The fire in the Channel Tunnel

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ABSTRACT: The Channel Tunnel, which connects the United Kingdom with France, was designed and built between 1986 and 1993 with consideration of fire and life safety at the top of the agenda. Its design was constantly monitored by a bi-National Safety Authority appointed by an Inter Governmental Commission of the Governments of France and the UK.

In November 1996 a shuttle train carrying heavy goods vehicles suffered a serious fire which severely damaged the tunnel, though nobody was seriously hurt in the incident.

This paper discusses the design for fire management, the fire itself, and lessons learned from the incident.

1. TUNNEL DESIGN AND FIRE DEFENCES

1.1 *Overall configuration*

Although called 'the channel tunnel', there are in fact three tunnels running parallel beneath the English Channel. Two railway tunnels of 7.6 metres diameter, set 30 metres apart, and between them a service tunnel of 4.8 metres diameter. These three tunnels are connected together at intervals of 375 metres by cross passages, and the railway tunnels are also connected at 250 metre intervals by piston relief ducts of 2 metres diameter. Fresh air is supplied to the system through the service tunnel, via controlled louvres in the cross passages, thus maintaining a positive air pressure in the service tunnel.
There are two crossover caverns at roughly the 'third points' along the tunnel's length, dividing the rail tunnels into six 'intervals'.

1.2 *Tunnel lining*

The greater proportion of the tunnels are lined with precast reinforced concrete lining rings, 1.5 metres wide. The thickness of the rings varies with loading conditions between 400mm and 800mm.

Where concrete was considered inappropriate, the lining rings are of cast iron.

The crossover caverns are lined with in-situ mass concrete. At the location of the fire the tunnel lining was precast reinforced concrete segments.

1.3 *Permanent installations*

1.3.1 There are two ventilation systems installed in the tunnel. The Normal Ventilation System supplies fresh air to the Service tunnel at both ends of the tunnel at a rate of 88m³/sec, sufficient to provide for the needs of 20,000 people in the tunnel.

1.3.2 A second system, called the Supplementary Ventilation System, supplies large volumes of fresh air directly into the railway tunnels to control the flow of smoke, or to provide additional cooling capacity in the event of traction power failure, 260m³/sec. on the English side, and 300m³/sec. on the French side. The fans supplying this air are reversible so that air can be fed in on one side and drawn out at the other.

1.3.3 Fire hose connections are available adjacent to each cross passage, fed with water from a fire main installed in the service tunnel.

1.3.4 Power supply and other cabling in the tunnel, as well as any equipment which uses inherently flammable materials were rigorously tested for flame propagation, smoke density and toxicity, and all are classified as 'low smoke and fume'.

1.4 *Rolling stock, tourist and HGV*

1.4.1 The tourist wagons, which form the shuttle trains, are the largest railway vehicles in the world, are made of stainless steel, and are insulated against noise using fire resistant rockwool. The door systems which close off the wagon ends during transit of the tunnel are designed to resist a fire inside the wagon for up to 30 minutes, i.e. for a period longer than the transit time of 27 minutes.

1.4.2 Air conditioning units carried beneath the floor of the wagons also perform the function of purging the wagon of fuel vapours before the train commences its journey through the tunnel.

1.4.3 Each wagon is equipped with comprehensive fire detection and extinguishing system. As well as passenger-operated alarms there are a series of detectors that are automatically triggered by smoke, fumes and inflammable vapours. These detectors are sensitive to ions, or ultra-violet radiations, smoke and gases. If smoke density continues to increase to a preset danger level, halon gas is automatically discharged into the area concerned.

1.4.4 HGV shuttle wagons are basically flat wagons upon which is mounted an open framework of stainless steel which supports a thin sheet roof. This design enables 44 tonne trucks to be carried without breaching the 22 tonne axle load restriction, and also provides protection against the possibility of flapping tarpaulins on the HGV's damaging lineside equipment or the overhead power supply cable.

1.4.5 Because of the open nature of the HGV shuttle wagons it was not possible to install fire detection systems on the wagons themselves. Instead, fire and smoke detectors were installed on the loading wagons and at intervals along the railway tunnels.

1.5 *Fire fighting, first line, water supply, smoke control*

1.5.1 The first reaction when fire breaks out must be to alert the National Fire Service, however Eurotunnel has its own resident emergency reaction force, trained and equipped to quickly move into action in any part of the system, and this force can be mobilised immediately. Access to the tunnel system is normally via the service tunnel using specially designed vehicles which are wire-guided in the tunnel to prevent collisions. Each vehicle carries a 'pod' containing equipment appropriate to the emergency, and these pods are interchangeable between vehicles to give maximum flexibility of response.

1.5.2 Fire fighting water is supplied to the tunnel system through a water main located in the service tunnel in order to obviate the risk of damage in the event of a train derailment. Water is supplied to two outlets in the railway tunnels adjacent to each cross passage, at 125 metre intervals along the tunnel.

1.5.3 As noted earlier, fresh air is supplied to the system through the service tunnel, and the direction of smoke movement in the rail tunnels is controlled by activation of the supplementary ventilation system.

1.6 *Special arrival sidings*

In the event of a fire breaking out on a train the normal reaction is to transfer passengers from the affected wagon into adjacent wagons, and then to isolate the wagon containing the fire by closing the fire resistant doors at either end of the wagon. The train should not be stopped. On arrival at the destination terminal the burning train would be run into a specially designed reception siding where passenger evacuation and fire fighting can be carried out expeditiously without affecting the operation of the rest of the system.

1.7 *Dangerous Goods restriction*

In order to minimise the risk of fire on shuttle and through freight trains Eurotunnel has banned a wide range of hazardous commodities from passage through the tunnel. Generally these are products which either burn fiercely if ignited, or would render the atmosphere in the tunnel toxic if released. Fuel tankers and nuclear waste flasks are the more obvious examples.

2. THE FIRE

2.1 *Sequence of events*

2.1.1 The fire occurred in Interval 3 of the tunnel on 18 November 1996. The exact cause of the fire remains unknown, but it appears that the fire may have been the result of the deliberate setting fire of a heavy goods vehicle on board one of the shuttle wagons before it entered the tunnel. It was certainly not caused by any mechanical or systems failure in Eurotunnel's equipment or rolling stock.

2.1.2 The train, which carried the fire into the tunnel, was an HGV freight shuttle train which left the loading platform at 21.42, entering the tunnel at 21.48.

At 21.49 The Fire Equipment Management Centre in the UK received notice of a smoke alarm triggered in the tunnel. Two further smoke alarms were registered by 21.50.

By 21.54, following further smoke alarms and a confirmed flame alarm, the Rail Control Centre had ordered all trains to reduce speed and the dampers in the piston relief ducts were ordered to be closed to prevent the spread of smoke to the other rail tunnel.

At 21.57 an alarm signal on board the train indicates that one of the loading jacks may have dropped, and the driver's STOP lamp illuminates. The train must not continue with a jack dropped for fear of causing a derailment, so the train is brought to a controlled stop with the Amenity Car adjacent to a cross passage.

At 21.59 the train driver informs the Rail Control Centre of a loss of traction power.

By 22.04 both the UK and French First Line of Response teams had entered the tunnel.

At 22.12 the Rail Control Centre began the activation of the Supplementary Ventilation System.

At 22.21 The Rail Control Centre opened the cross passage doors adjacent to the incident in order to disperse smoke locally to permit train evacuation.

By 22.25 all passengers from the train had been evacuated into the service tunnel, and by 22.42 had been removed to surface on board a Tourist Shuttle train which had been stopped in the other rail tunnel for this purpose.

French Second Line of Response team was on location by 22.56, and were joined by the UK team at 23.55.

National Fire fighting teams were at the fire location by midnight and began fighting the fire.

05.00 the fire was declared extinguished.

2.2 *Severity and damage*

2.2.1 What no doubt began as a small fire on board one of the vehicles on the train may have increased in size as the train progressed down the tunnel though the indications are that only one vehicle was on fire when the train stopped. The train was stopped in the tunnel due to a secondary failure indicator not connected to the fire. The original source of the fire spread to several wagons due to the movement of other trains in the tunnel, and to the activation of the supplementary ventilation system. It is estimated that temperatures up to 1000 °C were reached at the heart of the fire.

2.2.2 The tunnel was severely damaged over a length of 46 metres, suffered serious damage over about 280m, and was affected to some extent over a total of 500m.

3. RECOVERY AND REPAIR

3.1. *Making safe and removal of debris*

3.1.1 After the fire had been extinguished the first task was to remove the damaged train from the tunnel. There was some delay in commencing this operation to permit the French Authorities to carry out their investigation in the tunnel, but this time was used to prepare plans for recovery of the tunnel itself.

3.1.2 The Initial appraisal of the damage to the tunnel indicated that a considerable proportion of the thickness of the reinforced concrete lining had been destroyed, and a decision was taken to quickly install some temporary support to the damaged lining. Steel colliery arches were erected at 1.5 metre centres, supporting a light steel mesh to prevent further fall of debris as the tunnel was being cleared.

3.2 *Scheduling of repairs.*

3.2.1 Before any actual repair work could begin the method of recovery and repair had to be agreed in detail with the Safety Authority, set up by the Inter-Governmental Commission before construction of the Tunnel itself began.

A preliminary proposal, supported by calculations was submitted to the Authority on November 27, and agreement was reached by 24 January 1997.

3.2.2 Repair of the tunnel was divided into two categories of work, civil engineering and electro-mechanical engineering.

3.2.3 Civil engineering consisted mainly of the preparation of the damaged concrete of the lining by grit-blasting, for which 250 tonnes of grit were required, and the replacement of damaged reinforcing steel. The replacement of lining concrete by 680 tonnes of plain shotcrete and 630 tonnes of fibre reinforced shotcrete, followed finally by finishing to profile. French contractor Freyssinet completed all of this work in 60 days.

3.2.4 Electro-mechanical work began with the replacement of 500 metres of railway track and supporting track blocks followed by the replacement of 2600 metres of traction power catenary cable, 4000 metres of signal cabling, over 4400 metres of lighting and other power cables, 4200 metres of fibre optic communications cables, and 1000 metres of 400mm diameter cooling water pipes. All of this work was completed in less than one month by Eurotunnel's own teams.

3.3 *Logistics*

3.3.1 The guiding principle in the logistical planning was to cause minimum disruption to the commercial operation of the unaffected part of the tunnel.

The fire occurred in the middle third of the South running tunnel, and it was possible to close this section by utilising the two crossover tunnels at either end of this section to route trains around the work area.

3.3.2 The work area itself had to be isolated from the operational tunnel by closing off the railway tunnel at each end with airtight temporary bulkheads.

3.3.3 All necessary plant, equipment and materials for the whole of the recovery operation was loaded on to a single works train, which entered the tunnel on 29 January 1997, and did not leave the tunnel until all work was complete on 26 March 1997.

3.3.4 The work force gained access to the work via the service tunnel which runs parallel to and between the two rail tunnels for the whole of their length.

3.3.5 On completion of the civil engineering work Eurotunnel's teams mobilised a second works train, loaded with all the necessary rails, blocks, cable drums and pipes for the renewal of the fixed equipment in the tunnel.

3.3.6 The initial target date of 15 May 1997, set for re-opening of full commercial operation was met, within the original budgetary provision.

4. LESSONS LEARNED

4.1 *For construction*

1). The various detectors installed in the tunnel system to give warning of smoke or flames in the tunnel were effective.

2). Numerous on-train sensors, insisted upon by the safety regulators, have proved unreliable, frequently giving warning signals later found to be incorrect.

3). The precast concrete lining of the tunnel, though not specifically designed for fire resistance, generally stood up well to all except the most severe heat conditions.

4). The failure of traction power is believed to have been due to a combination of heat and smoke, causing a short-circuit which tripped out the power.

5). Some difficulty was encountered during evacuation of passengers, firstly because the Rail Control Centre could not ascertain with sufficient precision where the train was with respect to the nearest cross passage, and escaping passengers had difficulty finding the escape passage due to smoke. These two issues have been addressed and rectified.

6). The fire detector monitoring panels should be located in the Rail Control Centre rather than the Fire Equipment Monitoring Centre.

7). A fire suppression system, based on high pressure water mist, should be developed and installed on the shuttles. This system is now developed and a contract for installation has been awarded.

4.2 *For Operation*

4.2.1 It should be recorded that all passengers and crew of the affected train were able to walk away from a potentially devastating fire.

However certain aspects of procedure were seen to be capable of improvement:

1). There should be systematic checks of each loaded train before departure by staff in direct contact with the Rail Control Centre.

2). On receipt of the first in-tunnel fire alarm the tunnel should immediately be put into emergency configuration, rather than waiting for confirmatory indicators. On receipt of a second alarm, the train which triggers the alarm should be stopped and evacuated unless it is close to the tunnel exit.

3). Because of the open nature of the HGV wagons, the normal 'drive out' policy should only apply if the train is close to exiting the tunnel. In all other cases the driver should carry out a controlled stop and evacuate the train.

4). The policy of decoupling the front loco and amenity car on HGV shuttles has been dropped in favour of priority evacuation of passengers.

5). The Chef de Train should be in charge of train evacuation, rather than the driver.

6). The process of closing piston relief ducts and activating the Supplementary Ventilation System should begin immediately there is a single fire alarm of any type.

5. CONCLUSION

This was an extremely intense and disastrous fire, which caused a major disruption of Eurotunnel's commercial operation.

That full commercial operation was able to recommence after only six months is not only a tribute to the organisation and determination of the repair teams, but proves again the value of twin tunnels

and the provision of a continuous service tunnel,
both for evacuation and repair.