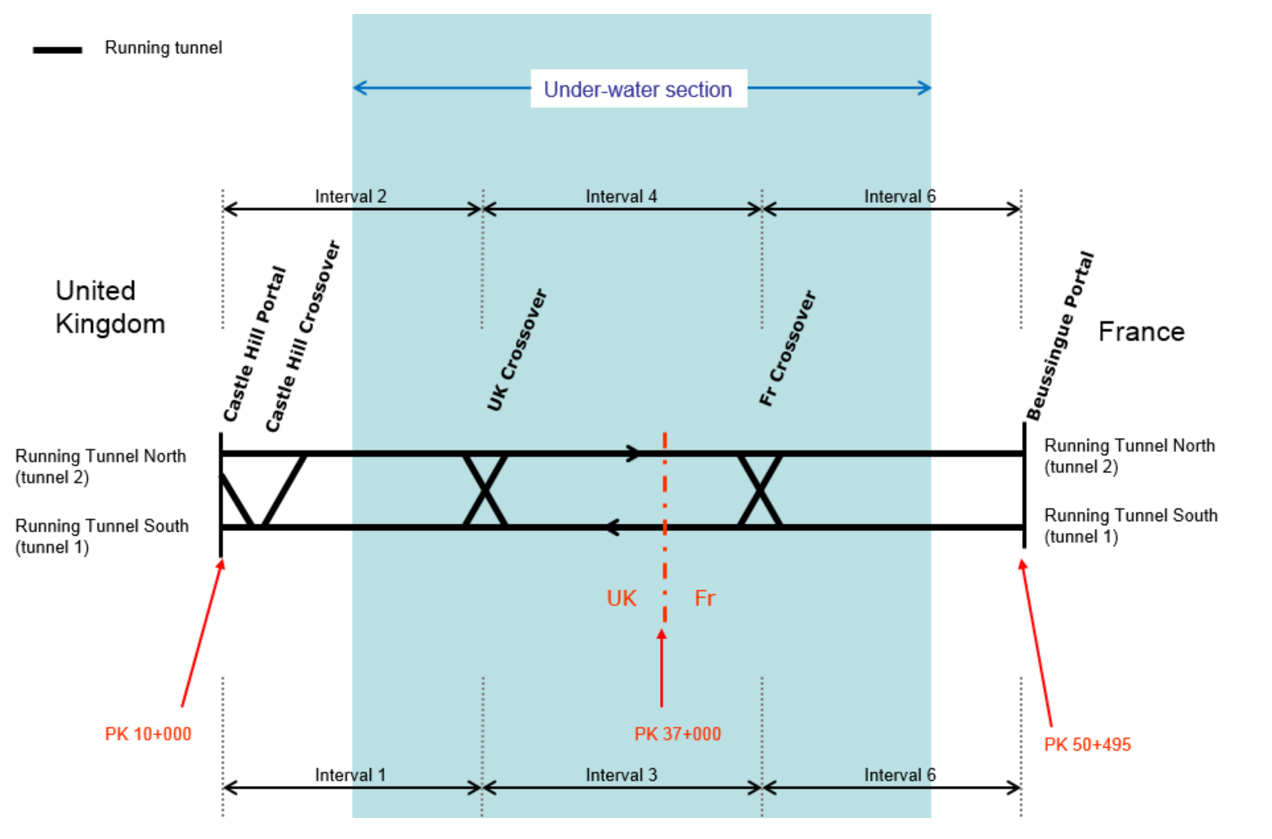

Figure 7: Diagram of the tracks in the tunnel

3.1.4 - Electrical traction equipment

3.1.4.1 - The electric traction installations

The overhead power lines are fed with a nominal alternating current of 25kV.

The overhead power line comprises six sectors of which four cover the two North and South rail tunnels (two per tunnel). The mid-point of both sectors in each tunnel is at PK 35.3.

Each sector is divided into elementary sections approximately 1,200 metres long.

When the tunnel was opened, in 1994, the power supply to the two sectors on the UK

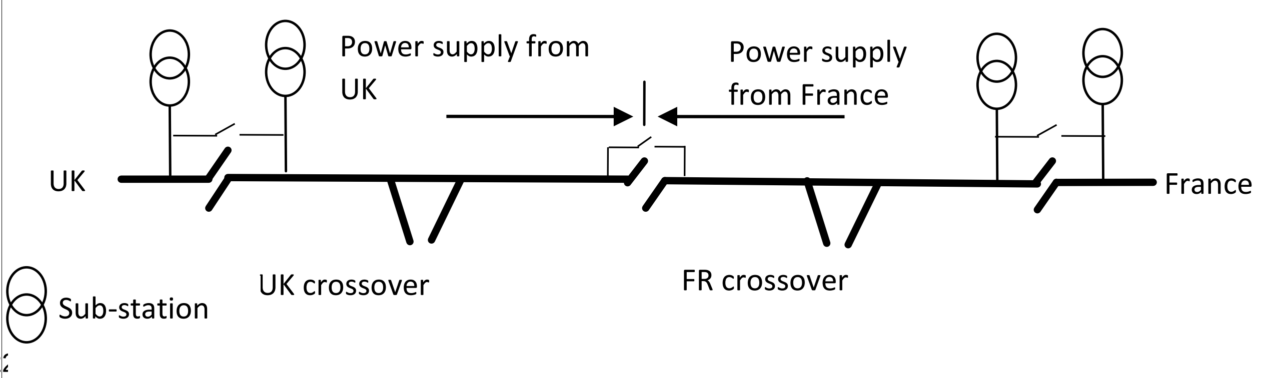

Figure 8: Power supply in the North tunnel in symmetrical mode

side was provided from England whilst that for the two sectors on the French side was provided from France. This method of operation is known as “symmetrical mode”.

There is another method of operation where one of the tunnels, the two tunnels or even the whole installation can be powered by either end. It is called the “extended mode”.

Since 2007, the extended mode powered by France has been the normal method of operation.

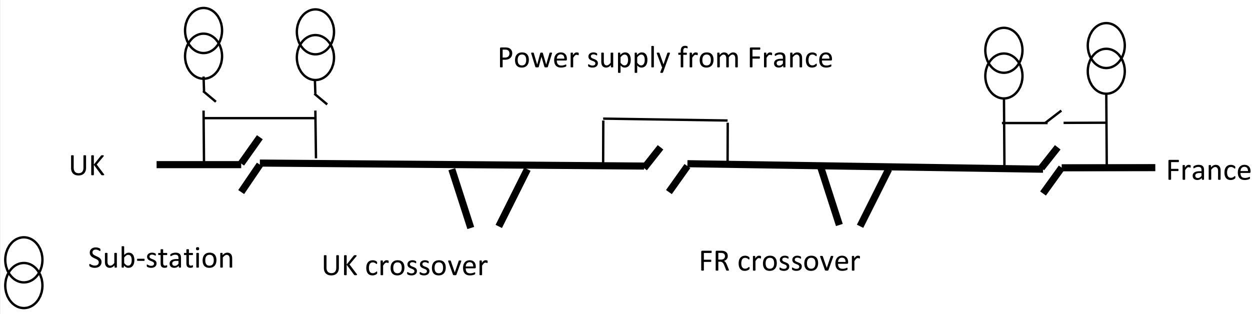

Figure 9: Power supply to running tunnel North and UK terminal in extended mode.

3.1.4.2 - Management of electrical traction equipment

The electrical traction equipment is controlled by the EMS controller at the rail control centre (see paragraph 3.1.7).

In the event of an overhead power line incident in the tunnel, when operating in extended mode, the EMS controller should:

- supply power to the UK terminal from the British substation;
- cut off the power to a minimum of 3 elementary sections (SEL) around the area in which the incident has occurred, the section of the incident and either side of this;
- restore the power supply for sections required for other trains which have been stopped in the tunnel.

3.1.5 - Ventilation equipment

Ventilation of the tunnel plays a fundamental role both during normal operations and in the event of a disruption.

In the latter case, not only is it able to provide fresh air for people in the tunnel, but it is used to control the removal of smoke and thus facilitate the evacuation of people present and fire-fighting operations.

Ventilation equipment is operated by the EMS controller.

3.1.5.1 - Ventilation principles

Rail tunnels

The rail tunnels are at ambient pressure and are connected by piston relief ducts to reduce pressure in front of trains.

In the event of smoke in one of the running tunnels, it is essential that this does not spread to the other rail tunnel or the service tunnel. For this purpose:

- the piston relief ducts can be blocked by dampers;
- the cross passages are isolated from the rail tunnels by doors which are normally closed;
- rail tunnels are isolated from each other at the crossovers by sliding doors, which are open only when a train passes from one tunnel to the other.

The service tunnel

The service tunnel is maintained at a higher pressure than the rail tunnels. It is sealed at both ends by air locks.

This higher pressure ensures that the service tunnel is free from smoke in the event of a fire in one of the rail tunnels and can be considered as a safe refuge. It also makes it possible to create an air ‘bubble’ 4 to 5 m in length at the rail tunnel end of a cross-passage (CP) when the door to the latter is open.

In the event of a fire in a tunnel requiring evacuation of a freight shuttle, the evacuation door of the amenity coach of a freight shuttle should normally stop in line this air bubble, allowing the occupants of this coach to evacuate safely into the service tunnel.

To guarantee that this high pressure is maintained, specific rules for opening cross-passage doors are applied. According to the procedures in force at the time of this incident, two and only two doors giving access to one of the rail tunnels must be open at the same time[1] and no doors into the other tunnel are allowed to open.

3.1.5.2 - Ventilation installations

Two ventilation systems can be used in the Channel Tunnel.

The normal ventilation system (NVS)

The role of this system is to maintain the service tunnel at high pressure and to ensure permanent ventilation of all the tunnels. It is operational at all times and the fans are always set in the ’supply’ position.

Air is blown in the service tunnel from two units located at Shakespeare Cliff in the UK and Sangatte in France. Air flow in the service tunnel is fed to the rail tunnels by 39 pairs of air distribution units (ADU). The air introduced into the rail tunnels is then driven towards the portals by natural air movements and by the movements of trains.

1 Opening just one door would generate too fast an air flow through that door while opening more than two doors would risk reducing the high pressure in the service tunnel, or even reversing the direction of pressure so that smoke could get into the service tunnel. This rule has evolved, you can now open 3 cross passage doors.

Supplementary ventilation system (SVS)

The supplementary ventilation system (SVS) is only used in the event of an incident where smoke is present or to provide fresh air to trains that are stopped for a long period of time.

The air is blown into or extracted from the running tunnel concerned from the two units at Shakespeare Cliff and Sangatte in order to create an air flow used to push the smoke, pollution or heat in one direction thereby protecting the passengers and train staff and enabling the rescue services to carry out their tasks as effectively as possible.

The two units are capable of providing air to one of the rail tunnels, or to them both. The SVS is designed to achieve this even if one or more of the dampers of the piston relief ducts, or the underwater crossover doors, remain open.

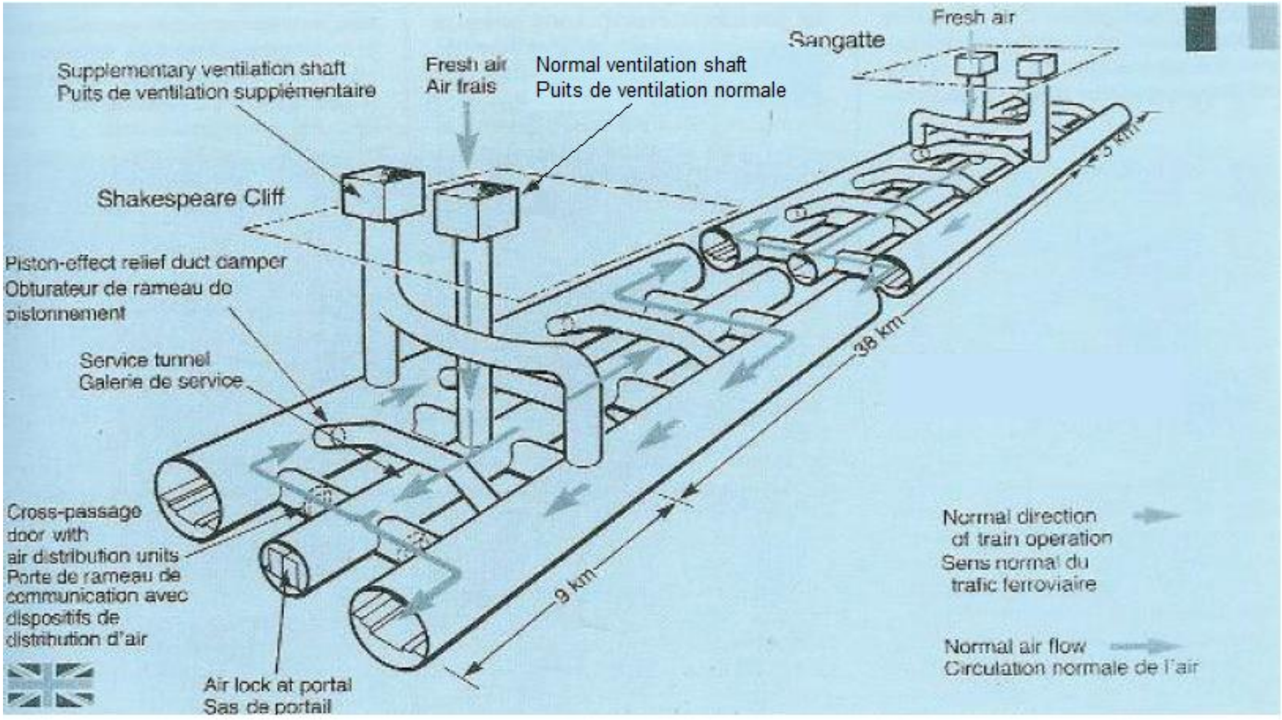

Figure 10: Ventilation equipment

Fans

A ventilation plant is set up near each end of the tunnel, at Shakespeare Cliff in the United Kingdom and at Sangatte in France.

In each plant, two fans feed air to the NVS and two fans feed the SVS.

All fans have adjustable and reversible blades.

The NVS fans work normally in feeding mode, with one fan operational at each end.

For the SVS, one end operates in feeding mode and the other in extraction. One fan is normally used at each end but two fans at one end can work simultaneously if the need should arise.

3.1.6 - Communication equipment

The global communication system comprises three radio networks, two telephone networks and a public address system.

Track to train radio

The track-to-train radio system provides voice and data communications between the rail control centre (RCC) and the trains in the rail tunnels and at the terminals.

Concession radio

The concession radio allows verbal communications at any part of the concession by Eurotunnel staff and the staff of various organisations working on the concession, using portable equipment.

Tactical radio

The tactical radio is a UHF network which can be used in the service tunnel and covers an area wide enough for combined local operations of the emergency services of one or both countries. Members of the emergency services (fire brigade, ambulance and police) are equipped with mobile radios connected to this network.

Operation of the tactical radio requires the presence of one or two STTS communication vehicles, acting as relays to connect with Eurotunnel’s own telephone network.

Operational and emergency telephone system

The operations and emergency telephone system allows automatic connection to the active rail control centre (RCC), simply by picking up the handset of one of the telephones installed in the tunnel. It is not necessary to dial a number and all calls are logged in writing and recorded. These telephones are installed at each cross-passage, as well as other places.

Administration telephone system

The administration telephone system covers the whole concession area including the tunnels where the telephones are installed, amongst other places, in tunnel technical rooms. It is also possible to connect using telephone points at each cross-passage. It is linked to the French and British public networks.

Public address system

A public address system covers the entire concession with the exception of the rail tunnels. It can be used to broadcast to all areas, or to selected areas, in particular in the service tunnel and the cross-passages.

3.1.7 - Rail control centre

Real time rail traffic management is undertaken from one of the two rail control centres (RCC), one situated in Great Britain in Folkestone and the other in France at Coquelles.

These two centres do not operate at the same time. The operational centre may change with each shift; it is defined on a rotation basis.

Each RCC consists of six workstations which are arranged in a similar way with screens which provide visual display of the information required, and terminals which enable the initiation of procedures. Warning signals are also shown on these screens. Certain procedures are automatically initiated as soon as the controller confirms that the situation justifies them.

Figure 11: Rail controller's workstation

The supervisor

The supervisor is responsible for monitoring the progress of operations and giving instructions to the other controllers in the event of any disruption. In the event of a fire in the tunnel, he must confirm each instruction to be followed with each controller in order to ensure that they are carried out in the order stipulated in the procedures.

The rail traffic management controller

The RTM controller is responsible for the management of rail traffic across the entire concession during normal operations and in degraded conditions.

In addition to Eurotunnel's own traffic (passenger shuttles, freight shuttles and works trains), he also manages passenger trains and conventional freight trains using the Channel Tunnel system.

The equipment available to him includes:

- monitors showing the status of the equipment, track occupancy status, state of the power supply, traffic graph, etc

- control and signalling equipment (TVM);
- track-to-train radio equipment allowing him to contact the trains;
- computer terminals allowing him to activate procedures, in particular emergency procedures.

In the event of a fire on a train in one of the tunnels, the RTM controller is responsible for authorising the train in question to stop and for managing the movement of the other trains so that the incident can be dealt with.

The engineering management system controller

The EMS controller manages fixed systems associated with tunnel operations (power supply, ventilation, lighting, drainage, pumping, cooling, etc.), in normal circumstances and in degraded conditions. In particular, he is responsible for implementing emergency measures relating to the protection of individuals and equipment in the event of degraded conditions or in an emergency.

The equipment available to him includes:

- monitors showing the status of the equipment under his supervision and rail traffic in the tunnel;
- control devices for this equipment;
- computer terminals allowing him to activate procedures in particular emergency procedures.

The fire detection controller

The FD controller manages the fire detection system in the rail tunnels and the service tunnel. He is also responsible for managing vehicle traffic in the service tunnel and for calling the emergency services in the event of an emergency.

In the event of an alarm in one of the systems for which he is responsible, he immediately advises the other controllers verbally. In an emergency, he is responsible for the correct deployment of emergency services to the areas identified.

The information system controller

The ISIS controller is responsible for supervising the operation of the integrated staff information system (ISIS). This allows him to process and supply information relating to the quality of the rail service in real time to the staff concerned. He is responsible for providing information relating to dangerous substances to other RCC controllers and to the emergency services if necessary.

Train crew management controller

This controller is responsible for real-time management of Eurotunnel train crews (passenger and freight shuttles).

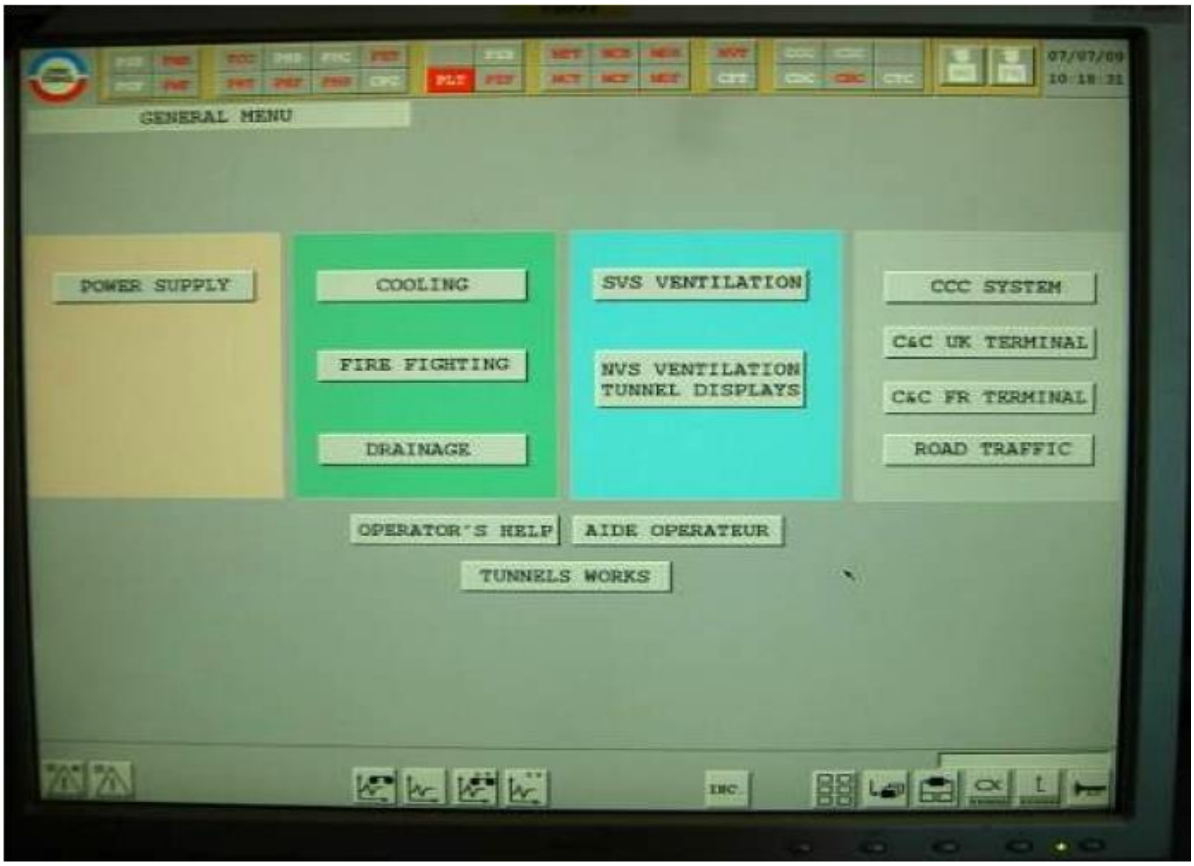

Figure 12: An operator screen EMS

3.1.8 - Fire safety

3.1.8.1 - Fire safety devices

Smoke and flame detectors

Static smoke and flame detectors are fitted approximately every 1,500 m in each rail tunnel. These detectors record the presence of ionised particles, the reduction in the transparency of the air (due to the presence of smoke) and carbon monoxide levels. As soon as a value reaches a threshold which is considered to be outside the normal range, the RCC is alerted.

Smoke detectors are installed in the leading and rear loading wagons of freight shuttle trains. In the event of detection, an alarm is activated on the control board at the chef de train's workstation in the amenity coach.

Fire hydrant system

This network provides fire hydrants that are situated 125 metres on either side of each cross-passage. These fire hydrants are each fitted with French and British type connectors.

Station d'Attaque du FEu (SAFE)

Figure 13: SAFE station in action

SAFE stations are areas approximately 800 metres long situated in the rail tunnels (two per track). They are equipped with a fire containment system which emits a fine water mist to the part of the train where a fire has been detected.

They are announced by a warning board "SAFE at 1000m"

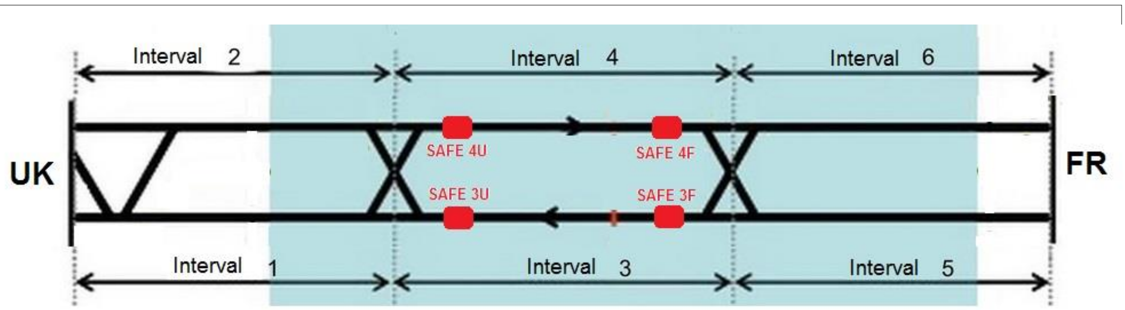

Figure 14: Position of the SAFE stations

3.1.8.2 - Procedures in the event of detecting a fire on board a freight shuttle

There are two levels of fire alarm:

- level 1 relates to an alarm from a single, fixed detection station;

- level 2 is activated if several alarms go off simultaneously in a single detection station or if a level 1 alarm is confirmed by an adjacent detection station within 3mins or where someone detects the presence of flames or smoke.

Where an alarm is raised by on-board detectors on a freight shuttle, this alarm is communicated by the chef de train to the driver who informs the RCC. It is treated as a level 1 alarm.

Based on the information provided by the FD controller, the supervisor determines the level of alarm and relays this decision to all the controllers simultaneously. He decides on which strategy to apply depending on the position of the train within the tunnel and the availability of the SAFE stations.

The controllers, the driver and the chef de train apply the procedures defined in their relevant job instructions.

3.1.8.3 - Management principles of freight shuttles in the event of fire

In normal circumstances, in the event of a level 2 fire alarm for a freight shuttle, the train in question must continue until it reaches the next SAFE station it comes across. If the warning board for the second SAFE station has been passed, the shuttle must seek to exit the tunnel towards the emergency siding of the destination terminal according to the “Moving Train” strategy[2].

If the train with the alarm is running with the amenity coach at the rear, the driver must bring the train to a controlled stop as soon as it is practicable to do so, applying the “stopping train” strategy[3].

If one or several SAFE stations are not available, the procedure ORCC 4060 “Application instructions - Supervisor” specifies the strategy to use according to the position of the train.

3.1.9 - Freight shuttles

3.1.9.1 - Train consist

Each Eurotunnel freight shuttle is typically made up of the following traction and rolling stock:

Two locomotives (one at either end of the shuttle providing the tractive power);

One amenity coach (for the lorry drivers to travel in during the crossing);

Two rakes of carrier wagons (to carry the lorries);

Three loader wagons (to enable the lorries to drive onto and off the shuttle);

A typical consist is shown on figure 15.

[2] Moving Train: set of procedures aimed at not stopping the train within the tunnel.
[3] Stopping Train: set of procedures aiming to make a controlled stop as soon as possible.

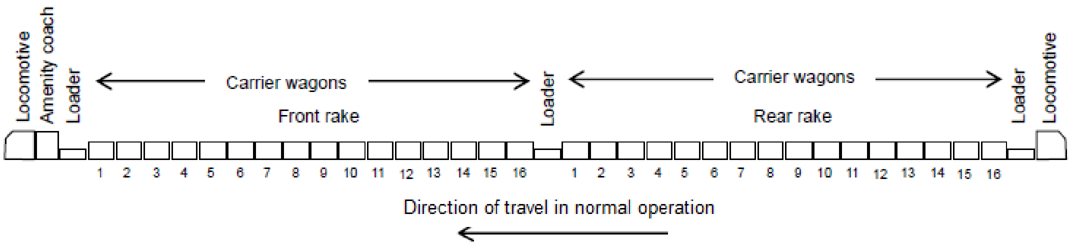

Figure 15: Composition of a freight shuttle

3.1.9.2 - Rolling stock

Carrier wagons

Unlike the passenger shuttles, the carrier wagons of the freight shuttles do not have solid sides and barriers creating a compartment on each wagon during transit.

Two types of carrier wagons are currently in use on Eurotunnel freight shuttles. A freight shuttle consists of a single type of carrier wagon (Breda or Arbel).

The first generation wagons, manufactured by Breda (Italy), comprise a solid roof and lattice bodysides which form an integral part of the vehicle structure. The roof and bodysides contribute to the structural integrity of the wagon.

Figure 16: Breda wagons

The second generation wagons, manufactured by Arbel-Fauvet-Rail (France), were also originally supplied with a roof and bodyside construction formed of four sets of individual sections, each known as ‘a pagoda’. These did not contribute to the structural integrity of the wagon. The four pagodas covered the entire wagon length and provided a physical barrier between the lorries and the overhead power line.

Figure 17: Arbel wagons with four pagodas (historical)

Over the years, the design of the Arbel wagons has changed as the pagodas have been progressively removed.

Figure 18: Arbel wagons with front pagoda only

Figure 19: Arbel wagons without pagoda

At the time of the incident all the original pagodas had been removed from the Arbel wagons. However, the wagons of the rear rakes were fitted with a single pagoda of an alternative design covering the front section only.

Loader wagons

Loader wagons are flat wagons which are permanently incorporated into the rake of each shuttle. They are provided to allow lorries to drive onto and off the shuttle. They are fitted with side plates which are lowered during loading and unloading operations, bridging the gap between the edge of the platforms and the wagon.

There are three loader wagons on each shuttle. They are located at the front (behind the amenity coach), in the middle (between the two halves of the shuttle) and at the back of the train (ahead of the trailing locomotive).

The two end loader wagons are equipped with a smoke detection device. Visual and audible alarms are sent to the chef de train if smoke is detected.

Amenity coach

The amenity coach is a passenger coach which conveys the lorry drivers during the journey through the Channel Tunnel. The chef de train also travels in the amenity coach where he has a dedicated workstation.

In normal operation, the amenity coach is coupled between the leading locomotive and the front loader wagon[4]. There are four side access doors: two on each side at the ends of the coach.

The outside doors are fitted with seals and ventilation air inlets are fitted with dampers that close automatically if a fire alarm is activated by the driver or by order of the chef de train if they have not closed automatically.

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4 In exceptional cases, with “en tiroir” operation, it is at the rear, just in front of the trailing locomotive[5] The train driver needs to know if the train comprises of Arbel wagons to check on arrival at a platform that the power to the overhead line has been isolated (see section 4.6.3.4).

If smoke is detected by one of the detectors fitted on the loader wagons, an audible alarm and a visible alarm alert the chef de train. He is then able to advise the driver of a fire alarm simply by pressing a button on the workstation. He is also able to speak directly with the driver using a telephone or radio.

The amenity coach is equipped with individual breathing masks, in sufficient number for all passengers and crew.

Locomotives

The locomotives used on the freight shuttle are class 9 locomotives built by the consortium of ABB and Brush Traction exclusively for operation on Eurotunnel's infrastructure.

All locomotives are equipped with three bogies, each with two motorised axles and are capable of a top speed of 160 km/h.

The locomotives are fitted with the TVM430 in-cab signalling equipment commonly used on the high speed lines in France and on the UK High Speed 1 route.

3.1.10 - Loading of freight vehicles

The process used by Eurotunnel to manage the transit of lorries on its Folkestone terminal is linear, with the lorries moving through the various stages of the process one after the other.

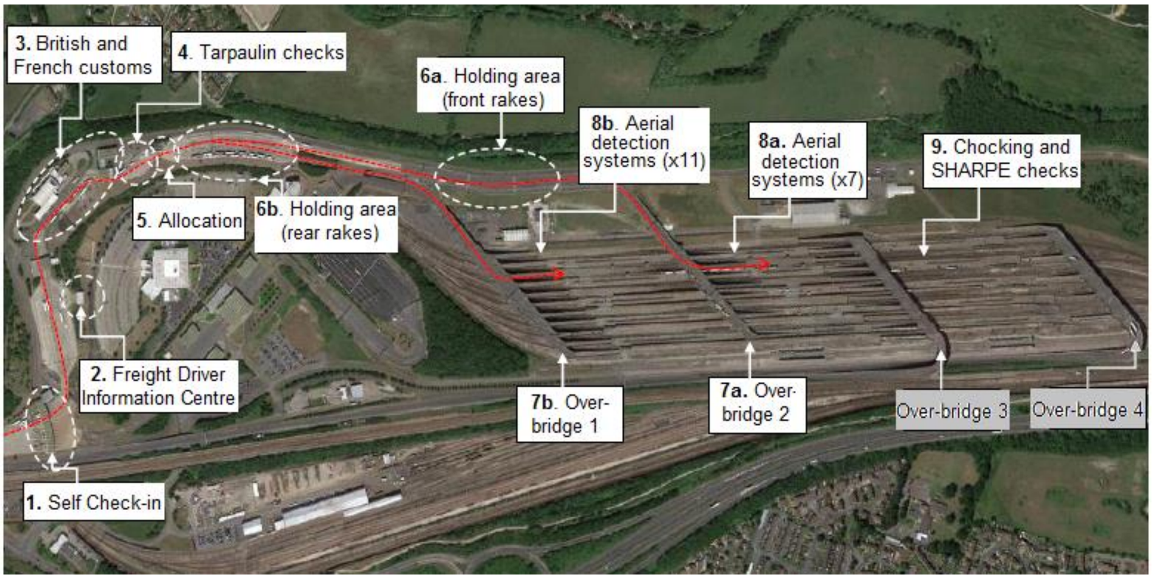

Figure 20: Boarding process for lorries at Folkestone

A lorry booked with Eurotunnel to cross the Channel on the freight shuttle from the UK to France enters the Folkestone terminal through the unmanned self-check-in booths.

As it approaches the self-check-in booths, detectors built into the access road automatically measure the lorry to confirm that it is less than 19,400 mm long and less than 4,250 mm high.

Figure 21: Over-length and over-height detection

If an alarm is raised by the detection systems, the lorry will not be allowed to pass the self-check-in booths until it has been attended to by an agent. In the case of a lorry detected to be over-height, the lorry will be directed towards the Freight Driver Information Centre where an agent will physically measure the height of the lorry using a stick set at 4,250 mm.

Figure 22: Physical height measurement at the Freight Driver Information Centre

Most lorries have adjustable suspension systems and if the lorry is confirmed to be over-height during the manual measurement, the lorry driver will be asked to lower his suspension until the overall lorry height is reduced to an acceptable level.

The lorry will then be allowed to proceed to the security and passport checks by the British and French customs. Sampled inspections of goods transported are carried out by customs at this location. The purpose of these inspections is to check that the consignment is as declared and to confirm its nature. It is not to check safety aspects such as loose tarpaulins or over height aerials.

Once the security checks are complete, the lorry will go through to the tarpaulins check area. This is manned by a team of agents on the ground and in a CCTV control room. At the time of the fire in January 2015, their role was to identify tarpaulin defects on curtain-sided lorries. This is purely a visual inspection with two agents on the ground, one on either side of the lorry, and one agent in a booth monitoring a screen showing the state of the roof of the lorry.

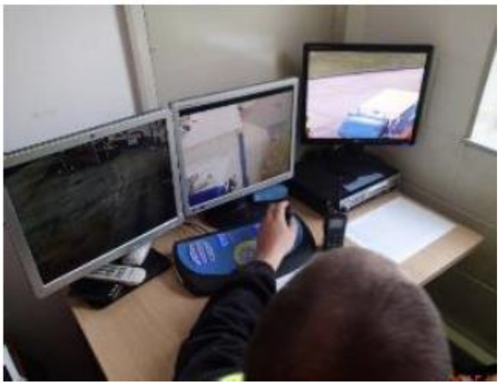

Figure 23: Tarpaulin checks

If the inspection reveals concerns with the tarpaulins, the agents will contact the allocation agents to arrange for this lorry to be allocated to a mission made of wagons with roof protection.

The allocation is the next step in the loading process. It is conducted by agents in a booth who will manually allocate each lorry to a specific mission based on the advice from the agents in the tarpaulin check area and based on their own set of criteria. For example, one of these criteria is that lorries that are carrying road vehicles must be allocated to a Breda wagon (because of the additional protection afforded by the roof). Another example relates to the fire load rating of the lorries; only lorries with a low fire load are allowed on the first three wagons immediately behind the amenity coach.

The allocation decision is communicated to the lorry drivers by showing them a letter indicating the lane where they are to drive their lorry to in the next holding area.

Lorries are kept in this holding area until the shuttle is ready for boarding. They will then drive to the designated platform using one of two over-bridges which pass over the railway lines. Access to the platform is through a ramp which leads the lorries from the over-bridge to the allocated platform.

Depending on whether they have been allocated to a rear or front rake, the lorries use either over-bridge 1 or 2, respectively.

An agent meets the lorries at the bottom of the ramp. This agent carries out a further visual inspection of the lorries immediately before they board the shuttle to confirm that they are in a fit state to travel. As well as inspecting the vehicle for obvious problems (eg: missing petrol cap, loose tarpaulins), this agent also responds to any alarms raised by the aerial detection system fitted at the bottom of the ramp.

The aerial detection system automatically detects aerials that are higher than 4,250 mm above road level. If an aerial is detected, the agent will ensure that the lorry driver lowers the aerial to an acceptable height.

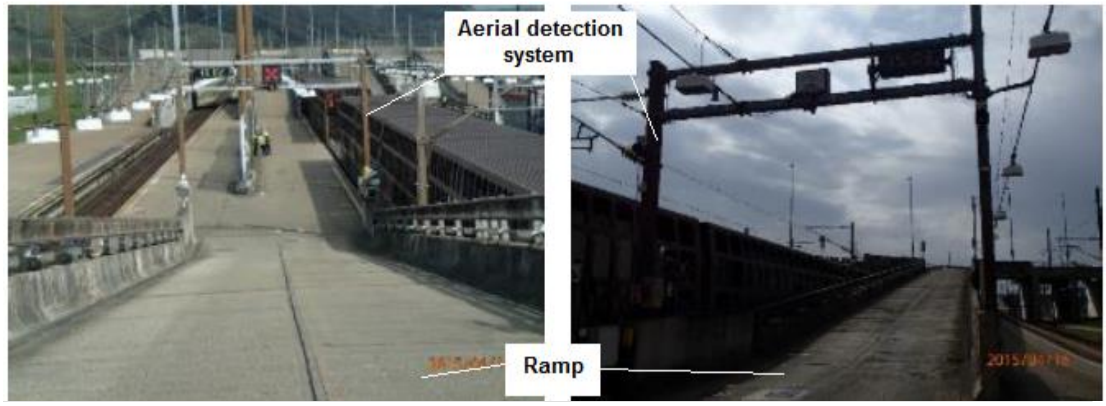

Figure 24: Over-bridge, ramp, platform and aerial detection system

The lorry is then allowed to proceed onto the loader wagon and boards the shuttle.

Once the lorry has boarded the shuttle, it drives along the wagons until instructed to stop by another group of two agents. These agents invite the lorry driver to leave the shuttle and to board a bus on the platform which will take him to the amenity coach at the front of the train. The agents then proceed to chock the lorries to ensure that they cannot move during the journey. They also carry out the final safety checks referred to as the SHARPE (Smoke, Heater, Aerial, Refrigerator, Petrol cap and Electrics) checks.

Upon completion of the loading process, all lorry drivers are driven to the amenity coach in two buses (one for the rear rake and one for the front rake).

3.1.11 - Train departure procedure

The plates bridging the gap between the loader wagons and the platform are raised by the agents at the bottom of the ramps.

The chef de train in the amenity coach checks that the loading documentation has been adequately completed and counts the lorry drivers to confirm that he has the expected number of passengers. He then closes the amenity coach doors and checks the indications on his workstation to confirm that the train is ready to depart (eg: bridge plates raised, doors closed, etc).

He transmits his status report to the Terminal Control Centre (TCC) and to the driver highlighting the position of the amenity coach (at the head of the train or at the rear), the type of carrier wagons used[5] (Arbel or Breda) and whether the train is carrying any dangerous goods. He then activates one of the switches on his workstation to indicate to the driver that the mission is ready to depart.

On receiving the status report from the chef de train, the driver requests from the Rail Control Centre (RCC) a route by pressing a button on his radio. On receiving an indication to proceed, the driver checks that he has received the indication from the

[5] The train driver needs to know if the train comprises of Arbel wagons to check on arrival at a platform that the power to the overhead line has been isolated (see section 4.6.3.4).

chef de train that the mission is ready to depart and then applies traction and releases the brakes to enable his train to move out of the platform.

Departing trains are monitored by three Agents de Feu (AdF). The working instructions for the AdF explains that their main role is to identify the appearance of smoke or flames and whether customers or any other persons are still in the vehicles. Should an AdF identify any such concerns they are required to contact the RCC immediately to stop the departing train. The train would then carry out a wrong direction move to return to the platform where the concern would be investigated. The role of the AdF was introduced following the first fire in the Channel Tunnel in 1996.

On the UK terminal, the role of the AdF is fulfilled by two of the agents in charge of chocking lorries and the platform safety coordinator, PSC (a loading supervisor who operates across all platforms). Before departure of a mission, the two agents that have been chocking the vehicles on the rear rake position themselves one at the bottom of the ramp to over-bridge 4 and the other on over-bridge 4, looking down at the mission. The platform safety coordinator positions himself on the ramp to over-bridge 3 in line with the middle loader. The role fulfilled by the platform safety coordinator as an AdF was added after the fire in 2008.

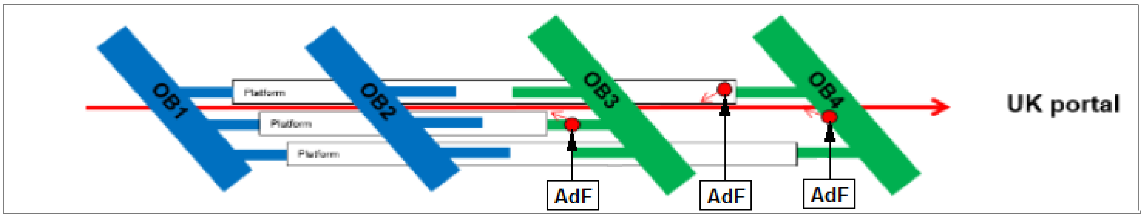

Figure 25: Position of AdF on departure of a mission made of Arbel wagons

The strategy is that the two agents near over-bridge 4 look at the front rake and the PSC on the ramp of over-bridge 3 looks at the rear rake.

Figure 26 shows the typical view that these AdFs have when carrying out their duty.


Figure 26: AdF's view of a departing train

3.1.12 - Role of crew members on board

During the movement of the train

The driver starts the train when the signal allows him to do so, subject to having received the “driving allowed” instruction from the chef de train. He drives his train according to the signals. He is vigilant at all times, looking out for any unusual situations occurring in particular by listening for noises and checking for smells and smoke.

The chef de train remains at his workstation unless called away for a particular task. He monitors correct operation of the shuttle’s equipment. He checks for any alarms.

In case of evacuation

The chef de train notifies the driver if he thinks an evacuation is necessary.

The driver advises the rail traffic management controller (RTM) with whom he comes to an agreement. He then informs the chef de train of the decision regarding evacuation.

The driver performs a controlled stop. He advises the chef de train when the stop has been completed.

The chef de train leads the evacuation into the service tunnel. He may be assisted by a certified agent, if one is present on board the train, following his instructions. He notifies the RCC once all of the passengers are in the service tunnel and he has checked that the amenity coach is empty. He also advises the RCC that all of the passengers are on board the assisting train if this is how the passengers are being evacuated to the outside.

Upon its arrival, the first line of response team (FLOR) takes charge of the safety of the evacuees and assists the chef de train, as required.

3.1.13 - Organisation of rescue operations in the event of a fire

3.1.13.1 - Organisation principles

Eurotunnel is responsible for calling the emergency services in an emergency.

As a general rule, the RCC is responsible for coordinating rescue operations in the tunnel.

If the accident is serious enough to require the intervention of emergency services from outside Eurotunnel, and if the accident has occurred in the French part of the concession, the Préfet in the Pas de Calais region, or his representative, may decide to implement the specialist emergency plan (PPS) if he considers that French resources alone will be sufficient, or the bi-national emergency plan (BINAT) if he considers that UK resources will also be required.

3.1.13.2 - Emergency resources

Emergency centre

An emergency centre (FEMC) is located in each of the terminals at Folkestone and Coquelles.

The emergency centre is adjacent to the tunnel portal. It acts as an operations base for the FLOR teams and a place for parking the STTS vehicles.

An agent of Eurotunnel's sub-contractor responsible for FLOR France is normally present at the FEMC in Coquelles. He has the same information relating to smoke and flame detectors as the FD controller at the RCC.

Emergency personnel

The fire-fighting system is based on two levels of staff that may be required to intervene:

- The first line of response (FLOR). On the French side, these are agents of Eurotunnel sub-contractor, trained to carry out tasks of fire safety agents (ASI) for the tunnel. On the British side, these are firefighters from the Kent Fire and Rescue Services (KFRS) working for the Eurotunnel 24 hours a day. Nine French ASI and eight UK firefighters are available at all times. They carry out regular patrols in the tunnel, with French and English patrols alternating.
- The second line of rescue (SLOR). These are firefighters from external rescue centres who, when they receive a call from Eurotunnel, attend to fight the fire and ensure people's safety. The SLOR also includes police services and emergency medical services.

Vehicles available to fire fighters

Seven emergency STTS vehicles are present at each of the emergency centres, i.e. 14 for the whole tunnel. These are as follows:

- 4 STTS fire and rescue vehicles used by the FLOR teams,
- 2 STTS ambulances,
- 1 STTS control and communication vehicle (STTS-Com). In a bi-national emergency, the STTS-Com vehicle for each country is used to set up a joint forward control centre

If necessary, the emergency services can use Eurotunnel's STTS maintenance vehicles or service cars to gain access to the service tunnel.

Figure 27: STTS fire and rescue

3.1.14 - Eurotunnel's safety management system

At the time of the fire on 17 January 2015, Eurotunnel's safety management system was defined in a document entitled "Health and safety management system" SAFD 1000. This document dates back to 2008 and has been revised 6 times, the last revision being dated 27 February 2014.

One of the basic premises of Eurotunnel's safety management system as stated in SAFD 1000 is that the technical systems and operating procedures must be satisfactory as they "*have prevented the occurrence of major incidents or events with severe consequences*".

Consequently, Eurotunnel's approach to on-going safety management is as follows:

- ensuring members of staff have the skills to operate systems in accordance with the procedures,
- measuring and assessing the level to which the tasks performed comply with the relevant standards and procedures,
- using the 'Return of Experience system' (REX) to learn from incidents and accidents,
- when modifications are made to technical systems, standards or procedures, ensuring that the overall level of safety is at least as high as before (in accordance with the French safety principle of "globalement au moins equivalent – GAME"- "overall at least equivalent").

The elements of the safety management system that are relevant to this investigation are its approach to change management and the management of recommendations.

3.1.14.1 - Approach to change management

Procedure ORF9 0590 "Procedure for handling technical modifications" describes the processes used by Eurotunnel to manage its activities related to implementing changes that could potentially affect safety.

In order to manage the risks associated with a change, ORF9 0590 explains that Eurotunnel's approach is to identify and assess the hazards associated with the proposed change and implement necessary mitigation measures.

The assessment process is based on UK and French practices of carrying out risk assessment. This is generally consistent with the approaches suggested in article R 4121-1 of the Code du Travail in France and by the UK's Health and Safety Commission in its code of approved practice entitled "Management of Health and Safety at Work" in the UK.

The risk associated with each hazard is determined by two elements:

- the frequency with which the hazard appears,
- the seriousness of the consequences with regard to personal injury.

If the change results in an increase in risk, the necessary mitigation measures are defined. The residual risk after implementation of the mitigation measures has to meet the GAME principle (ie the overall level of safety should be at least equivalent to that which existed before the change).

Procedure ORF9 0590 states that Eurotunnel follows the Safety Directive 2004/49/EC and Regulation No. 352/2009[6] of the European Commission on the Common Safety Method (CSM) for the evaluation and assessment of risks. This requires an independent assessment body to review the risk assessment prepared in support of a significant change.

3.1.14.2 - Management of recommendations

The recommendations made in reports from the national investigation bodies following an accident or incident are examined by Eurotunnel and passed to the relevant managers. Each manager is responsible for making proposals and then implementing the actions decided on.

These actions are monitored centrally by Eurotunnel's safety management team.

The safety management team provides the Intergovernmental Commission (IGC) and the Channel Tunnel Safety Authority (CTSA) with Eurotunnel's response to the recommendations and reports to them periodically on the actions taken.

3.1.15 - IGC and CTSA

The Intergovernmental Commission (IGC), set up by Article 10 of the Treaty of Canterbury 1986, is the National Safety Authority (NSA) for the Channel Tunnel within the meaning of the Safety Directive 2004/49/EC. The IGC is responsible for:

- the issuing of safety certificates to companies operating trains in the Channel Tunnel,
- the safety authorisation of Eurotunnel as the company in charge of the infrastructure,
- authorisation to place into service on the Channel Tunnel infrastructure vehicles that are already authorised in other Member States.

The Channel Tunnel Safety Authority (CTSA), established by Article 11 of the Treaty of Canterbury, advises and assists the IGC on all matters concerning safety in the operation of the Channel Tunnel. It does not advise on the protection of the infrastructure, other than in the context of the safety of people and safety of train movements.

As the NSA for the Channel Tunnel, the IGC is responsible for ensuring that appropriate action is taken in response to the recommendations made by the national investigation bodies following an accident or incident.

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[6] Now superseded by Regulation 402/2013

3.2 - Mission 7340

3.2.1 - Mission formation

On 17 January 2015, mission 7340 is formed of the following vehicles:

- leading locomotive number 9701;
- amenity coach number 5904;
- front loader wagon 7801;
- 16 Arbel wagons without pagoda;
- middle loader wagon 7855;
- 16 Arbel wagons with a front pagoda;
- rear loader wagon 7814;
- trailing locomotive number 9814.

3.2.2 - Load on mission 7340

The load on mission 7340 consists of 28 lorries and 2 vans. All of the carrier wagons are loaded with a lorry or van, other than the last wagon of each set of 16 which remains empty.

The incident lorry is loaded on carrier wagon 15 of the front rake.

There are no vehicles carrying dangerous goods identified on the load summary plan[7]. The first three lorries on the front rake have been identified as low fire load vehicles.

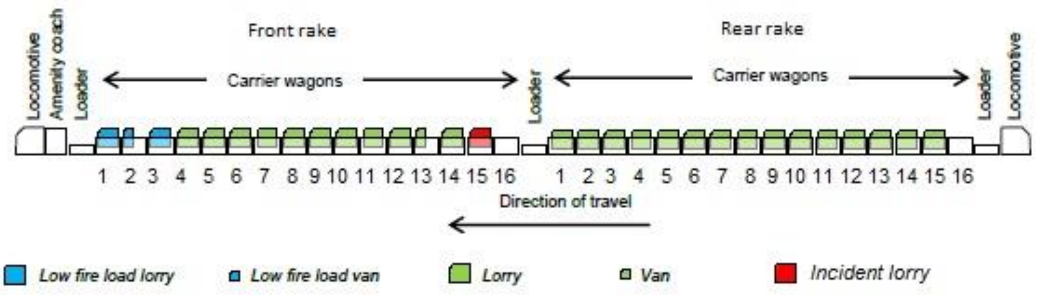

Figure 28: Loading of mission 7340

[7] The load summary plan is a document prepared by Eurotunnel staff for every mission showing the number of vehicles and passengers allocated to that mission. It also identifies the vehicles that have dangerous goods and low fire loads.

3.2.3 - *The incident lorry*

The articulated lorry involved in the incident is owned and operated by Giraud International from Romania, part of the Geodis group since 2009.

It comprises a MAN tractor unit and a Krone trailer.

The trailer is a 3-axle curtain-sided trailer loaded with iron brake drums.

Figure 29: The incident lorry during the loading phase

4 - Report of the investigations

4.1 - Loading and train departure

4.1.1 - *Summary of witness evidence*

Note: The summaries given below have been compiled by the technical investigators on the basis of the statements given by the various people they have met, retaining the details given by the person that appear useful in clarifying the events. There may be discrepancies between these various statements; or with the observations given elsewhere, or with the description of facts established by the investigators as presented in chapter 5.

4.1.1.1 - Evidence from the loading team and AdF

The loading team starts working at 08:00 hrs on Saturday 17 January 2015 and has carried out 3 or 4 unloading/loading sequences before mission 7340. The weather that day is dry with good visibility.

The agents in the tarpaulins check area do not notice anything untoward with the incident lorry and it is allocated to the front rake of mission 7340 which is departing from platform B9.

The loading agent at the bottom of the ramp from over-bridge 2 down to platform B9 successfully tests the aerial detection system before proceeding with the loading.

The aerial detection system activates for the 3rd or 4th lorry during the loading sequence. On visual inspection, there is nothing untoward found by the agent and the lorry is loaded on mission 7340. There are no other actuations of the aerial detection system during the loading of the front rake.

During the chocking operations of the lorries on the front rake, the agents notice that something is plugged into the cigarette-lighter of the vehicle on carrier wagon 2. The driver is already in the bus when this is identified. At the end of the loading sequence and before entering the amenity coach, the driver is asked to unplug the item.

During the chocking operations of the lorries on the front rake, the agents also notice that the cab heater of the lorry loaded on carrier wagon 5 or 6 has been left on. They get the driver to address the matter immediately as he is still near his vehicle.

The agent at the bottom of the ramp from over-bridge 2 chocks the last two lorries on the front rake, including the incident lorry.

During the chocking operations on the rear rake, no lorry is identified with any anomalies that need addressing.

The two agents in charge of chocking the lorries on the rear rake become two of the three AdFs during the departure of mission 7340. One positions himself at the bottom of the ramp to over-bridge 4 and the other one on top of over-bridge 4.

During the departure of mission 7340, the AdF positioned near the bottom of the ramp to over-bridge 4 identifies what he thinks is a metal aerial which appears higher than normal on the last lorry of the front rake. He is unsure whether the aerial is over-height.

The AdF speaks to the rear bus driver who is in the vicinity at the time who reminds him that the platform is equipped with an aerial detection system. The AdF does not take any further action. The AdF is working his 4th live shift since completing his training.

The AdF who is standing on over-bridge 4 looking down at the lorries does not notice anything untoward.

The loading team becomes aware of the incident approximately 30 minutes after the loading of mission 7340 when they are asked to stop working. They are interviewed by Eurotunnel shortly after the incident when the AdF who had detected something unusual makes the statement about the aerial.

4.1.1.2 - Evidence from the train driver

The driver signs on for duty at 09:45 hrs on 17 January 2015 at the terminal in Coquelles.

Her first turn of duty is to drive mission 7180, the 10:58 hrs Coquelles to Folkestone freight shuttle service. This trip is uneventful and mission 7180 arrives at Folkestone at 11:30 hrs.

At Folkestone, she stays with the train which becomes mission 7340 and leaves Folkestone at 11:57 hrs.

She sees that there is an agent de feu on the departure platform. It seems to her that there is not one on the overbridge departing from Great Britain[8]. Her train is not stopped before entering the tunnel. The train enters the tunnel without incident.

Around PK12, she notices that her train has lost its power supply and she carries out a controlled stop in accordance with the requirements of procedure ORT2 001 – 'Reference instructions Driver', bringing the train to a stop at CP1138.

She then lowers the pantographs on the locomotives and informs the RCC of the controlled stop. When instructed, she raises the pantographs on the locomotives and checks that the power supply has been restored.

She then restarts her journey under the instructions from the RCC not to exceed 100 km/h.

4.1.1.3 - Evidence from the driver of the incident lorry

Following the incident, the driver of the incident lorry was interviewed by the French Police[9].

He confirmed that he frequently crosses the Channel either in the tunnel or by ferry and that the loading operation that day was uneventful.

He confirmed that his articulated lorry was fitted with a citizens band (CB) radio and a whip aerial.

The lorry driver agreed, through his employer, that the extract from the CCTV footage (figure 30) showed the whip aerial attached to the back of the cab of his lorry.

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8 This point has not been confirmed by the investigation.
9 The interview was carried out through an interpreter as the driver is Romanian

He was only able to provide limited details about the aerial: he provided the name of the supplier from which he purchased it and he stated that he recalled lowering the aerial on 5 January 2015 and had not raised it since.

4.1.2 - Summary of electronic information

Both locomotives on mission 7340 were fitted with an on-train data recorder or ATESS (‘Acquisition et traitement des evenements de securite en statique’) which records time, speed, distance and actions taken by the driver.

In addition, the investigators had access to the footage from the closed-circuit televisions (CCTV) positioned at various locations on Eurotunnel’s Folkestone terminal and inside the tunnel.

The internal clock on the ATESS system of the locomotives is not synchronised with the time used by the CCTV system. The investigators have adjusted the ATESS clock to match the time shown by the CCTV. This is based on Central European Time.

4.1.2.1 - The on-train data recorder

The data on the ATESS system shows that the driver of mission 7340 starts setting up locomotive 9701 for this journey at 11:36 hrs.

The driver receives the authorisation to depart at 11:56 hrs and the train departs at 11:57 hrs.

As is normal, the speed on departure is limited to 40 km/h by the in-cab signalling system. As the train is still accelerating the speed limit increases to 60 km/h.

The leading locomotive enters the tunnel at the UK portal at 11:59:41 hrs. Mission 7340 is travelling at approximately 50 km/h at the time.

At 12:00:08 hrs and 12:00:10 hrs the main circuit breakers open on the leading and trailing locomotives respectively.

At 12:00:32 hrs, the driver of mission 7340 starts applying the brakes. The train is travelling at 59 km/h at the time.

At 12:00:40 hrs, the limit speed is increased to 100 km/h by the in-cab signalling system and then to 140 km/h at 12:00:54 hrs.

Between 12:00:56 hrs and 12:01:38 hrs, the driver of mission 7340 releases and applies the brakes several times to bring the train to a stop inside the tunnel at CP1138 between PK11 and PK12 (this is associated with the loss of traction power at 12:00:08 hrs).

At 12:03:40 hrs, the train recommences its journey and accelerates to the limit speed of 100 km/h, which it reaches at 12:07 hrs.

The train remains at this speed until 12:24 hrs.

4.1.2.2 - The closed-circuit television recordings

Shortly after the incident, Eurotunnel reviewed the CCTV footage that it held in relation to the loading of the articulated lorry which was transported on carrier wagon

15 of the front rake of mission 7340. This data has enabled the following facts to be established.

The incident lorry crossed the Channel from the continent to the UK using Eurotunnel's services on Friday 16 January 2015. On that trip, it was allocated to the front rake of a Breda shuttle (Mission 7319) at Coquelles. This trip was uneventful.

On Saturday 17 January 2015, the incident lorry enters the Folkestone terminal through the self-check-in booths at approximately 10:35 hrs.

There is no activation by the over-height detection system on the approach to the self-check-in booths.

The incident lorry goes through the security checks by the British and French customs. It is not selected for further investigation and proceeds straight to the tarpaulins check area.

The CCTV footage from the following locations was made available to the investigators:

- at the tarpaulins check area during the allocation operation;
- on platform B9 during the loading operation;
- at the UK portal as the train was entering the tunnel;
- at CP1114 where the train first came to a stop.

CCTV at the tarpaulins check area

The CCTV footage of the incident lorry passing at 10:43 hrs the tarpaulins check area shows what appears to be a whip aerial standing higher than the leading edge of the trailer.

Figure 30: Extract from CCTV footage at tarpaulins check area

The CCTV footage shows the whip aerial oscillating as the lorry comes to a short stop in the tarpaulins check area.

CCTV on platform B9

There are various CCTV cameras looking at platform B9. They all show the same events.

At 11:38 hrs, the lorries destined to board mission 7340 are released from the holding area.

At 11:41 hrs, a line of lorries on over-bridge 2 is ready to board the front rake of mission 7340 with the leading lorry stopped at the bottom of the ramp to platform B9, in line with the aerial detection system (figure 31).

At 11:42 hrs, having completed the unloading of mission 7180, the agent located at the middle loader approaches the bottom of the ramp. He signals to the driver in the leading lorry to wait.

The agent pauses for few seconds next to the aerial detection system control panel, presumably to test the system[10].

[10] The quality of the CCTV footage is insufficient to be able to positively state that he did, but it only takes few seconds for an agent to test the system.

The agent then walks around the back of the leading lorry (figure 31).

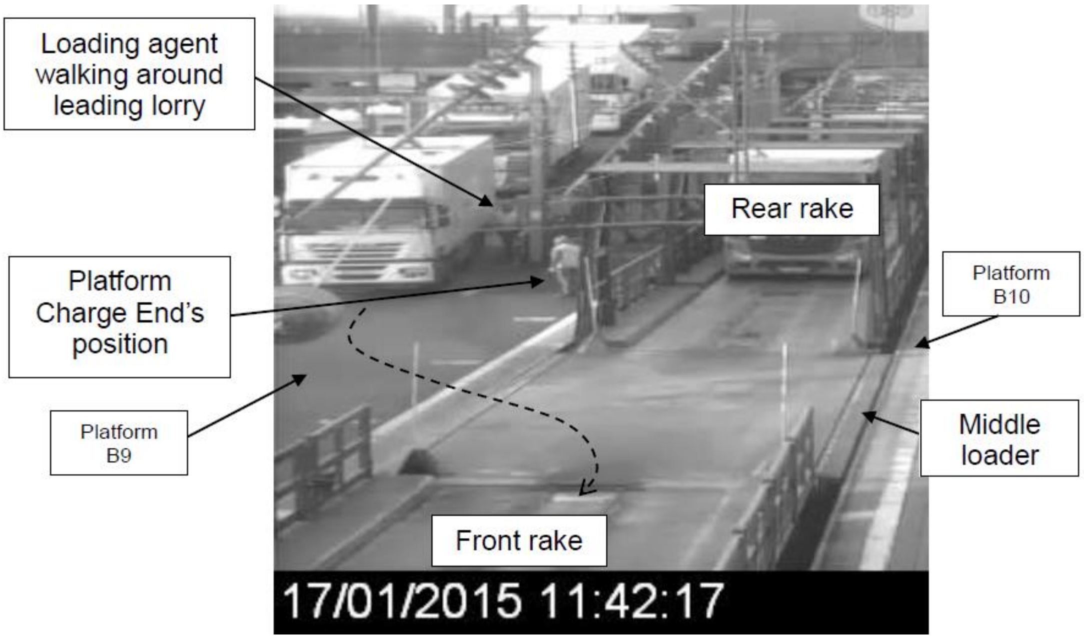

Figure 31: Loading lorries onto the shuttle.

In the meantime, the platform charge end[11] joins him at the bottom of the ramp, and positions himself on the side opposite the aerial detection system control panel.

By 11:42:30 hrs, the agent at the bottom of the ramp has completed his walk around the leading lorry and is now back near the aerial detection system control panel. He signals the driver of the leading lorry to board the shuttle. The loading of the front rake of mission 7340 has started.

Between 11:42:30 hrs and 11:47 hrs, the following process applies:

- the agent at the bottom of the ramp stays in the same position, near the aerial detection system control panel;
- the platform charge end stays in the same position, on the other side of the lorries;
- the lorries, in one continuous movement, pass in front of the aerial detection system, between the two agents and move onto the loader wagon.

At 11:46:20 hrs, the incident lorry passes in front of the aerial detection system and at 11:46:40 hrs, the lorry boards the loader wagon.

At 11:47:35 hrs, the incident lorry finally stops on carrier wagon 15 of the front rake. The loading of mission 7340 is now complete as the loading of the rear rake has also been completed.

[11] The platform charge end is a supervisor employed by Eurotunnel. The platform charge end operates across all platforms and his role is to ensure that the loading operations take place in a timely manner

The agent at the bottom of the ramp approaches the incident lorry to carry out the chocking operation.

The platform charge end has by that time returned to his vehicle on platform B10. He starts his vehicle and uses the middle loader to reach platform B9 where he stops. The platform charge end raises the bridging plates on the middle loader before re-joining his vehicle. He then disappears out of sight of the CCTV cameras.

By 11:54 hrs, all passengers have boarded the amenity coach. The bridge plates on all loader wagons have been raised. At 11:55:30 hrs, the doors to the amenity coach are closed.

At 11:57:07 hrs, mission 7340 starts to depart the platform.

CCTV at the UK portal

There are various CCTV cameras looking at the UK portal. They all show the same events which are shown on figure 32.

Mission 7340 enters the tunnel at 11:59:41 hrs.

At 12:00:08 hrs, as the lorry loaded on carrier wagon 15 of the front rake enters the tunnel, an electrical arc occurs between the overhead line and the lorry.

At 12:00:36 hrs, the trailing locomotive of mission 7340 enters the UK portal. Mission 7340 is entirely inside the Channel Tunnel.

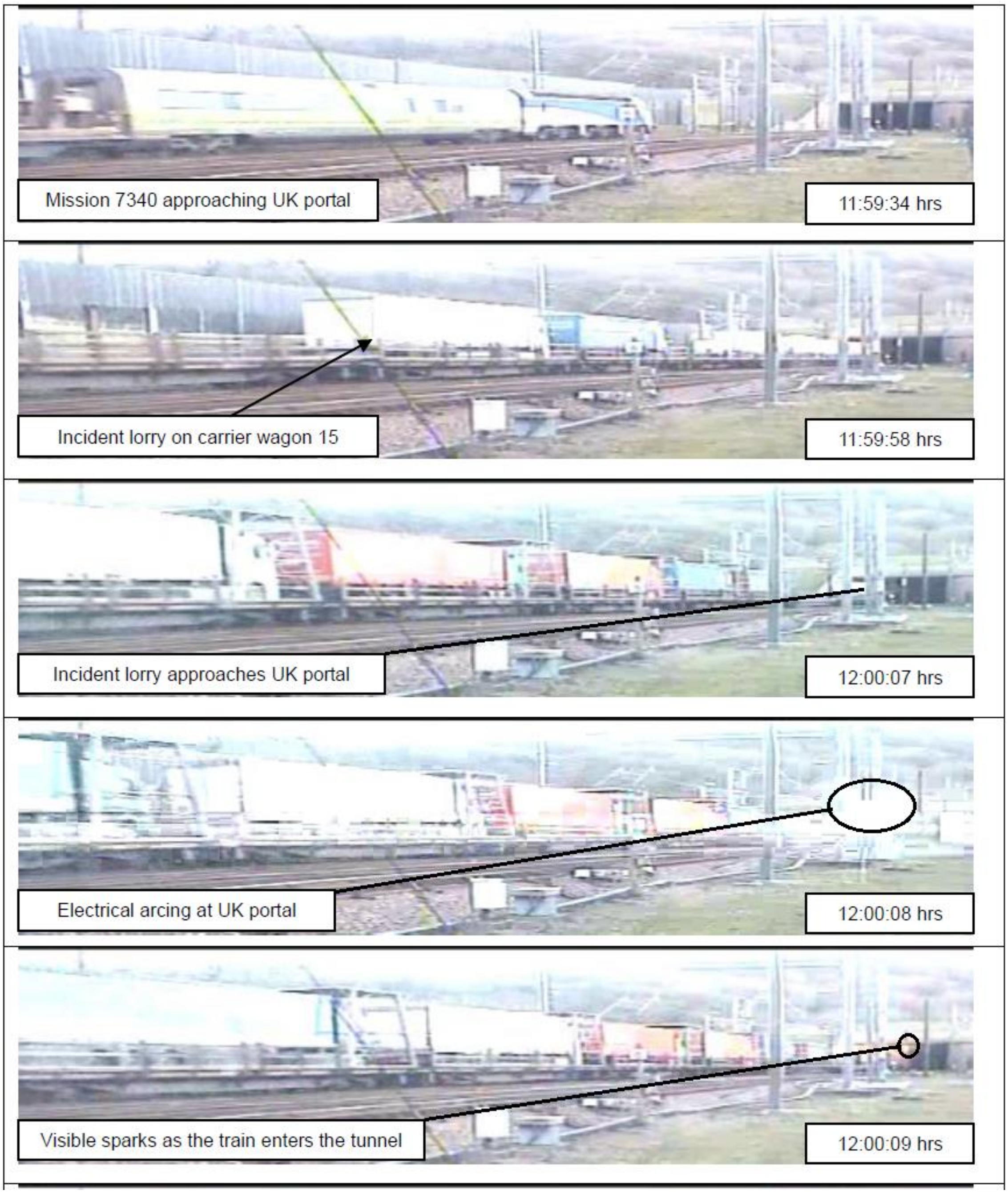

Figure 32: Train 7340 entering the tunnel

CCTV at CP1114

The third cross-passage inside the tunnel, CP1114, is fitted with a CCTV camera.

The footage from this camera shows that the leading locomotive of mission 7340 passes in front of the camera at 12:01 hrs.

At 12:01:35 hrs, mission 7340 comes to a stop with the leading end of carrier wagon 11 of the front rake in line with CP1114.

At 12:03:37 hrs, mission 7340 restarts its journey.

At 12:04:10 hrs, as the cab of the incident lorry passes in front of CP1114, the inside of the cab of the tractor unit appears to be filled with smoke.

Figure 33: Passage of incident lorry at CP 1114

4.1.3 - Summary of related Eurotunnel procedures

The loading of the train followed the rules applicable at the time of the incident as described in ORT2 0406 'UK Customer Service Department: Customer Service Agent Reference instructions'. The loading of mission 7340 complied with this procedure.

The investigators reviewed the entire process used by Eurotunnel to load lorries on to freight shuttles and concluded that the aerial detection system was the only system provided to detect over-height aerials. Furthermore, none of the loading agents, including those at the bottom of the ramps[12], were expected to identify over-height aerials[13].

The composition of the train was in accordance with the rules.

The actions of the driver and personnel within the RCC following the electrical arc at the UK portal were consistent with the instructions in the relevant procedures. These procedures did not require any visual inspections of the train to be carried out before the train exited the tunnel at the other end. The speed restriction to 100 km/h embedded in the procedures was dictated by concerns that the power trip could have been caused by a loose tarpaulin.

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[12] In accordance with the procedure, the agent at the bottom of the ramp only responds to the alarms raised by the aerial detection system. The agents might decide to carry out a visual inspection of the lorries for aerials but this is not prescribed in their operational instructions. It is only if the aerial detection system is inoperative that the agent is instructed to carry out a visual check of the lorries for aerials.

[13] Since the incident, the agents at the tarpaulins check area have been instructed to identify whip aerials and to systematically allocate lorries with whip aerials to Breda wagons.

4.1.4 - Height of the lorry and aerial

MAN and Krone provided dimensional information of the tractor and trailer units, respectively. Using this information, the investigators calculated that the height of the tractor unit would have been between 3,895 and 3,975 mm and the height of the trailer between 3,908 and 4,183mm (without the whip aerial) depending on the suspension configuration.

This complies with Eurotunnel requirements which states that vehicles carried on the freight shuttle should be no higher than 4,200 mm. This is also consistent with the lack of activation of the over-height detection system at the entrance to the terminal (set at 4,250 mm).

Based on the CCTV footage and data provided by Krone, the investigators estimated that the whip aerial seen on figure 30 protruded approximately 500 mm above the height of the trailer. Therefore, the whip aerial exceeded the maximum height of 4,200 mm in any trailer configuration (minimum 4,408 mm, maximum 4,683 mm).

Post-incident inspection of the burnt-out lorry failed to locate the whip aerial.

The investigators contacted the supplier from which the lorry driver purchased the aerial, who stated that it only supplies ML 145 type CB aerials. This is a common type of aerial, approximately 1,450 mm long, fitted with a magnetic base for ease of installation.

The orientation of the aerial relative to the base can be adjusted and locked in place with a screw. The whip aerial itself is made out of stainless steel and is tapered. The diameter at the tip of the aerial is approximately 1 mm.

As there remains some uncertainty as to whether this was the type of aerial that was fitted to the incident lorry, the investigators undertook a survey of CB aerials to determine their likely diameter. They found that the diameter of CB aerials is typically between 1 and 2 mm.

4.1.5 - The aerial detection system

4.1.5.1 - Description of system

Since the start of operation of the Channel Tunnel in 1994, there has been an aerial detection system fitted at the bottom of the ramps giving access to the platforms.

Eurotunnel originally installed this system because it was concerned that aerials protruding too high might come into contact with the live overhead power line during the loading and unloading operations. When Eurotunnel first started operating, all carrier wagons were fitted with a roof structure which ensured that aerials could not contact the overhead power line once the lorries were loaded on the carrier wagons.

However, in order to move from the platform to the carrier wagons, lorries have to transit over the loader wagons which have never been fitted with a roof structure. Therefore, for the short time when a lorry was transiting over a loader wagon, a high aerial was potentially at risk of contacting the live overhead power line.

The aerial detection system is permanently turned on and there is one installed at the bottom of each loading ramp.

It is made up of two sets of sensors connected to a programmable logic controller (PLC) which analyses the data received and responds accordingly. The PLC is located in a control panel attached to the portal holding the sensors. The control panel also contains the power supply and the sirens.

The bottom sensors (a transmitter and a receiver) are attached to either side of the portal. These sensors are approximately 1.85 metres above road level and are used to detect the presence of a lorry.

The top sensors (a transmitter and a receiver, also on either side of the portal) are used to detect the presence of an aerial at roof level and are installed 4,250 mm above road level.

Figure 34: Aerial detection system

The logic is that a confirmed activation lasting more than 100 ms at the bottom sensors triggers the scanning by the top sensors for 5 seconds (regardless of any short (< 1 second) loss of detection at the bottom sensors). Hence, it is only the part of the lorry that passes in front of the sensors in these 5 seconds that is scanned for an over-height aerial. At a speed of passage in front of the aerial detection system of 2 km/h, only the first 2.8 m of the lorry are scanned. As the speed of the lorry increases, the scanned length also increases.

This scanning by the top sensors continues until the 5 seconds have elapsed. The process is reset every time the activation of the bottom sensors is lost for 1 second (to represent the gap between lorries).

4.1.5.2 - System availability and reliability

The top sensors were supplied by Leuze (Germany) and, as installed by Eurotunnel, are theoretically capable of detecting objects as small as 0.8 mm in diameter.

The agent at the bottom of the ramp is tasked with testing the aerial detection system before every loading sequence. Testing involves blocking the bottom sensor (to simulate the presence of a lorry) while pressing a test button on the control panel. The test button activates a motor which drives an arm (5mm diameter) in front of the top sensors. Upon detection of the arm by the sensor, the alarm sounds and this confirms to the agent that all parts within the system are in working order.

Eurotunnel could not provide the original technical specification against which the aerial detection system had been designed in 1994. The investigators contacted Leuze, the supplier of the aerial detection system top sensors, to understand the maximum allowable speed of passage of an aerial in front of the sensors to ensure reliable detection. Based on the characteristics of the sensor, Leuze stated after the accident that the maximum speed for reliable detection of a 1 mm aerial is approximately 1 km/h. This increases to approximately 2 km/h for a 2 mm diameter aerial.

Using the CCTV footage, the investigators estimated that the incident lorry was travelling at a speed of between 4 km/h and 5.6 km/h as it passed in front of the sensors. They also confirmed that this was a typical speed for the other lorries being loaded.

This speed range (4 km/h and 5.6 km/h) is significantly higher than the speed declared by Leuze for reliable detection (1 km/h to 2 km/h depending on aerial size) and may explain why the aerial detection system did not activate for the incident lorry on the day of the incident. Figure 35 shows graphically the range of speeds for reliable detection for different diameter aerials (based on the calculation technique provided by Leuze) together with the speed at which the lorry was travelling.

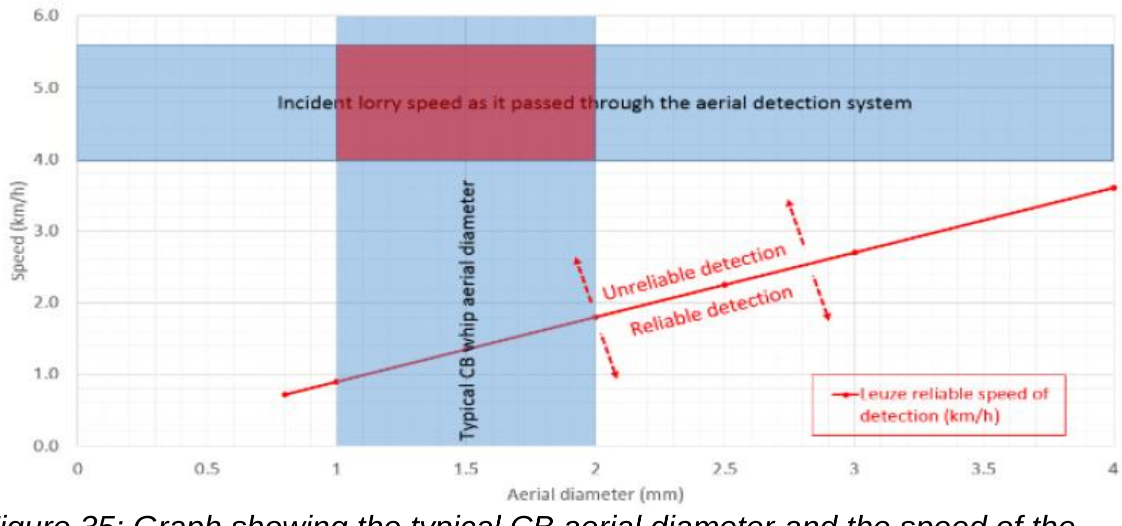

Figure 35: Graph showing the typical CB aerial diameter and the speed of the incident lorry against the declared speed for reliable detection

In July 2015, Eurotunnel tested one of its aerial detection systems to better understand the actual speed of detection. The tests were carried out with aerials of three diameters: 1, 1.5 and 2 mm. The test results with the 1 mm diameter are reproduced in table 1.

Speed (km/h)	Detection (yes/no)
24	No
24	No
22	No
21	No
16	Yes
16	Yes
14	No
11	No
10	Yes
6	No

Table 1 – Eurotunnel's test results for aerial detection system
1 mm diameter aerial

The number of tests carried out by Eurotunnel does not enable the calculation of a probability of detection curve[14]. Nevertheless, the results show that detection can occur at high speeds (16 km/h). But the results also show that detection cannot be guaranteed even at fairly low speeds (6 km/h). The very low speed of passage in front of the sensors needed to guarantee detection may explain why the aerial detection system did not activate for the incident lorry on the day of the incident. This very slow speed of passage needed to guarantee detection reduces the scanned length of the lorry.

The investigators also calculated the natural frequency of an oscillating whip aerial and, based on the likely amplitude of deflection witnessed on the CCTV footage, they estimated the maximum speed that the tip of an aerial might be travelling at when oscillating. This could easily be in excess of the speed for reliable detection declared by Leuze. Furthermore, the speed of oscillation could be additive to the speed of the lorry, making the aerial speed past the sensor even greater.

[14] A probability of detection curve in this case would quantify the reliability of detection in percentage terms against the speed of passage in front of the sensors.

4.1.6 - The role of the Agent de Feu in the detection of aerials

The operational instructions for the AdFs are described in ORT2 0417 'UK Sub contractor commercial operations instructions'. According to the instructions, an AdF must make sure that there is no:

- appearance of smoke;
- appearance of flames;
- customers in vehicles;
- freezers running;
- locomotives door open;
- persons on board;
- any other anomalies.

Eurotunnel provided evidence to confirm that departing trains are stopped, on average, once every two weeks by AdFs.

Although an over-height aerial could be construed to be an 'anomaly', the speed of the departing train would make reliable detection difficult. The investigators therefore concluded that AdFs were not expected to detect over-height aerials on departure.

Nevertheless, on 17 January 2015, the AdF located at the bottom of the ramp leading to over-bridge 4 saw an aerial on the incident lorry which he thought might have been over-height. However, instead of reporting it to the RCC immediately as stated in the procedure, he discussed it with the only person in the vicinity, the rear rake bus driver, to get a second opinion.

The bus driver, who had not seen the aerial on the departing lorry, explained that it can sometimes be difficult to assess whether aerials are really over-height. He reminded the AdF that there is an aerial detection system at the bottom of the ramp and that the aerial should have triggered the system had it been over-height. On that basis, the AdF decided not to call the RCC to raise an alarm.

The investigators observed that the overhead line is more than 400 mm higher at the platforms than it is in the tunnel (with the portals being the locations where the height of the overhead line reduces). This results in there being approximately 1,000 mm clearance between the highest point on a lorry and the overhead line at the platform.

With the whip aerial protruding approximately 500 mm above the highest point on the lorry, there was still 500mm clearance between the top of the aerial and overhead line. This might have given the impression to the AdF that the aerial was not necessarily over-height.

4.1.7 - Summary of the key findings associated with the loading and departure of the train

The incident lorry was loaded onto carrier wagon 15 of the front rake of mission 7340, an Arbel wagon without any pagodas.

The incident lorry had a whip aerial fitted to the back of the lorry's cab. The aerial was standing higher than that allowed by Eurotunnel procedures.

The aerial did not trigger the aerial detection system at the bottom of the ramp probably because it was travelling at too high a speed for the detector to reliably detect it.

The aerial detection system was the only system provided to identify over-height aerials. Furthermore, none of the agents involved in the loading process were required, according to their job description, to check for over-height aerials. However, one of the AdFs identified the aerial, but he was unsure whether it was over-height and took no further action.

There was an electrical arc between the overhead power line and the incident lorry. As a result of the associated loss of power, the driver brought the train to a controlled stop inside the tunnel, with its amenity coach in line with CP1138.

Once permission was granted from the RCC, the driver recommenced the journey at 100 km/h.

There appeared to be smoke inside the cab of the incident lorry as it passed in front of CP1114.

4.2 - Mission 7340 journey

4.2.1 - Summary of witness evidence

The summaries given below have been compiled by the technical investigators on the basis of the statements given by the various people they have met, retaining the details given by the person that appear useful in clarifying the events. There may be discrepancies between these various statements; or with the observations given elsewhere, or with the description of facts established by the investigators as presented in chapter 5.

4.2.1.1 - Statements from staff on board mission 7340

Driver of mission 7340

Mission 7340 leaves Folkestone at 11:57 hrs.

The train enters the tunnel without any specific incident. Towards PK 12, the driver reports a loss of overhead power line voltage. The regulation stipulates that she must make a controlled stop, which she does. She believes that she stopped at CP 1148 *[in fact it was CP 1138]* but is not certain as she lost her notes in the incident. She lowers the pantographs, informs the RCC and then raises the pantographs again. Power has been restored and she continues her journey at a maximum speed of 100 km/h.

Throughout the journey she recalls abnormal fluctuations of voltage (up to 27,200 volts).

At 12:23 hrs the chef de train advises her of a wagon fire alarm. She makes an emergency call to the RCC to inform them and continues on her way having not received any instruction to the contrary from the RCC. She has already passed the two SAFE stations. At 12:28 hrs *[in fact 12:24 hrs on the recordings]* she finally loses traction power. She therefore carries out a further controlled stop. She decides to stop before the French crossover and stops at CP 4418.

The chef de train

The chef de train starts his duty at 09:45 hrs in Coquelles. His first turn is a mission from France to Great Britain (departing at 10:58 hrs).

He sets off again at 11:57 hrs (3 mins late) on the same train, on mission 7340. He informs the British control centre that there is 1 driver on board, 41 passengers (38 lorry drivers, 2 maintenance technicians from Eurotunnel and himself). He is informed in return that there are no dangerous goods on board this mission.

The train stops for the first time about 1,000/1,500m inside the tunnel because of a power trip. The train sets off again two or three minutes later accelerating to a speed of 100 km/h.

Around 12:23 hrs he receives a fire alarm warning on his workstation. This alarm comes from the rear loader wagon. He informs the driver and closes the HVAC dampers. The amenity coach is thereby pressurised preventing any smoke from entering.

4.2.1.2 - Statements from the agents in the rail control centre

The supervisor

After the fire detection controller (FD) announced a second alarm, the supervisor declares a level 2 alarm on mission 7340. His first thought is to stop the train in a SAFE station. He is looking at his “fire” flow chart when the overhead power line trips.

He instructs the rail traffic controller (RTM) to speak to the driver and ask him if he can stop the train in the nearby SAFE station (SAFE procedure). The driver is not able to, so the supervisor decides to apply the “Stopping Train” procedure. It does not occur to him to reinstate the overhead power line as he is focused on the SAFE procedures and then the “Stopping Train” procedures. He states that at the time of the power trip, the controllers are operating within their reflex actions [*linked to fire alarms].*

The fire detection controller (FD)

At 12:22 hrs, a flame alarm is confirmed at detection station 38. Several seconds later an ionising smoke alarm sounds at the same station. The supervisor declares a level 2 alarm for mission 7340 at 12:23 hrs and at the same time receives a call from the train driver. At 12:24 hrs an additional alarm appears at the next station.

It is too late to stop at a SAFE station. Mission 7340 stops at CP 4418.

The rail traffic management controller (RTM)

At 12:00 hrs which is the time of the first power trip, the on-duty RTM controller returns to the RCC from getting his lunch (he is replaced during his absence by a relief RTM controller). After the power is turned back on, he has his lunch. As the train is passing the mid-point, he asks the relief RTM controller to replace him. During the handover, he notices a fire alarm on the control panel. Ten seconds later, the FD controller announces a second alarm.

As soon as the supervisor confirms the level 2 alarm, the relief RTM controller activates the incident monitor and the RTM controller calls all trains to slow down to 100km/h and to close the ventilation dampers on the amenity coaches.

The relief RTM controller receives an emergency call from the train driver advising him of an on-board alarm. A few seconds later, a further emergency call is taken by the relief RTM controller. He cannot understand the conversation as the emergency call “buzzer” is sounding. On the monitor the “emergency” warning light is visible. This warning light hides the train number of the caller. The relief RTM controller thinks that this second emergency call is coming from a train that is stopped at the tunnel portal by the closure of the access signals to the tunnel (CMAC). In reply to his request to know who is calling, the driver says “mission 7340”. The second power trip took place during the conversation and not at the start.

Engineering management system controller (EMS)

The supervisor declares a level 2 alarm in the running tunnel North after the FD controller announced a second alarm at CP 3912.

In response, the engineering management system controller (EMS) activates his incident monitor. He checks the correct working of the system and discovers that a damper on a piston relief duct (PRD) is in an unknown state and not closed as it should be. He calls the maintenance service (DI EM) and attempts an emergency closure which does not work. As the overhead power line trips, an automatic sequence (CO presence) is already in progress. He does not consider resetting the overhead power line as it is not his priority given the situation. He stated that this is the same method as the one applied during training exercises in the simulator.

4.2.2 - Use of voice recordings

We have not been able to obtain any voice recordings, as the recording tapes were re-used before the end of the investigation. However, two transcripts of voice communication have been provided by Eurotunnel.

Transcript by the Safety Directorate (DS VSF)

At 12:23:16 hrs the driver of mission 7340 announces a "wagon fire alarm" to the RCC via an emergency call on the track to train radio. The RTM controller repeats the message and ends the call.

At 12:23:56 hrs the RCC receives an emergency call from mission 7340. The driver indicates that she does not understand where the call comes from. She points out the absence of overhead power line voltage. The RTM controller asks her to confirm her mission number. She says "Mission 7340" and repeats that she no longer has any overhead power line voltage. The RTM controller asks her if she can stop in the SAFE station. After 2 or 3 seconds the driver says no and repeats that she has lost the overhead power line voltage. The RTM controller asks if she is going to carry out a "Stopping train" sequence. She replies "*ok, I will carry out a Stopping Train sequence*". This exchange marks the end of the communication.

Transcript by the Directorate of Infrastructure (DI TCS)

At 12:23 hrs, passage of block 3926 - 4074.

At 12:23 hrs, call from mobile - emergency call.

At 12:23 hrs, conversation with RCC France - duration 20 secs – quality: 5/5 "fire alarm".

At 12:24 hrs, call from mobile - emergency call.

At 12:24 hrs, conversation with RCC France – duration: 1min 8secs – quality : 4/5 *"driver indicates that an emergency call has been made - that she has lost the overhead power line – the RCC asks what train it was then asks if it is possible to stop at SAFE station – the driver says no - stopping procedure".*

4.2.3 - Use of on board recordings

Examination of the data recorders on board the locomotives enabled the investigators to clarify the timing of the main events as shown below:

At 11:57:14 hrs, the train sets off from the UK terminal.

At 12:00:08 hrs and 12:00:10 hrs, opening of the circuit breakers for locomotive 1 then locomotive 2

At 12:01:38 hrs, mission 7340 stops

At 12:03:37 hrs, mission 7340 sets off again

At 12:23:50 hrs, the “fire in the tunnel” button is pushed by the driver of mission 7340.

At 12:24:08 hrs, opening of circuit breakers for both locomotives.

At 12:26:22 hrs, mission 7340 stops again.

4.2.4 - Investigating the causes of the power trips

Operation of circuit breakers

On 17 January 2015 before the incident, the supply of 25kV to the overhead power line was provided in extended mode for the whole concession from France (see 3.1.4).

This mode is used for 98% of the time.

Using this mode, the most distant overhead power line sections are almost 60km from the sub-station.

Given that overhead power line impedance increases with distance, the maximum current in the overhead power line in the event of a short circuit decreases in relation to distance between the short circuit and the sub-station.

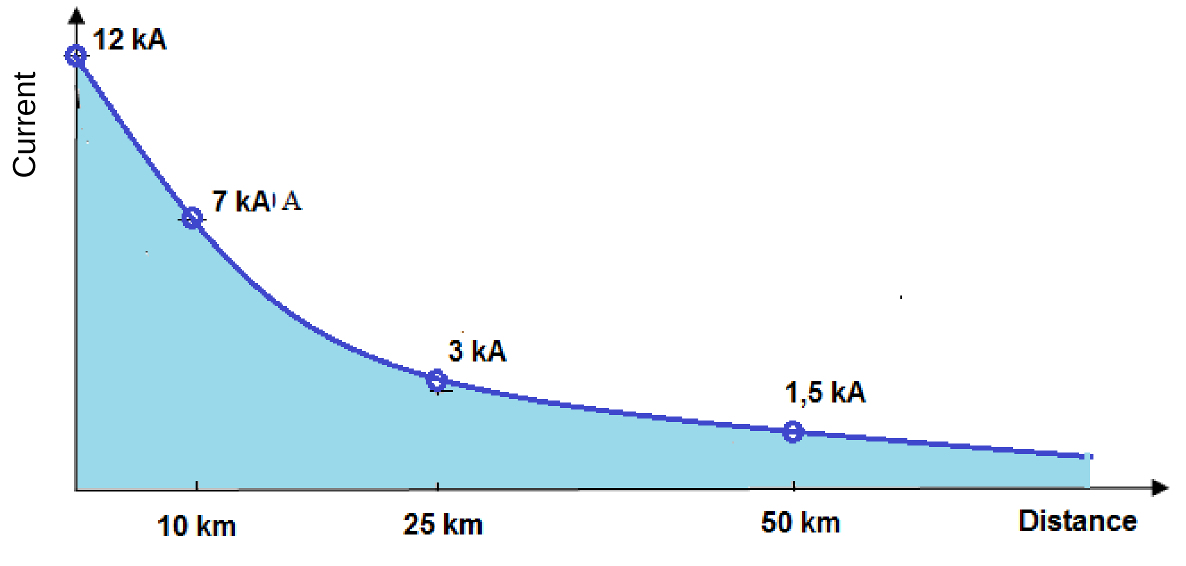

Figure 36: Maximum current depending on distance

A circuit breaker triggered by a maximum current criteria is not sufficient to efficiently protect the installations.

There are therefore two trigger requirements for a circuit breaker:

- maximum current (max I) 4,500 Amps for 50 ms which is only efficient in the case of a short-circuit near the sub-station;
- Unexpectedly low impedance (min Z) as measured at the feeder station: where Z=U/I represented by the graph below where Z=R+iX

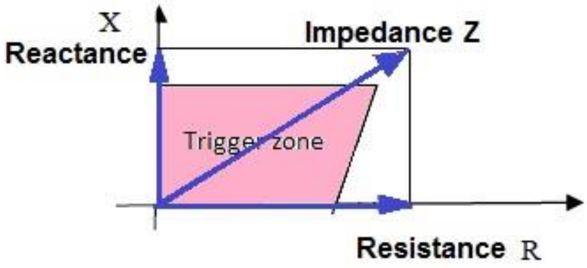

Figure 37: Trigger by minimum Z

First power trip

The opening of the main circuit breaker which provided power to the running tunnel North overhead power line was recorded at 12:00:08 hrs and it was triggered by the minimum impedance criteria.

The ATESS recorders for the locomotives show that the loss of line voltage caused the opening of the circuit breakers of the locomotives at 12:00:08 hrs and 12:00:10 hrs.

CCTV cameras monitoring the UK portal observed a flash at 12:00:08 hrs above a lorry loaded on the 15th wagon of mission 7340.

The lorry driver reported that his lorry was fitted with a CB aerial.

A close examination of the footage taken on the CCTV cameras monitoring the tarpaulins check area reveals the presence of a whip aerial, fitted to the lorry, the height of which noticeably exceeds the top of the cab and the roof of the trailer.

The height of the wagon floor is approximately 1,100 mm above rail level.

The height of the overhead power line is approximately 6,300 mm above rail level at the platform. This height reduces to 5,890 mm at the UK portal. At the UK portal, the clearance between the aerial and overhead power line would have been, in the worst case, approximately 100 mm. This explains why the electrical arc took place at this location.

These facts enable us to conclude that the cause of the first power trip is identified with some certainty. It is a short circuit caused by an arcing between the overhead power line and the CB aerial of the incident lorry. This arcing occurred at the location where the height of the overhead power line drops at the UK portal thereby reducing the distance between the contact wire and the end of the aerial.

Second power trip

The second power trip was also triggered by a minimum impedance criteria of the overhead power line. However, with a current of 4678 A the maximum current criteria could also have applied. The parameters of the power trip are as follows:

U= 15290V ; I = 4678 A

Z= 3,25 ohm ; X = 3,15 ohm

The cause of the second power trip was not obvious during the immediate investigation after the event; numerous investigations have therefore been carried out.

The position of the second power trip was determined by Eurotunnel by analysing recordings of the current and voltage at the time of the power trip. With some uncertainty linked to the method and data, this position has been located at PK 41.5±1km.

At the time of this power trip, the analysis of the on-board data recorders enables us to position the leading locomotive towards PK 42.16 and therefore wagon 15 of the front rake, where the incident lorry was loaded, towards PK 41.78.

Unlike the zone situated between PK 43.859 and 43.920 where the installations were severely damaged by the fire, the overhead power line between PK 40.5 and 42.5 was intact and its close examination post-incident did not detect any anomaly which would explain this second power trip.

It is therefore probable that the power trip was the result of a momentary arcing with a part of the incident lorry or a neighbouring lorry, such as a loose piece of tarpaulin, strap or lanyard. It is also probable that this part could have come adrift as a result of the heat of the fire, but that is not for certain.

It also appears that this arcing did not cause any significant damage to the overhead power line and therefore the overhead power line could have been re-energised.

4.2.5 - Investigating the causes of the stops

4.2.5.1 - RCC procedures

Procedures in the event of a power trip

Instruction OTI-1446 “Catenary trip in a running tunnel” applies to the RCC supervisor.

It requires that the RCC supervisor asks the EMS controller to reset and close the main circuit breaker of the sector of overhead power line concerned.

If there is no immediate power trip:

- He asks the RTM controller to limit the speed of trains in the tunnel;
- He asks the EMS controller to separate the power supply to the UK terminal from that of the running tunnel concerned ;
- He gathers information concerning the position of the trains situated under the section of overhead power line concerned by the first power trip.

In the event of an immediate power trip:

- He asks the RTM controller to inform train drivers under the sector of overhead power line concerned to keep their pantographs lowered until they receive further advice;
- He asks the EMS controller to separate the power supply to the UK terminal from that of the running tunnel concerned then to reset the supply to the overhead power line of the tunnel concerned;
- He gathers information concerning the position of the trains situated under the section of overhead power line concerned by the first power trip,
- He resets the supply to the various sectors then if there is no new power trip, he authorises successively each train to raise its pantographs and close its circuit breakers.
- He notifies the maintenance department for electric traction installations.

In the event of a 2nd subsequent power trip when all the traffic situated in the tunnel at the time of the 1st power trip has not exited:

- He authorises the EMS controller to reset the supply to the tunnel concerned.

Then:

- He asks the RTM controller to impose a speed of 100km/h on all trains in the two tunnels and a speed of 80km/h on Arbel shuttles in the tunnel concerned;
- He asks the EMS controller to close the PRD in the tunnels ;
- He advises the maintenance department.

Procedures in the event of fire on a freight shuttle

In the event that a fire is confirmed on a freight shuttle, the RCC is responsible for directing the shuttle concerned to one of the two SAFE stations if that is still possible.

In the event the train has gone past the SAFE stations, the RCC must apply the “Moving Train” procedure to get the train out of the tunnel and direct it towards the terminal’s emergency siding.

Finally, if for any reason, none of these procedures can be applied, the RCC gives an order to the driver to apply the “Stopping Train” procedure. In this case, the driver must carry out a controlled stop, which means stopping as soon as possible so that the front door of the amenity coach is in line with a cross passage door.

4.2.5.2 - Driver procedures

Procedures in the event of a power trip

“Application instruction - Driver” (ORT2-0001 Revision 31) details the measures the driver must take in the event of a loss of overhead power line supply. He must:

- Carry out a controlled stop unless he is advised by the RCC that the supply to the overhead power line is being reconfigured.
- Report back to the RCC and follow its instructions.

If the supply is reinstated during braking or after stopping and no anomaly is reported, he continues on his way.

Procedures in the event of a fire

As soon as the driver receives the “wagon fire alarm” message from the chef de train, the driver:

- presses the button “Tunnel fire”;
- manually closes the ventilation dampers on the locomotive;
- complies with the in-cab signalling instructions;
- reports back to the RCC sending the message “wagon fire alarm”;
- proceeds to isolate VACMA (Veille automatique avec maintien de controle d’appui – Driver’s vigilance device) if the speed control is working.

He gives the RCC the necessary information to determine the strategy to be followed. He then implements the instructions received from the RCC.

4.2.5.3 – The sequence of the stops

The 1st stop

Having noticed an absence of power supply, the driver initiates the procedure to carry out a controlled stop at CP 1138. She starts braking 24 secs after the power trip; she is then at PK 10.771.

The power supply is reinstated 26 secs after the power trip in the running tunnel North however the train is still in the UK terminal sector which still has no supply.

The separation between the two sectors being located at CP 1120, the leading locomotive reaches the re-energised sector of the overhead power line about 1 min after the power trip. The driver, focused on carrying out her controlled stop, does not notice that the supply has been reinstated and completes the stop instead of continuing with the journey.

The train comes to a stop at PK 11.408, one minute after the power trip.

1min 50sec after the power trip the voltage is reinstated in all sectors.

3min 32sec after the power trip mission 7340 restarts its journey at a speed restricted to 100 km/h in accordance with the RCC instructions. In the event of a power trip on the overhead line involving an Arbel shuttle, the source of the power trip is suspected to be associated with a tarpaulin coming into contact with the overhead power line. The train speed is therefore limited to 100 km/h in an attempt to limit aerodynamic turbulence and to prevent the tarpaulin in question from causing further power trips and possible damage to the tunnel equipment.

The 2nd stop

When the first flame alarm is sounded by the detection station SD38, the front of the train is about 2km before station SAFE 4F which extends from CP 4202 to CP 4276.

When the driver is informed by the chef de train of the fire alarm arising from the on-board detector located at the rear loader wagon, she alerts the RCC, and at this point she is still on the approach to the warning board “SAFE 4F 1000M”.

The procedures stipulate that it is the supervisor of the RCC who decides on which strategy to adopt, be it to stop at the SAFE station or to continue according to the “Moving Train” procedure.

By the time he has determined the position of the train from the occupancy of the track circuits and made a decision, it is too late to stop at the SAFE station. The “Moving Train” procedure is therefore the default choice.

At that moment in time, a momentary arcing causes a second trip of the overhead power line.

Absorbed by the fire procedures and by taking the necessary decisions, the supervisor does not consider re-energising the overhead power line, nor do the RTM and EMS controllers

The “stopping train” procedure is therefore unavoidable and implemented as quickly as possible to prevent a stop at the French cross-over which extends between CP 4464 and CP 4478.

The train stops at PK 44.202; the amenity coach is in line with CP 4418.

4.3 - Evacuation of passengers and exit of other trains

4.3.1 - Summary of witness evidence

The summaries given below have been compiled by the technical investigators on the basis of the statements given by the various people they have met, retaining the details given by the person that appear useful in clarifying the events. There may be discrepancies between these various statements; or with the observations given elsewhere, or with the description of facts established by the investigators as presented in chapter 5.

Driver of mission 7340

After the controlled stop at CP 4418, the driver confirms the stop with the RCC and she contacts the chef de train to tell him to proceed with the evacuation. The chef de train informs her that he has distributed the smoke masks. He carries out the evacuation on his own.

On opening the door of her cab, she discovers that there is already a large amount of smoke and she cannot see where she is going. Despite the conditions, she manages to find the walkway in the running tunnel North and then CP 4418.

The chef de train

Around 12:23 hrs he receives a fire alarm warning at his workstation. This alarm comes from the rear loader wagon. He informs the driver and closes the HVAC dampers. The amenity coach is thereby pressurised preventing any smoke from entering.

As a precaution, he hands out the breathing masks to every passenger. Once the train stops, he waits for the driver of mission 7340 and then together they start to evacuate the passengers via CP 4418 towards the service tunnel. The driver then does a safety check in the amenity coach to make sure no one was left behind. Once she is back with him, he calls the RCC so that they can close the door at CP 4418.

They wait for the evacuation vehicles which arrive around 14:20 hrs /14:30 hrs to take the passengers and maintenance staff to the emergency centre where doctors from the SMUR (Service mobile d’urgence et de reanimation – Emergency medical service) unit are waiting for them.

He and the driver stay near CP 4418 until 15:00 hrs /15:30 hrs when their managers arrive to look after them.

Lorry drivers

They state that the evacuation went calmly and they were quickly taken to the service tunnel.

4.3.2 - Conclusion of the investigation

Concerning the evacuation of the passengers

Examination of the recordings and emergency services reports confirm that the evacuation of the passengers went without significant difficulties and was conducted in line with current procedures. The evacuation of the driver was slightly hindered by the difficulty she experienced opening the box containing the breathing masks in the locomotive.

Concerning the evacuation of the other trains

At the time of the second fire alarm, two trains are in the running tunnel South and another two are about to enter it. The latter two trains are stopped before entering the tunnel and the first two exit on the British side (at 13:23 hrs and 13:36 hrs respectively) without having had to stop but they were slowed down.

No other train apart from mission 7340 is in the running tunnel North. Only one train has left the British terminal but it is stopped at the UK portal, the access signal to the tunnel having been closed.

4.4 - Managing the ventilation

4.4.1 - Summary of witness evidence

The summaries given below have been compiled by the technical investigators on the basis of the statements given by the various people they have met, retaining the details given by the person that appear useful in clarifying the events. There may be discrepancies between these various statements; or with the observations given elsewhere, or with the description of facts established by the investigators as presented in chapter 5.

The supervisor

After mission 7340 stops, the supervisor selects the monitors that allow him to see what is happening within the SAFE station and observes the smoke. He informs the controllers. The supplementary ventilation system (SVS) is then activated in both tunnels. A damper on one of the piston relief ducts (PRD) is faulty; the EMS controller initiates a sequence of emergency closures which does not succeed. He contacts the installation maintenance service.

The supervisor refuses to increase the speed of the trains in the running tunnel South (20km/h) despite several requests from the rail traffic management controller (RTM). When the maintenance service informed the RCC that the faulty PRD is virtually closed, the supervisor calls for the SVS to be reconfigured to limit it to the running tunnel North. He authorises both trains that are situated in the South tunnel to travel at 60km/h as there is carbon monoxide present in certain areas of the running tunnel South.

When the two trains in the South tunnel exit the tunnel, the Supervisor reconfigures the SVS in both tunnels to ventilate the South tunnel in line with the requests expressed by the leader of the rescue team (FLOR) who is on site.

Engineering management system (EMS)

The supervisor announces a level 2 alarm in the running tunnel North after the FD controller declares a 2nd alarm at CP 3912.

In response, the EMS controller activates his incident screen. He verifies the sequential order of events and states that a valve on the piston relief duct (PRD) is in an unknown state and not closed as it should be. He calls the maintenance service (DI EM) and attempts an emergency closure which cannot be achieved. When the overhead power line trips for a second time, an automatic sequence (CO presence) is in progress. He does not consider resetting the overhead power line as it is not his priority given the situation. He stated that this is the same method as the one applied during training exercises in the simulator.

As soon as the call is made to the trains in both tunnels to slow down to 10km/h, he starts the supplementary ventilation system (SVS). It is because of the fault on the PRD that the speed of the trains in both tunnels is reduced to this level.

Having examined his monitors, he opens two doors at the relevant cross-passages. He reconfigures the overhead power line to enable the trains that have stopped in the UK terminal behind mission 7340 to reach the platforms.

Once the evacuation is complete, he closes the doors at the cross-passages and returns the setting of the SVS to +2 and -2[15]. The screens are full of alarms. He reports the loss of an SVS fan at the Sangatte plant. He sends maintenance to the site. A decision is made not to reuse this fan, as it requires putting the plant on "local" setting thereby running the risk of losing the second fan.

4.4.2 - Conclusion of the investigation

At 12:28 hrs, the supplementary ventilation system (SVS) is switched on at a high level in both tunnels, blowing from France to Great Britain.

At 12:39 hrs, the passengers having been evacuated, the SVS is set at a lower level in order to limit the spread of the fire.

At 12:47 hrs, the 21kV network trips in the running tunnel North because of a failed cable. This leads to the loss of half of the fans of the ventilation systems (NVS and SVS) at the Sangatte plant. This failure has no effect on performance as the system has been designed with full redundancy. The network is reconfigured manually and the full ventilation systems are resumed at 14:21 hrs.

At 13:17 hrs, the SVS is turned off in the running tunnel South which allows the speed of the trains in this tunnel to be increased (from 20km/h to 60km/h). At 13:38 hrs, once these trains exit the tunnel, the SVS is turned back on in this tunnel.

Following a request from the fire services, the direction of the SVS is reversed at 13:57 hrs (blowing from Great Britain to France) then again at 14:46 hrs (blowing from France to Great Britain).

It is reversed again at 23:09 hrs (Great Britain to France).

The SVS is finally switched off at 00:22 hrs on 18 January 2015.

The functioning and management of the ventilation systems were satisfactory. The trip of the 21kV network and the malfunction of the PRD damper 4935 were managed in line with procedures and did not have an adverse effect.

[15] The setting relates to the angle of the SVS fan blades which are adjustable to +7 (maximum feed rate) to -7 (maximum extraction).

4.5 - Firefighting

4.5.1 - Summary of witness evidence and reports

The summaries given below have been compiled by the technical investigators on the basis of the statements given by the various people they have met, retaining the details given by the person that appear useful in clarifying the events. There may be discrepancies between these various statements; or with the observations given elsewhere, or with the description of facts established by the investigators as presented in chapter 5.

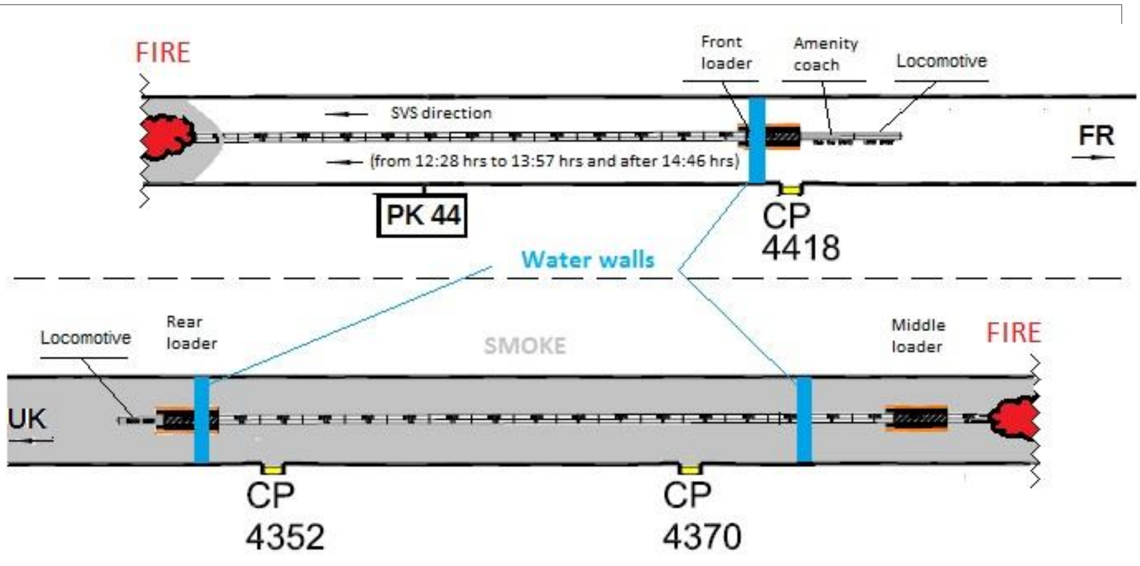

Figure 38: Positioning the burning train and the water walls

Evidence of the fire detection controller (FD)

At 12:24 hrs, the FD controller calls the FLOR UK (vehicle L31) on patrol at the UK crossover UK [PK27] to go to CP 4418 telling them that a fire alarm is sounding.

At 12:25 hrs, the FLOR France (vehicles L32 and L34) is sent to CP 4418.

At 12:28 hrs, the FD controller calls the FLOR UK to send vehicle L33 to CP 3088 to earth the overhead power line.

At 12:35 hrs, the FD controller calls CODIS (Centre Opérationnel Départemental des Services d'Incendie et de Secours – Regional control centre for the fire and rescue services).

At 12:37 hrs, the evacuation is complete.

At 12:40 hrs, a car leaves from PK32 for Salamander (see section 4.7.2) then returns to CP 3088.

At 12:55 hrs, after going to PK32, L33 goes to CP 3088 where the EMS controller had decided to set the earthing poles for the overhead power line (MALT procedure – Mise a La Terre).

The FD controller stated that he had some difficulty communicating with the FLOR.

Report from the French first line of response (FLOR France)

At 12:30 hrs, call from the FD controller about a fire alarm on a freight shuttle at CP 4418.

At 12:40 hrs, information from the FD controller that all passengers have been evacuated.

At 12:50 hrs, the first SLOR France fire engines arrive at FEMC (Fire Equipment Management Centre).

At 13:04 hrs, the STTS FLOR France vehicles arrive at CP 4418. One of the STTS FLOR UK is there, the second is at CP 3088 to carry out the earthing of the overhead power line at the rear of the train.

At 13:01 hrs, the French police arrive at FEMC.

At 13:25 hrs, the French chief firefighter (from SDIS 62) arrives at FEMC.

At 13:30 hrs, authorisation to implement the Salamander procedure.

At 13:40 hrs, earthing of the overhead power line is effective at CP 3088 and 4418.

At 13:42 hrs, request for engagement of the second line of response (SLOR) as soon as possible.

At 13:44 hrs, the location of the STTS-Com is planned at CP 4464.

At 14:00 hrs, “water walls” are in place at CP 4418 and CP 4370 and a third is being set up at CP 4352.

Figure 39: The implementation of a “water wall” (in an exercise)

At 14:10 hrs, departure of the first teams of SLOR France towards CP 4418 where they arrive at 14:36 hrs.

At 14:40 hrs, the 40 passengers arrive at FEMC (*the driver and the chef de train remained at CP4418).*

At 14:51 hrs, a team formed of two agents from FLOR France and two firefighters from SDIS 62 wearing individual breathing apparatus (ARI) with thermal cameras enter the running tunnel North to locate the source of the fire and to begin extinguishing it.

At 15:44 hrs, the fire is confirmed to be located 270m from CP 4418. A new team of FLOR France and SDIS 62 enters the tunnel.

At 16:48 hrs, implementation of additional fire hoses from CP 4418 (SDIS 62) and CP 4370 (FLOR Fr) to fully extinguish the fire.

Report from the British first line of response (FLOR UK)

At around 12:23 hrs, the FD controller calls the FLOR UK team which is on patrol with a STTS vehicle towards the UK crossover (PK 27). He asks them to provide assistance with the evacuation of a freight train that is on fire at CP 4418.

Upon arrival at CP 4418, this team does not find any passengers. They then go to the next CP where they do not find anyone either. The FD controller explains that the passengers are in a non-standard cross-passage. In conjunction with FLOR France, they escort the passengers towards the service tunnel.

The FD controller sends the second STTS from FLOR UK to CP 3088 to earth the overhead power line.

The Eurotunnel incident officer (EIO) from FLOR France asks the team of the first STTS to meet at CP 4370 which is located towards the middle of the train. The door at CP 4370 having been opened, two agents enter the tunnel equipped with breathing masks and a thermal camera to locate the position of the fire. They witness the presence of a lot of smoke. After conducting a difficult search, they report that the fire is in the front rake about 60 feet (18m) [*in fact the fire is 150m away]* from the door to the cross-passage.

The team receives the instruction to set up a water wall in the middle of the train. The loader wagon is not facing the cross-passage, so the water wall has to be placed behind the first lorry that is identified as being the source of the heat. It is therefore placed behind the 2nd lorry beyond CP 4370.

The two FLOR UK teams gather at CP 4370.

Shortly after, the EIO asks them to set up a third water wall on the rear loader wagon, the leader of FLOR points out to him that that is not in line with the Salamander procedures and it could harm the functioning of the two main water walls.

The EIO confirms he wants this third water wall which is installed from CP 4352. Water pressure remains sufficient.

At that moment, the FLOR UK hears banging and shouting coming from the rail tunnel at CP 4370. The EMS controller is not able to open this door remotely. The FLOR UK opens it manually. Once opened, no one is to be seen but there are hand prints in the soot on the other side of the door. Two minutes later, firefighters appear in the service tunnel through CP 4352. They say they had entered the running tunnel North at the front of the train, that they had gone through two water walls and through the fire and that they tried to exit at CP 4370 (they only had 50 bars in their breathing apparatus by this point) and they had to run to the next cross-passage, CP 4352.

Report by the Departmental Fire and Rescue Service (SDIS 62)

At 12:31 hrs Eurotunnel calls the regional operations centre for fire and rescue services (CODIS) to advise them that a freight shuttle has stopped in the running tunnel North where smoke is present and carbon monoxide has been detected.

At 12:46 hrs, the first firefighting and SDIS command resources arrive at Eurotunnel's emergency centre (FEMC).

At 13:01 hrs, a second message from Eurotunnel provides additional information.

From 13:20 hrs, a STTS SLOR France and STTS-Com are equipped, but because of a lack of driver, cannot enter the service tunnel.

The sous-préfet of Calais arrives at the Operational Command Post[16](PCO) at 13:30 hrs.

From 13:46 hrs, the FLOR reports the presence of a fire on mission 7340. The Salamander procedure is implemented. The full deployment of this procedure is effective at 14:08 hrs.

At 14:08 hrs the chief firefighter reiterates his request for STTS drivers. At that time, SDIS 62 is in a position to prepare a second STTS SLOR and an STTS ambulance. At 14:15 hrs, the STTS drivers are available. One of the STTS vehicle breaks down on departure. It is replaced by another one.

The first STTS SLOR arrives at CP 4418 at 14:36 hrs.

At 14:56 hrs, a first two-man team from SDIS 62 enters the running tunnel North with a thermal camera to locate the source of the fire. Other mixed teams (SLOR and FLOR) are set up. *At 15:44 hrs a first message from STTS-Com reports the presence of two lorries on fire.*

At 15:56 hrs, intervention is organised: fire engagement, firefighting, logistics and assistance to people.

At around 16:00 hrs, the FLOR UK located at the cross-passage at the rear of the train hears banging sounds on the door at CP 4352 [*in fact it is CP 4370].* This information is forwarded to the PCO. The source of these banging noises is not clear and fearing that there are people at risk on the rear rake, the sous-préfet initiates the bi-national emergency plan (BINAT). The fax declaring the BINAT GO is sent to the British authorities at 16:17 hrs.

The rear rake is quickly inspected by the mixed teams up to CP 4370. Nobody is located in the running tunnel North. However, the presence of hand prints in the soot covering the walls of the wagons is noted.

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[16] PCO = Poste de Commandement Opérationnel: Incident Coordination Centre (located in France)

The firefighters bring the fire under control at 16:20 hrs.

After a second inspection of the rear rake, the end of the emergency bi-national action plan (message BINAT STOP) is declared at 17:53 hrs.

SLOR UK Commander's Report

The SLOR UK commander goes to the midway point of the tunnel with the STTS3 to wait for the BINAT GO signal to be given. He instructs STTS4 which still is not totally staffed to join him as soon as the team is complete.

Whilst en route, he tries several times to contact the FD controller but does not manage to make contact. Once near the midway point, the FD controller contacts him on the concession radio giving him the instruction to go straight to the incident scene where they urgently need his help. The commander asks for confirmation that he is authorised to go through the midway point and the FD controller confirms the previous instruction. He again asks for confirmation that BINAT GO has been initiated and the FD controller assures him that it has.

When he informs his operation centre that he is waiting at CP 4418, the operation centre tells him that BINAT GO has not been initiated and that SLOR UK should return to the international border [*PK 37*], which they do.

However, *[as he is also FLOR competent and hence allowed to stay in the French part of the tunnel],* the commander stays at CP 4418 with the French teams in order to stay abreast of the developments regarding this incident.

When returning to CP 4370 to inform the FLOR UK about the progress of the operations, he hears banging and shouting coming from the cross-passage door and witnesses the incident described above.

Once BINAT GO is initiated, the SLOR UK returns to CP 4418. The commander decides to use the FLOR UK rather than the SLOR UK to tackle the fire in the tunnel with the French teams.

The SLOR UK is sent back to CP 4370 to recover the hoses that are in the tunnel. It then returns to CP 4418 and is held on stand-by.

Once the fire has been put out, the commander of operations for the French emergency service asks the SLOR UK to do a visual inspection to see whether there are any possible stowaways in the lorries. The SLOR UK commander points out that this check is not necessary as it has already been done. He then receives a written order to carry out this task. Even though only one side of the train has been attended, the BINAT STOP is initiated. The SLOR UK therefore ceases this check and returns to the UK terminal.

Figure 40: Pictures of firefighters in the service tunnel. **on**

on managing the STTS and their drivers

At 12:55 hrs, 5 drivers with 3 STTS maintenance vehicles are sent to the emergency centre (FEMC).

At the RCC supervisor’s request, the 3 STTS maintenance vehicles are despatched to CP 4418 to recover the passengers who had been evacuated from mission 7340.

A driver who is also a telecom technician is sent to the tunnel at the request of the FD controller to carry out a task in a technical room.

A driver stays at FEMC.

From 13:20 hrs, a STTS SLOR and STTS-Com are equipped but they cannot enter the service tunnel due to a lack of drivers.

An additional driver is sent to FEMC at 14:00 hrs which enables the SLOR to set off then two other drivers arrive at 14:25 hrs.

The use of drivers and vehicles by the RCC supervisor was less than ideal; it would have been preferable to use the STTS first to convey the SLOR to the incident site, and then once unloaded, use them to take the passengers back to the terminal.

4.5.2 - Conclusion of the investigation

It is observed that the water walls were set up on the loader wagons from 14:00 hrs which is about one and a half hours after the train on fire had stopped.

These water walls are designed to prevent the fire from spreading to the locomotives and the rear rake and not, strictly speaking to tackle the fire.

SLOR efforts to put out the fire only really began at 15:56 hrs which is about three and a half hours after the train had stopped. About an hour was lost due to the absence of STTS drivers. If the drivers had been available immediately, the task could have begun sooner but probably not before 15:00 hrs which is still two and a half hours after the train stopped.

In 2008 the time to intervention was two hours and this had been found to be excessive which had led to a review of some of the procedures including the earthing procedure.

The fire was declared as contained from 16:20hrs.

Examination of the alternative scenarios (see paragraph 4.10) suggests that the limited consequences of this fire compared to the one in 2008 are solely due to the position of the incident lorry and the low combustible charge of its load and that of the lorry in front of it.

The lack of efficiency in fighting the fire in the tunnel despite the efforts made by the services involved demonstrates the relevance of the implementation of SAFE stations and confirms that a fire on a train that has stopped outside of these stations will not generally be contained until it reaches its maximum size (defined by the position of the lorries and the nature of their loads).

If the load configuration and combustible charge of the lorries is unfavourable, material consequences similar to those in 2008 will probably be unavoidable in fires of this type.

A firefighting crew in the running tunnel encountered difficulties as they tried to re-join the service tunnel using CP4370 and had to run to the next cross-passage (CP4352) as the level of air in their breathing apparatus was getting low.

4.6 - The problem with the pagodas on the Arbel wagons

The incident occurred because there was no roof on the Arbel wagon to separate the over-height aerial from the overhead power line. Had the incident lorry been loaded on an Arbel wagon with a front pagoda, the incident would not have occurred. This has led the investigators to research the history of the design of the Arbel wagons.

4.6.1 - Arbel wagon pagoda design

Shortly after the Arbel wagons entered service in 2000, Eurotunnel started to notice fatigue cracks developing in the construction of the pagodas. The fatigue cracks in the pagodas did not affect the overall structural integrity of the wagon but they presented a safety risk, as they could eventually have resulted in an entire pagoda assembly becoming detached from its wagon.

After initially repairing the fatigue cracks on the pagodas by welding, Eurotunnel faced the situation where the pagodas could no longer be weld-repaired because of the lack of parent material remaining in the structure.

4.6.2 - Modifications to the design of the Arbel wagons

By 2007, Eurotunnel had a group of pagodas which were non-repairable and made an application to the IGC, supported by a comparative risk assessment, for authorisation to operate the Arbel wagons without the central two pagodas (this left one pagoda at each end of the wagon).

The IGC initially expressed its opposition to the proposal in the absence of validation trials investigating the effects of the removal of the pagodas on the lorry tarpaulins. These trials were undertaken by Eurotunnel on two wagons between August 2007 and January 2008. On 30 January 2008, the IGC authorised Eurotunnel to operate the Arbel wagons with the central two pagodas removed. In its authorisation letter, the IGC made it clear that it considered this situation to be temporary while a long-term solution to the problem of the pagodas was developed. In response, Eurotunnel started a programme to develop an alternative pagoda design based on a bolted construction.

The number of serviceable pagodas continued to decrease and Eurotunnel met in August 2011 with the CTSA to discuss the removal of the rear pagoda from the Arbel wagons. Eurotunnel presented a comparative risk assessment to support its proposed modification (discussed further in Section 4.6.3).

In September 2011, the CTSA wrote to Eurotunnel to explain that, provided that certain operational conditions were met, it proposed to take no further action on the matter. The conditions related to Eurotunnel modifying its operational practices to ensure that the Arbel wagons would always be operated with the single pagoda at the leading end in the direction of travel. This aimed to ensure that the cab of lorries would remain under the pagoda at all times to protect the lorry drivers from electric shock when leaving and entering their cabs. Based on the September 2011 letter from the CTSA, Eurotunnel started modifying the Arbel wagons and removed the rear pagodas.

As the number of serviceable pagodas was still decreasing, in June 2012 Eurotunnel applied to the IGC for the removal of the remaining pagoda from the Arbel wagons.

This submission was again supported by a comparative risk assessment (again, discussed further in Section 4.6.3).

The IGC authorised this modification on 27 July 2012 and by the end of 2012, Eurotunnel had removed all pagodas from the whole fleet of Arbel wagons except for one and a half shuttles.

At that time, Eurotunnel encountered operational difficulties with tarpaulins becoming loose and causing overhead line power trips. Eurotunnel concluded that the front pagodas must have had a positive effect at preventing tarpaulins from becoming loose and this led Eurotunnel to start re-fitting front pagodas on some wagons (discussed further in section 4.9).

As it still had approximately 80 serviceable pagodas of the original design, Eurotunnel decided to mount these pagodas in the short term while it placed an order for the procurement of pagodas of an improved design.

The work on the improved design of pagodas had started in 2008 in response to the IGC's request to look for a longer term solution to the problem of pagoda (section 4.6.2).

In 2009, Eurotunnel successfully trialled two prototypes of this design. The improved design was based on a bolted construction which seemed to be better able to sustain the operational loads.

However, the work on this design was shelved in 2009 at the time when Eurotunnel introduced project Salamander (section 4.5.1).

In early 2013, Eurotunnel placed an order for the procurement of 150 pagodas of the design that had been developed in 2008-2009 and proceeded to start installing them on its Arbel wagons.

This covered half of the fleet of Arbel wagons. The intention was that the rear rakes of Arbel wagons would be fitted with a pagoda but not the front rakes. Eurotunnel relied on its allocation stage to decide which lorry should be allocated to each wagon: a lorry perceived to be at-risk was either allocated to a Breda wagon or to an Arbel wagon with a pagoda.

The plan was that in time, the front rakes would be fitted with a new wind deflector, as aerodynamic turbulence had been identified as the reason why Eurotunnel was experiencing an increased frequency of tarpaulin problems.

Work on the design of the wind deflector started in April 2013 and is still on-going.

By June 2013, Eurotunnel started installing the 150 pagodas of the bolted design and, on 20 August 2013, it identified the first fatigue crack on one of these pagodas. This was quickly followed by other cracks on other pagodas. Eurotunnel realised that the improved design, despite having been successfully validated in 2009, was not delivering what it expected. The problem appeared to be related to difficulties associated with mass production of the pagodas.

On 3 November 2013, Eurotunnel started to remove the bolted pagodas and restarted work on developing an alternative design.

In early 2014, Eurotunnel had completed its redesign work and successfully fatigue tested the new design of pagoda.

It placed a new order for 150 pagodas with a different supplier shortly afterwards and started installing the new pagodas on the Arbel wagons in August 2014, again on the rear rakes.

Eurotunnel stated that its intention was to continue with the wind deflector programme to eventually fit wind deflectors to the rest of the fleet.

In the interim period between the incident on 17 January 2015 and the time when a validated technical solution on the wind detector becomes available, Eurotunnel has ordered more pagodas of the existing design with the intention to fit them on the front of all its Arbel wagons.

4.6.3 - Risk assessments in support of the removal of pagodas

Risk assessments and mitigations claimed

In accordance with its safety management system described in SAFD 1000, the applications by Eurotunnel to remove the rear and front pagoda in late 2011 and mid-2012 were supported by comparative risk assessments looking at the effects of the removal of the pagodas on some of the operational risks.

The key risk upon which Eurotunnel was focussed appeared to be lorry drivers receiving electric shocks during the loading and unloading operations. This risk had increased because the physical barrier between the lorry drivers and the overhead power line had been removed. A specific risk assessment led Eurotunnel to introduce the CCAQ project (Coupure Catenaire a Quai) which requires that the power is isolated from the overhead power line during loading and unloading operations. This measure eliminates the risk of electric shock at the platform.

The 2012 application for the removal of the last pagodas included an additional comparative risk assessment looking at the other effects of the modification. The increased safety risk of a lorry fire starting due to electrical arcing between the overhead power line and an aerial fitted to a lorry was not specifically considered. However, the risk of a fire starting due to electrical arcing with an open trailer (eg car transporter) was considered and so was the accidental collapse of the overhead power line following the total or partial detachment of tarpaulins.

This risk assessment recognised that the removal of the physical barrier between the lorries and the overhead power line had increased the likelihood of electrical arcing between a lorry and the overhead power line. It acknowledged that the risks associated with electrical arcing instead of being *removed,* as they were before the removal of the pagodas, now had to be *controlled*.

In accordance with Eurotunnel’s SMS and consistent with the permitted approaches described in the CSM on risk evaluation, the increased risk had to be mitigated to bring the residual risk back to an overall level equivalent to its level before the introduction of the modification. The mitigations claimed in the risk assessment were:

- the over-height system at the entrance to the terminal (a system which is not sensitive enough to detect aerials);
- the aerial detection system at the bottom of the ramp; and
- the introduction of the SAFE stations.

The introduction of the SAFE stations, despite bringing benefits to the protection of the assets and operation, had no impact on the safety of lorry drivers and Eurotunnel personnel. This is because the stations are only activated after the evacuation of people. Furthermore, Eurotunnel, whilst claiming benefit from the aerial detection system, did not assess its integrity. It has now been established that the integrity of the aerial detection system is insufficient to reliably detect small aerials.

Therefore, the arguments presented in the comparative risk assessment did not actually demonstrate that the overall risk to lorry drivers and Eurotunnel personnel had been managed to be equivalent to that before the removal of the pagodas.

The risk assessment also considered the increase risk of damage to the overhead power line due to a fire on the train. Eurotunnel had commissioned a study looking at the effects of a shuttle fire on the structural integrity of the overhead power line to inform its risk assessment. The report concluded that a shuttle fire would only have an effect on the structural integrity of the overhead power line when the speed drops below 25-30 km/h. The report made a couple of recommendations to increase the tension in the overhead line to avoid it sagging when heated by the passage at slow speed of a shuttle carrying a lorry on fire. These recommendations are quoted in the risk assessment as demonstration that Eurotunnel had mitigated the risk. The risk assessment overlooked the fact that the absence of a physical barrier also reduces the protection of the power line from accidental contacts with burning debris or loose tarpaulins likely to lead to a power trip.

CTSA/IGC acceptance

In accordance with the European Common Safety Method (CSM) for risk evaluation, the risk assessment was reviewed by an assessment body. The assessment body concentrated mainly on checking that the process for risk assessment described in the CSM had been followed. The review by the assessment body did not identify that some hazards had been omitted and that some of the mitigation measures were not relevant to the safety of individuals.

The application file submitted by Eurotunnel to the IGC to support its application to remove the last pagoda in June 2012 contained:

- a description of the Coupure Caténaire à Quai (CCAQ) project and the associated specific risk assessment,
- the comparative risk assessment looking at the rest of the operations;
- the study of the effect of a shuttle fire on the overhead power line;
- the report by the assessment body.

The application file was reviewed by the CTSA who primarily checked that the process described in the CSM for risk evaluation had been followed. On that basis, the CTSA made its recommendation to the IGC that the proposed change could be accepted. Following this recommendation, the IGC authorised the operation of Arbel wagons without any pagodas in July 2012. This approach was consistent with that required by the CSM which generally does not require an NSA to challenge an application provided that the process has been followed[17]; it is only expected to intervene if it believes there to be a substantial safety issue. No such safety issue was raised by the IGC or CTSA at the time.

[17] Article 15 of Regulation 402/2013 on the CSM for risk evaluation and assessment.

4.6.4 - Summary of key findings associated with the management of pagodas

The original design of the Arbel wagons was flawed in that the pagodas were subject to rapid fatigue failures, which could not continue to be repaired.

Eurotunnel's approach to this, at least in the short term, was to remove the pagodas from the Arbel wagons.

The removal of the pagodas increased the risk to lorry drivers during the loading/unloading operations due to electric shock. This was mitigated by isolation of the overhead power supply at the platforms during the loading/unloading operations.

The removal of pagodas also resulted in an increased likelihood of a fire occurring following electrical arcing between over-height objects and the overhead power line. The increased likelihood of a fire occurring resulted in an increase in risk to the safety of the lorry drivers and Eurotunnel staff. This risk was partially recognised by Eurotunnel in its justification for the modification, but the mitigation measures claimed in the risk assessment would not reduce the risk to an equivalent level to that before the modification.

The CTSA and IGC accepted Eurotunnel's comparative risk assessments, primarily on the basis that it complied with the CSM on risk evaluation and authorised operation of the Arbel wagons without pagodas.

4.7 - Measures taken by Eurotunnel after the fire in 2008

4.7.1 - Fire of 11 September 2008

On 11 September 2008 a large fire broke out on a freight shuttle which led to a controlled stop in the Channel Tunnel.

No deaths or serious injuries were caused by this incident however there was considerable material damage. All the carrier wagons and lorries were burnt out. The two locomotives and the amenity coach sustained damage linked to the high temperature and smoke which they were exposed to. The running tunnel North through which the shuttle was travelling sustained significant damage and could not be put back into service until February 2009.

The fire broke out in a lorry and spread throughout the whole shuttle.

It was a Breda shuttle, which was completely covered. The source of this fire was specific to the incident lorry and is not related to any electrical arcing problems with the overhead power line as experienced in fires that have occurred since then.

4.7.2 - Measures taken by Eurotunnel after the fire

On 11 March 2009 Eurotunnel presented its action plan to the CTSA in which it draws lessons from the fire in 2008.

This action plan called “Project Salamander” comprises three aspects:

- Tightening up on prevention;
- Speeding up and improving intervention by firefighting services; and
- The creation of areas dedicated to firefighting in the tunnel (SAFE stations).

Alongside this project, other measures have been taken concerning, in particular, maintenance rules and layout of the amenity coaches as well as the arrangements for the controlled stops of freight shuttles.

4.7.3 - The joint investigation and recommendations

This serious incident was subject to a joint investigation by BEA-TT and RAIB.

The investigation led to the drafting of 39 recommendations which focused on the following particular areas:

- Evacuation of people;
- Firefighting;
- Rolling stock;
- Permanent installations;
- Rail control centre procedures and tools;
- Safety management system.

These recommendations were formally raised on 16 November 2010 when the report was published.

4.7.4 - *Implementation and monitoring of recommendations*

In its annual report of 2011, the IGC summarised the progress on the implementation of these recommendations:

- Eurotunnel deemed that 24 recommendations were justified and implemented them. The IGC felt that these implementations allowed for the closure of these recommendations.
- Eurotunnel deemed that 6 recommendations were not justified and the IGC agreed with Eurotunnel.
- The IGC deemed that 9 other recommendations warranted further studies.

In its 2012 report, the IGC considered the further studies carried out by Eurotunnel and the CTSA allowed for closure of these last 9 recommendations:

- 2 recommendations were not kept;
- 7 are considered as settled.

Of the 8 recommendations which were not adopted in the end, recommendation n°38 concerning the change management process has again been called into question in this investigation.

4.7.5 - *Recommendation n°38.*

The investigation into the 2008 fire had already highlighted some concerns with the quality and robustness of the safety assessments carried out by Eurotunnel in support of changes that it was making to its operations. As a result of these concerns, the following recommendation to Eurotunnel was made in the investigation report (ET/2010):

"*Examine the change management process and its implementation in order to improve the quality and rigour of the safety studies performed to justify projects involving changes to procedures and practices.*"

In January 2012, the IGC reported Eurotunnel's response to this recommendation in its first annual report on the recommendations:

"*Eurotunnel feels that this recommendation is pointless since this item is already covered in existing texts.*

The change management process is managed by means of the change management system known as ECM and each major modification is submitted to the IGC Safety Authority.

The change management process (techniques, procedures, etc.) is described in detail in the Safety Management System document SAFD 1000, Paragraph 6.2.8."

The IGC accepted Eurotunnel's response. Eurotunnel has provided no new evidence to confirm that the concern regarding the quality of the implementation of the change management process had been addressed.

4.8 - Measures taken by Eurotunnel after the fire of 2011.

4.8.1 - Incident on 24 March 2011

On 24 March 2011, a freight shuttle departing from Coquelles at 19:42 hrs tripped the overhead power line as it was entering the tunnel at the French portal. Power was successfully reinstated and the train restarted two minutes later. At 19:57 hrs a first fire alarm was detected by the tunnel detectors near CP4417 and a message was sent to all trains to reduce speed to 100 km/h and close their dampers. There were no further alarms and at 20:01hrs the service returned to normal.

Shortly after arrival in Folkestone the agents began to unload the lorries and at 20:28 hrs an agent on carrier wagon 3 of the rear rake raised a fire alarm, reporting that an agricultural tractor on the flatbed trailer of a truck, was on fire. The overhead power line at the platform was isolated. The fire was confirmed and the two lorries ahead of the affected one were unloaded. The Kent Fire and Rescue Service arrived and extinguished the fire.

4.8.2 - Measures taken by Eurotunnel after the fire

Eurotunnel's investigation concluded that the cause of the initial arcing was an aerial belonging to the burned tractor.

It is noticeable that the tractor was the middle of three tractors loaded on the flatbed trailer, a long distance away from the front of the lorry. As a result it is possible that this tractor was not scanned for over-height objects by the aerial detection system.

Following the incident, Eurotunnel modified its loading instructions to ensure that all flatbed trailers carrying agricultural vehicles would be allocated to Breda wagons.

4.9 - Measures taken by Eurotunnel after the fire of 2012

4.9.1 - Incident on 29 November 2012

Shortly after starting the removal of the last pagoda on the Arbel wagons in July 2012, Eurotunnel began to notice an increase in the number of power trips particularly as a result of loose tarpaulins.

This culminated on 29 November 2012 when Eurotunnel suffered an incident in which a car loaded on a transporter caught fire following arcing with the overhead power line at the UK portal. By the time the shuttle arrived in France, a major fire had developed on the car transporter which required the intervention from the firefighters.

Eurotunnel's investigation concluded that the cause of the initial arcing was either an aerial (which might have raised because the car was loaded backwards on the transporter) or a loose tarpaulin on one of the cars. The CCTV footage taken during the loading operation showed the presence of both the aerial and tarpaulin.

The aerial detection system did not activate during the loading of the car transporter on the shuttle. The reliability of the detection system was not assessed at the time as Eurotunnel was believed that it was the aerodynamic forces associated with the aerial travelling backwards which had led to the aerial possibly being over-height.

Following the incident, Eurotunnel modified its loading instructions to ensure that all car carriers would be allocated to Breda wagons.

4.9.2 - Measures taken by Eurotunnel after the fire

In December 2012, faced with this increase in incidents which appeared to be linked to the removal of the last pagoda on the Arbel wagons, Eurotunnel decided to:

- start a programme of re-fitting an end pagoda to some of its Arbel wagons (see section 4.6.2) ; and
- introduced the tarpaulins check area.

4.10 - Alternative scenarios

4.10.1 - Methodology

The investigators commissioned a study by a tunnel fire specialist in order to obtain an expert view on the impact that the position and type of lorries had on the outcome of the fire. The rest of this section is based on the work carried out by this fire specialist. The study considered three alternative scenarios. These are discussed below.

4.10.2 - Scenario 1 – A lorry had been loaded on the last carrier wagon of the front rake

Had the last carrier wagon of the front rake been loaded with a lorry, it is likely that the fire would have spread to this vehicle before the train came to a stop. Once the train had stopped, the temporary reversal of air flow before the SVS was active would have helped establish the fire on this vehicle. At the same time, the fire was also spreading to the lorry on carrier wagon 14. Therefore, by the time the SVS was fully established, three vehicles would have been involved in the fire.

Once the lorry on the last carrier wagon of the front rake was ablaze, the chances of the fire spreading across the loader wagon to the lorry on the first carrier wagon of the rear rake would have been significantly increased. When the SVS was reduced to a low level at 12:39 hrs, it is likely that the temperature 20 metres away would have been sufficient to promote fire spread to the lorry loaded on the first carrier wagon of the rear rake. The fire would have continued to progress to the subsequent lorries on the rear rake until such a time as the fire size became limited by the available oxygen.

4.10.3 - Scenario 2 – A full size lorry had been loaded on wagon 13 instead of the van

Had a lorry been loaded on wagon 13 instead of a van, it is likely that the fire would have crossed the smaller gap between the lorries during the period of low ventilation. Slow fire spread towards the front of the train is likely to have continued (the rate depending on many factors).

4.10.4 - Scenario 3 – The incident lorry had been loaded on the first carrier wagon of the front rake

Had the incident lorry been loaded on the first carrier wagon of the front rake, it is likely that the fire would have spread to the lorry loaded on the second carrier wagon before the train came to a halt. Once the fire was established on this lorry, it is likely that the fire would have spread to the lorry loaded on the third carrier wagon and beyond until such times that the fire size became limited by the available oxygen.

It appears unlikely that the fire would have spread across the loader wagon to the amenity coach which may have sustained damage similar to the damage caused to the van loaded on carrier wagon 13 in the actual incident.

4.10.5 - *Conclusion on alternative scenarios*

In conclusion, it can be observed that the loading configuration in the actual fire was fortuitous. If the incident lorry had been located in almost any other location on the train, or with different lorries on wagons 13 and 16, the fire would almost certainly have spread to many more lorries and would have been much more difficult to manage.

5 - Sequence of events

On 17 January 2015 at 10:35 hrs lorry, registration number B139CAL enters the Eurotunnel British terminal.

At 10:43 hrs it goes through the tarpaulins check area, the lorry CB aerial is discernable on the CCTV recordings. The aerial exceeds the height of the cab and trailer.

The incident lorry is allocated in 15th and last position of the batch of vehicles destined for the front rake of the next mission which consists of Arbel wagons without pagodas.

At 11:38 hrs the lorries leave the holding area and head towards the loading ramps.

At 11:42:30 hrs, having checked that the aerial detection system located at the bottom of the loading ramp to platform B9 is working, the agent in charge of loading the front rake goes round the first lorry then tells the driver to proceed to the loader wagon. The loading of the lorries has started.

The aerial detection system is triggered on a lorry in 3rd or 4th position but no anomaly is visually confirmed.

The 15th lorry does not trigger the aerial detection system as it passes in front of it.

At 11:57 hrs, mission 7340 departs.

At 11:57 hrs, the agent de feu who is standing by the bottom of the ramp to overbridge 4 sees something on the 15th lorry which he identifies as an aerial and which seems to him to extend beyond the normal height. However, he is not certain. As he is new to this role, he mentions it to a colleague who reassures him by reminding him of the presence of an aerial detection system.

At 11:59:41 hrs, the lead locomotive enters the tunnel at about 50km/h.

At 12:00:08 hrs, the aerial on the lorry loaded on wagon 15 on the front rake arcs with the overhead power line just before the portal to the tunnel causing a loss of power supply to the overhead line.

At 12:00:32 hrs, the driver applies the brakes.

At 12:00:34 hrs, the supply to the overhead power line is reinstated in the running tunnel North however at this moment in time, mission 7340 is still in the electrical sector of the UK terminal where the voltage is late in being reinstated. The driver of mission 7340 carries out a controlled stop at CP 1138.

At 12:01:38 hrs, the train stops with its amenity coach in line with CP 1138.

At 12:01:58 hrs, the power supply is reinstated in the electrical sector of the UK terminal.

The driver receives authorisation from the RCC to restart and is instructed not to exceed 100 km/h.

At 12:03:40 hrs, the train sets off again and accelerates to 100 km/h and then continues at this speed.

At 12:04:10 hrs, the CCTV camera at CP 1114 shows that the cab of the incident lorry is full of smoke indicating that the fire has taken hold.

At 12:22:50 hrs, a flame alarm is raised by detection station SD38 then a few seconds later, a smoke alarm is raised at the same station. The train is then at PK 40.180 about 2 km before SAFE 4F station which extends from CP 4202 to CP 4276.

At 12:23 hrs, the chef de train receives a fire alarm from the rear loader wagon. He informs the driver and closes the ventilation dampers of the amenity coach.

At 12:23:16 hrs, the driver relays the fire alarm to the RCC. The train is roughly at PK 41 at the warning board “SAFE 4F 1,000M”. The conversation lasts 20 secs.

At 12:23:56 hrs, the RCC receives an emergency call from mission 7340. The communication lasts 1min 08 secs.

At 12:24:06 hrs, the power is lost on the overhead line; at this time the leading locomotive is located at PK 42.16 and has passed the entrance to the SAFE station. No attempt is made by the RCC to re-energise the overhead power line.

At 12:24:13 hrs, another fire alarm is raised at SD 40.

At 12:24:13+ hrs, the supervisor asks the driver to stop at the SAFE station but as it is too late, he initiates the stopping train procedure.

At 12:25:04 hrs, end of communication between the RCC and mission 7340.

At 12:26:22 hrs, the train stops at PK 44.202; the amenity coach is in line with CP 4418.

At 12:30 hrs, start of evacuation.

At 12:35 hrs, arrival of FLOR at CP 4418.

At 12:37 hrs, end of evacuation of all people from the train into the service tunnel.

At 13:40 hrs, earthing of the overhead power line.

At 14:00 hrs, setting up of water walls.

At 14:40 hrs, arrival of passengers at the terminal in Coquelles.

At 15:56 hrs, the SLOR FR team starts putting the fire out.

At 16:17 hrs, the BINAT plan is initiated.

At 16:20 hrs, the fire is under control.

At 17:53 hrs, the BINAT plan ends.

6 - Analysis and preventative recommendations

6.1 - Causes of the incident

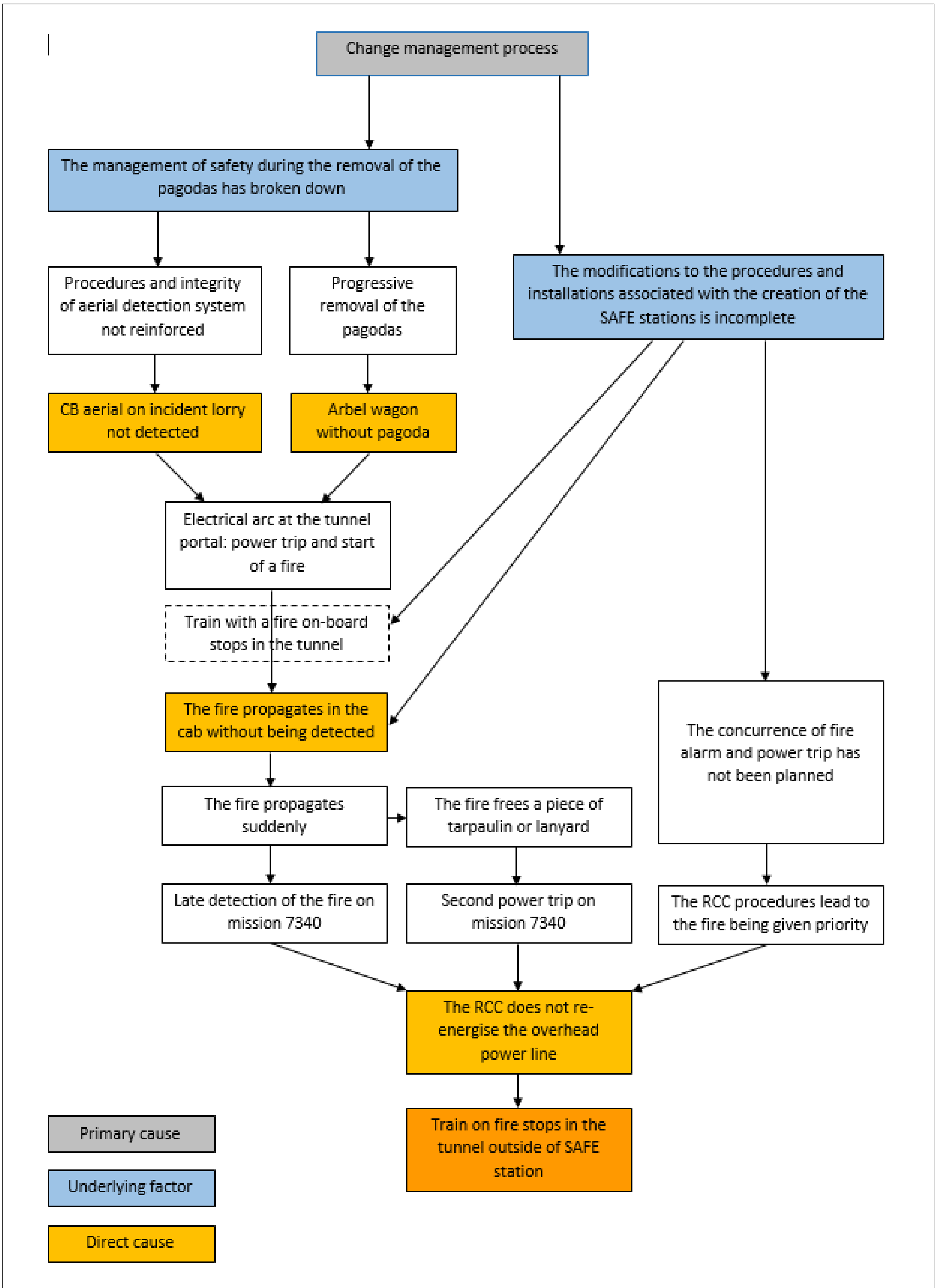

Figure 41: Causal tree

The fire was caused by an electrical arc between the overhead power line and the CB aerial on a lorry loaded on an Arbel shuttle with no pagodas.

The fire broke out in the cab of the incident lorry then spread to the outside and was only detected about 23 mins later.

When the on-board and fixed detectors raised the alarm, the train could still have stopped at the SAFE 4F station but the procedures in place at the time did not lead to the driver doing so. About a minute later, the fire caused an electrical arc which led to a second power trip.

Even though it was technically possible, the RCC did not try to re-energise the overhead power line so the train was inevitably forced to stop.

It had gone through the last SAFE station and the tunnel exit was still more than 15km away, the controlled stop took place in the tunnel.

The causal tree identifies the need for preventative measures to be made in the following areas, which are linked to the direct causes.

- Processes and systems for detecting aerials and small objects;
- Pagodas or other physical barriers between the vehicles and the overhead power line;
- Fire detection systems;
- RCC procedures in the event of fire and simultaneous power trip.

Even though it was not directly linked to the main cause of the incident, the train stopping in the tunnel with a fire on board, following the first power trip, raises the question about the suitability of such a stop had the fire grown more rapidly.

Examination of the underlying causes leads to measures aimed at improving Eurotunnel’s change management process.

In addition, the emergency and firefighting efforts have also been analysed.

6.2 - Processes and systems for detecting aerials and small objects

The fire occurred because an over-height aerial on the lorry loaded onto carrier wagon 15 of the front rake of the mission caused an arc between the overhead power line and the lorry.

Eurotunnel relied on sensors located at the bottom of the loading ramps, referred to as the aerial detection system, to identify over-height aerials, and therefore mitigate associated risks. None of the loading agents, including the AdFs, were expected to identify over-height aerials when the aerial detection system was in operation.

Tests organised by Eurotunnel after the incident, and data provided by the manufacturer of the sensors, demonstrated that the aerial detection system was not sensitive enough to reliably detect thin aerials at the speed at which lorries typically passed in front of the sensors.

The very low speed of passage in front of the sensors needed for reliable detection would significantly reduce the scanned length of the lorry and hence increase the risk that the system would not detect an aerial fitted remote from the front of the cab.

6.3 - Pagodas and other physical barriers

The fire occurred because there was no roof on the Arbel wagon to separate the over-height aerial from the overhead power line.

Since the introduction into service of the Arbel wagons, Eurotunnel has been faced with technical difficulties associated with the integrity of their pagodas. Following a period of repair, the pagodas became unserviceable and Eurotunnel began to remove them.

In the justification for the modification, Eurotunnel recognised the increased likelihood of a fire and hence the increased risk to lorry drivers and staff. However, the mitigation measures claimed in the risk assessment would not reduce the risk to an equivalent level to that before the modification. The investigators observed that other rolling stock and operational changes were made that may have reduced the risk, but these were not claimed within the comparative risk assessment and their benefit has not been assessed.

Over the years, Eurotunnel has trialled several alternative designs of roof construction and is continuing to work on a long-term technical solution.

In the interim period between the incident and the time when a validated technical solution becomes available, Eurotunnel has ordered pagodas of the existing design with the intention to fit them on the front of all its Arbel wagons.

In the absence of physical barrier between the lorries and the overhead power line, the aerial detection system is critical to safety and hence needs to be both fit-for-purpose and reliable.

Recommendation R1 (Eurotunnel)

Management of the risks associated with over-height objects

Provide arrangements, that are both fit-for-purpose and sufficiently reliable, for mitigating the risk associated with arcing between over-height objects such as parts of a lorry, or its payload, and the overhead power line. This may be achieved by completion of the reinstallation of pagodas, installation of an alternative validated roof design, installation of an improved system to detect of over-height objects and associated procedural measures, or an alternative solution.

6.4 - Fire detection systems.

Smoke appeared to be developing inside the cab of the incident lorry when the train came to a stand inside the tunnel following the initial power trip (12:00 hrs). However, as there was no requirement for the train to be inspected following the overhead power line trip, this early sign of a developing fire was not identified.

It was 23 minutes later that the fire was detected.

By the time the fire was detected by the equipment fitted inside the tunnel and on the train, there was little time available for the staff involved using the existing processes to bring the train to a stop in the second SAFE station.

The opportunities to stop the train within either of the two SAFE stations were missed.

The incidents in 2011 and 2012 also involved the onset of a fire at one of the portals with the smouldering fire remaining undetected until the shuttle arrived on the other side of the tunnel. Under marginally different circumstances, these incidents could have been very similar to the fire on 17 January 2015. They reinforce the need to detect a smouldering fire as early as possible to maximise the opportunity to use the SAFE stations.

Eurotunnel has changed its operating procedures for dealing with an overhead power line trip at the tunnel portals on a train comprising of Arbel wagons. It now requires the train involved to stop at the first SAFE station for further investigation.

Eurotunnel has also undertaken a broad consultation with manufacturers to look for innovative systems to detect more rapidly and reliably any outbreak of fire including whilst they are still confined in the cab of the vehicle concerned. At the date of publication of this report, this consultation still had not produced any results.

Recommendation R2 (Eurotunnel):

Continued monitoring of the improvements in fire detection system

Conclude the current consultation with manufacturers looking at innovative systems to detect more rapidly and reliably any outbreak of fire, including whilst they are still confined in the cab of the vehicle concerned. If applicable, establish a programme for installation of any new systems that are identified.

Put in place a process to continually monitor any technical improvements in the speed and reliability of fire detection systems.

6.5 - RCC and driver procedures

When the fixed or on-board alarms were raised, mission 7340 was still on the approach to the warning board “SAFE 4F at 1,000m”. Given the speed of the train was limited to 100km/h, it remained technically feasible to stop at this SAFE station for at least another 1min 30sec.

To prevent a following train from approaching too close to a train on fire, current procedures provide that the decision to stop is taken by the RCC supervisor once he has established the position of any following train. In this case, the time necessary to gather the information to inform his decision came too late to stop mission 7340 at the SAFE station.

Furthermore, when the second power trip occurred, the various controllers were focused on the fire procedures and no attempt was made to re-energise the overhead power line which very possibly would have allowed the train to reach the tunnel exit.

The crossovers are areas where an evacuation of passengers is difficult: there is no walkway in the tunnel to enable the passengers to join a cross-passage and it is difficult to achieve good smoke control at the locations. Electrical installations that are vital to Eurotunnel's operations are located at the crossovers and immobilising a burning train at a crossover would probably have disastrous consequences for the continued use of the Channel Tunnel. It appears that Eurotunnel agents did not appreciate how far a freight shuttle would coast leading them to overestimate these risks and make a rushed decision to stop the train.

Recommendation R3 (Eurotunnel):

Limiting the likelihood of a train on fire stopping outside of the SAFE stations

Review the decision making process in the event of the detection of a fire on a freight shuttle so as to initiate the stopping of the train quickly on approaching a SAFE station.

Review RCC procedures in order to deal with cases of fire and concurrent power trips in an optimum way.

***Furthermore ET is invited to assess by testing or simulations, the distance freight shuttles can coast in the areas of the crossovers at various speeds for instance 140, 100 and 50km/h*.**

6.6 - Stop after first power trip

The power supply was reinstated in the running tunnel North 26sec after the first power trip. It took 1min 50sec to re-establish it in the UK terminal sector, where the train was. During this time and in accordance with instructions, the driver initiated the controlled stop procedure. By being focused on this procedure, she did not realise that the power supply had been re-established above her locomotive and she completed the stop when she should have continued on her journey.

After stopping, the procedures stipulate that the driver must lower the pantographs, check that the engine is not located under a neutral section, re-raise the pantographs and restart the train.

The stop lasted a total of two minutes during which the fire could have spread and damaged the overhead power line preventing the train from starting up again.

This stop did not significantly affect how the incident developed, and hence no recommendation has been made, but Eurotunnel is invited to seek ways to avoid such stops and/or to limit their duration.

6.7 - Management of changes linked to safety.

Preliminary risk analysis by Eurotunnel

In accordance with its safety management system described in SAFD 1000, the applications by Eurotunnel to remove the rear and front pagoda in late 2011 and mid-2012 were supported by a comparative risk assessment looking at the effects of the removal of the pagodas on some of the operational risks.

This risk assessment recognised that the removal of the physical barrier between the lorries and the overhead power line had increased the likelihood of electrical arcing between a lorry with an open trailer and the overhead power line. It acknowledged that the risks associated with electrical arcing now had to be *controlled*.

In accordance with Eurotunnel's SMS and consistent with the permitted approaches described in the CSM on risk evaluation, the increased risk had to be mitigated to bring the residual risk back to an overall level equivalent to its level before the introduction of the modification. The mitigations claimed in the risk assessment were:

- the over-height system at the entrance to the terminal (a system which is not sensitive enough to detect aerials);
- the aerial detection system at the bottom of the ramp; and
- the introduction of the SAFE stations.

The introduction of the SAFE stations, despite bringing benefits to the protection of the assets and operation, had no impact on the safety of lorry drivers and Eurotunnel personnel. This is because the stations are only activated after the evacuation of people. Furthermore, Eurotunnel, whilst claiming benefit from the aerial detection system, did not assess its integrity. It has now been established that the integrity of the aerial detection system is insufficient to reliably detect small aerials.

Therefore, the arguments presented in the comparative risk assessment did not actually demonstrate that the overall risk to lorry drivers and Eurotunnel personnel had been managed to be equivalent to that before the removal of the pagodas.

Acceptance by the safety authority

In accordance with the CSM on risk evaluation, the risk assessment was reviewed by an independent assessment body. The assessment body concentrated mainly on checking that the process for risk assessment described in the CSM had been followed. The review by the assessment body did not identify that some hazards had been omitted and that some of the mitigation measures were not relevant to the safety of individuals.

The CTSA and the IGC accepted Eurotunnel's submission for the removal of the last pagodas, primarily on the basis that Eurotunnel had followed the process described in the CSM on risk evaluation and had engaged an assessment body to review its compliance with the CSM.

Feedback of experience

Risk and hazard assessments are not absolute processes and there is always a chance that a hazard will be overlooked, or its risk underestimated.

Because of this, it is important that the analyses are revisited in the light of practical experience from operation of the related systems. Eurotunnel has a process for this, it is referred to as "retour d'experience" – REX.

However, the lessons from the fires of 2011 and 2012 which took place whilst the programme of removal of the pagodas was in force have not been sufficiently taken on board with regard to:

- Increase in the frequency of electrical arcing between a lorry and the overhead power line and the resultant increase in the frequency of a consequential fire;
- Poor efficacy at detecting aerials;
- The link between power trips and fires and the need to provide for their coincidence in the procedures.

Recommendation n°38 in 2008 investigation

The investigation into the 2008 fire had already highlighted some concerns with the quality and robustness of the safety assessments carried out by Eurotunnel in support of changes that it was making to its operations. As a result of these concerns, the following recommendation to Eurotunnel was made in the investigation report (ET/2010):

"*Examine the change management process and its implementation in order to improve the quality and rigour of the safety studies performed to justify projects involving changes to procedures and practices.*"

In January 2012, the IGC reported Eurotunnel's response to this recommendation in its first annual report on the recommendations:

"*Eurotunnel feels that this recommendation is pointless since this item is already covered in existing texts.*
The change management process is managed by means of the change management system known as ECM and each major modification is submitted to the IGC Safety Authority.
The change management process (techniques, procedures, etc.) is described in detail in the Safety Management System document SAFD 1000, Paragraph 6.2.8."

The IGC accepted Eurotunnel's response. Eurotunnel has provided no new evidence to confirm that the concern regarding the quality of the implementation of the change management process had been addressed.

Recommendation R4 (Eurotunnel)

Improvements to the change management process

Eurotunnel should review its change management process and its implementation to understand the reasons for the shortcomings identified in this investigation in the areas of hazard identification, risk assessment, provision of necessary control measures and feedback from the 'return of experience'. This review should include consideration of whether Eurotunnel's arrangements for internal checking of the safety studies undertaken as part of the implementation of the change management process are sufficient.

Eurotunnel should make improvements to its procedures to ensure the correct identification of relevant hazards, accurate evaluation of the operational risks and that the necessary mitigation measures are correctly identified and implemented.

Once its change management process has been improved, Eurotunnel is invited to apply the process to check that all risks associated with the removal of the pagodas on the Arbel wagons have been correctly identified and mitigated.

The RAIB and BEA-TT remind Eurotunnel that in accordance with the CSM on risk evaluation the proposer of the change remains responsible for the application of the CSM (Article 5 of Regulation 402/2013 – "The proposer shall be responsible for applying this regulation (…)").

The RAIB and BEA-TT observe that the CSM on risk evaluation states that "an assessment body shall carry out an independent assessment of the suitability of both the application of the risk management process (…) <u>*and of its results*</u>" (Article 6 of Regulation 402/2013).

Some statements in the assessment report from the assessment body and Article 6 of the CSM might have given the impression to Eurotunnel that a thorough independent review of the proposed change had taken place when it had not.

Recommendation R5 (Eurotunnel)

Control of the work done by external bodies

Review its arrangements for ensuring that the scope and depth of any checks by external bodies commissioned by Eurotunnel is clearly defined and implement any necessary changes.

The RAIB and BEA-TT remind the IGC and CTSA that in accordance with the CSM on risk evaluation, it may request additional checks or risk analysis if it is able to demonstrate the existence of a substantial safety risk (Article 15 of Regulation 402/2013).

Finally, the RAIB and BEA-TT also invite the IGC to provide other National Safety Authorities and the European Rail Agency with the feedback on the implementation of the Common Safety Method on risk evaluation and assessment and its potential difficulties.

6.8 - Fire fighting

In general terms, the performance and the management of the fixed installations have been satisfactory. The trip of the 21kV network and the malfunction of the PRD damper 4935 were managed in line with procedures and did not have an adverse effect.

Nevertheless, considering the position of the 21kV cable in each running tunnel, the loss of the 21kV network in the event of a fire and its associated effects on the ventilation systems is highly probable. This loss will have no effect on the system provided that the redundancy is available (as was the case on 17 January 2015) but the system is made more fragile.

Recommendation 16 of the 2008 investigation asked Eurotunnel to examine a modification to the 21kV network in order to make that network more reliable in the event of a fire and to be able to restore power quickly to equipment that has been cut off in the event of a failure.

Following some studies, Eurotunnel concluded that any potential modifications to the 21kV network increased its complexity and introduced new risks which would outweigh any potential benefit. However, Eurotunnel decided to incorporate in the instructions for the EMS controller arrangements aimed at anticipating the effects of a fire on the 21kV network by, for example, sending maintenance technicians to reconfigure the power supply on the relevant fans.

The time necessary to reinstate the power supply to the Sangatte plant in 2015 was 1 hr 34 min compared to 1 hr 51 min in 2008.

BEA-TT and the RAIB invite Eurotunnel to reflect on the reasons behind the continued delay in reinstating power supply to the ventilation plants.

It took three and a half hours after the train stopped before the SLOR was ready to start the firefighting activities.

Almost an hour was lost in conveying the firefighters from SLOR France from the terminal emergency centre (FEMC) to the site of the fire.

This delay was due to a non-optimum use of the SSTS vehicles and their drivers by the RCC.

Three vehicles were sent empty to CP 4418 to recover the passengers who had been evacuated from mission 7340 whereas it would have been preferable to have first used these STTS to convey the SLOR to the site of the incident, and once unloaded, use them to repatriate the passengers to the terminal.

At the time of the fire in 2008, the time it took to convey the passengers to the terminal had been deemed to be excessive as the passengers had to wait two and a half hours in the service tunnel to be evacuated.

The RCC's decision meant that the time taken to move the passengers was slightly quicker than in 2008 (about two hours) at the cost of a significant delay in the SLOR intervention.

Recommendation R6 (Eurotunnel)

Optimising the use of the emergency transport system

To improve the management of transport methods in the event of a fire in the tunnel so as to allow both evacuation of passengers in an acceptable time period, and the rapid commencement of firefighting operations.

If STTS drivers had been immediately available, SLOR's response time would have been about two and a half hours.

In 2008 the response time, which was two hours, had been deemed excessive and did not allow for the fire to be tackled efficiently. It only prevented the fire from spreading outside of the incident train which was completely burnt out.

This SLOR response time, which seems difficult to reduce significantly, confirms that the fire on a train that is stopped in the tunnel outside of a SAFE station will not generally be contained until it reaches its maximum size. The eventual outcome shall essentially depend on how the vehicles are distributed on the train and the nature of their loads.

The emergency response was marked by an incident which could, under slightly different circumstances, have led to harm to firefighting personnel. As the work of the emergency services is not normally covered within the scope of BEATT's investigations, it is up to Eurotunnel and the emergency services concerned to draw their own useful conclusions.

6.9 - Sharing of evidential documents and voice communications

related to the incident

Eurotunnel and the other parties involved provided the investigators with the relevant documents, recordings and other technical explanations in a timely manner.

However, despite the transcripts prepared by Eurotunnel being made available, as indicated in section 4.2.2, the recordings of the conversations between the driver and the RCC could not be listened to, as the tapes had been re-used.

BEA-TT and the RAIB invite Eurotunnel to plan a systematic preservation of the audio recordings related to any incident being subjected to a judicial or technical inquiry.

7 - Conclusions and recommendations

7.1 - Causes

The fire was caused by an electrical arc between the overhead power line and the CB aerial which had not been detected by the aerial detection system and which was mounted on a lorry loaded on an Arbel shuttle without a pagoda.

The fire broke out in the cab of the incident lorry then spread to the outside and was only detected about 23 mins later.

When the on-board and fixed detectors raised the alarm, the train could still have stopped at the SAFE 4F station but the procedures in place at the time did not lead to the driver doing so. About a minute later, the fire caused an electrical arc which led to a second power trip.

Even though it was technically possible, the RCC did not try to re-energise the overhead power line so the train was inevitably forced to stop.

It had gone through the last SAFE station and the tunnel exit was still more than 15km away, the controlled stop took place in the tunnel.

Causal analysis led to three recommendations being made which concern the following areas and which are linked to the direct causes.

- Processes and systems for detecting aerials and small objects;
- Pagodas or other physical barriers between the vehicles and the overhead power line;
- Fire detection systems;
- RCC procedures in the event of fire and simultaneous power trip.

Examination of the underlying causes led to the drafting of three recommendations to improve Eurotunnel's change management process.

Furthermore, the review of the emergency operations and firefighting activites has led to a recommendation being made, which is linked to the timescales for despatching firefighters inside the tunnel.

7.2 - Recommendations

Recommendation R1 (Eurotunnel)

Management of the risks associated with over-height objects

Provide arrangements, that are both fit-for-purpose and sufficiently reliable, for mitigating the risk associated with arcing between over-height objects such as parts of a lorry, or its payload, and the overhead power line. This may be achieved by completion of the reinstallation of pagodas, installation of an alternative validated roof design, installation of an improved system to detect of over-height objects and associated procedural measures, or an alternative solution.

Recommendation R2 (Eurotunnel):

Continued monitoring of the improvements in fire detection system

Conclude the current consultation with manufacturers looking at innovative systems to detect more rapidly and reliably any outbreak of fire, including whilst they are still confined in the cab of the vehicle concerned. If applicable, establish a programme for installation of any new systems that are identified. Put in place a process to continually monitor any technical improvements in the speed and reliability of fire detection systems.

Recommendation R3 (Eurotunnel):

Limiting the likelihood of a train on fire stopping outside of the SAFE stations

Review the decision making process in the event of the detection of a fire on a freight shuttle so as to initiate the stopping of the train quickly on approaching a SAFE station.

Review RCC procedures in order to deal with cases of fire and concurrent power trips in an optimum way.

Recommendation R4 (Eurotunnel)

Improvements to the change management process

Eurotunnel should review its change management process and its implementation to understand the reasons for the shortcomings identified in this investigation in the areas of hazard identification, risk assessment, provision of necessary control measures and feedback from the 'return of experience'. This review should include consideration of whether Eurotunnel's arrangements for internal checking of the safety studies undertaken as part of the implementation of the change management process are sufficient.

Eurotunnel should make improvements to its procedures to ensure the correct identification of relevant hazards, accurate evaluation of the operational risks and that the necessary mitigation measures are correctly identified and implemented.

Recommendation R5 (Eurotunnel)

Control of the work done by external bodies

Review its arrangements for ensuring that the scope and depth of any checks by external bodies commissioned by Eurotunnel is clearly defined and implement any necessary changes.

Recommendation R6 (Eurotunnel)

Optimising the use of the emergency transport system

To improve the management of transport methods in the event of a fire in the tunnel so as to allow both evacuation of passengers in an acceptable time period, and the rapid commencement of firefighting operations.

In addition to the formal recommendations, the following invitations have been prepared:

The fear of immobilising a train in the France crossover played an important role in the management of the incident. Eurotunnel is invited to assess, by testing or calculations, the distance freight shuttles can coast in the areas of the crossovers at various speeds like 140, 100 and 50km/h.

Because of the untimely stop inside the tunnel of mission 7340 at the time of the first power trip, Eurotunnel is invited to seek ways to avoid such stops and/or to limit their duration.

Once its change management process has been improved, Eurotunnel is invited to apply the process to check that all risks associated with the removal of the pagodas on the Arbel wagons have been correctly identified and mitigated.

The IGC is invited to provide other National Safety Authorities and the European Rail Agency with the feedback on the implementation of the Common Safety Method on risk evaluation and assessment and its potential difficulties.

The time necessary to reinstate the power supply to all ventilation system was 1 hr 34 min. Eurotunnel is invited to reflect on the reasons behind this persistent delay.

Eurotunnel is invited to plan a systematic preservation of the audio recordings related to any incident being subjected to a judicial or technical inquiry.

8 - Annex

8.1 - Annex 1 Decision to open an investigation by BEA-TT

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MINISTRY OF ECOLOGY, SUSTAINABLE DEVELOPMENT AND ENERGY

Land Transport Accident
Investigation Bureau

La Défense, 20 January 2015

The Director

DECISION

The Director of the Land Transport Accident Investigation Bureau.

Having regard to the Transport Code, notably articles L. 1621-1 to L 1622-2 and R 1621-1 to R 1621-26, which relate particularly to the technical investigation following a land transport accident or incident.

Having regard to the Memorandum of Understanding concluded on 23 October 2009 between the British Rail Accident Investigation Branch and the French Land Transport Accident Investigation Bureau concerning the carrying out of technical investigations into railway accidents and incidents occurring on the cross-Channel fixed link.

Having regard to the circumstances of the fire which occurred on 17 January 2015 on a Eurotunnel freight shuttle, which was travelling in the direction of the terminal at Coquelles, in interval 4 of the north railway tunnel of the cross-Channel fixed link.

HAS DECIDED

Article 1: To open a technical investigation under article L. 1621-1 and R 1621-22 of the Transport Code into the fire which, on 17 January 2015, affected a Eurotunnel freight shuttle in interval 4 of the north railway tunnel of the cross-Channel fixed link.

Article 2: This investigation will be undertaken in cooperation with the British Rail Accident Investigation Branch under the conditions defined in clause 5.2 of the aforementioned memorandum.

The Director of the Land Transport Accident Investigation Bureau

Claude AZAM

Tour Pascal B
92055 La Défense cedex
Tél: 01 40 81 23 27 - www.bea-tt.developpement-durable.gouv.fr