Fire in the Chunnel!

Photo: Sygma

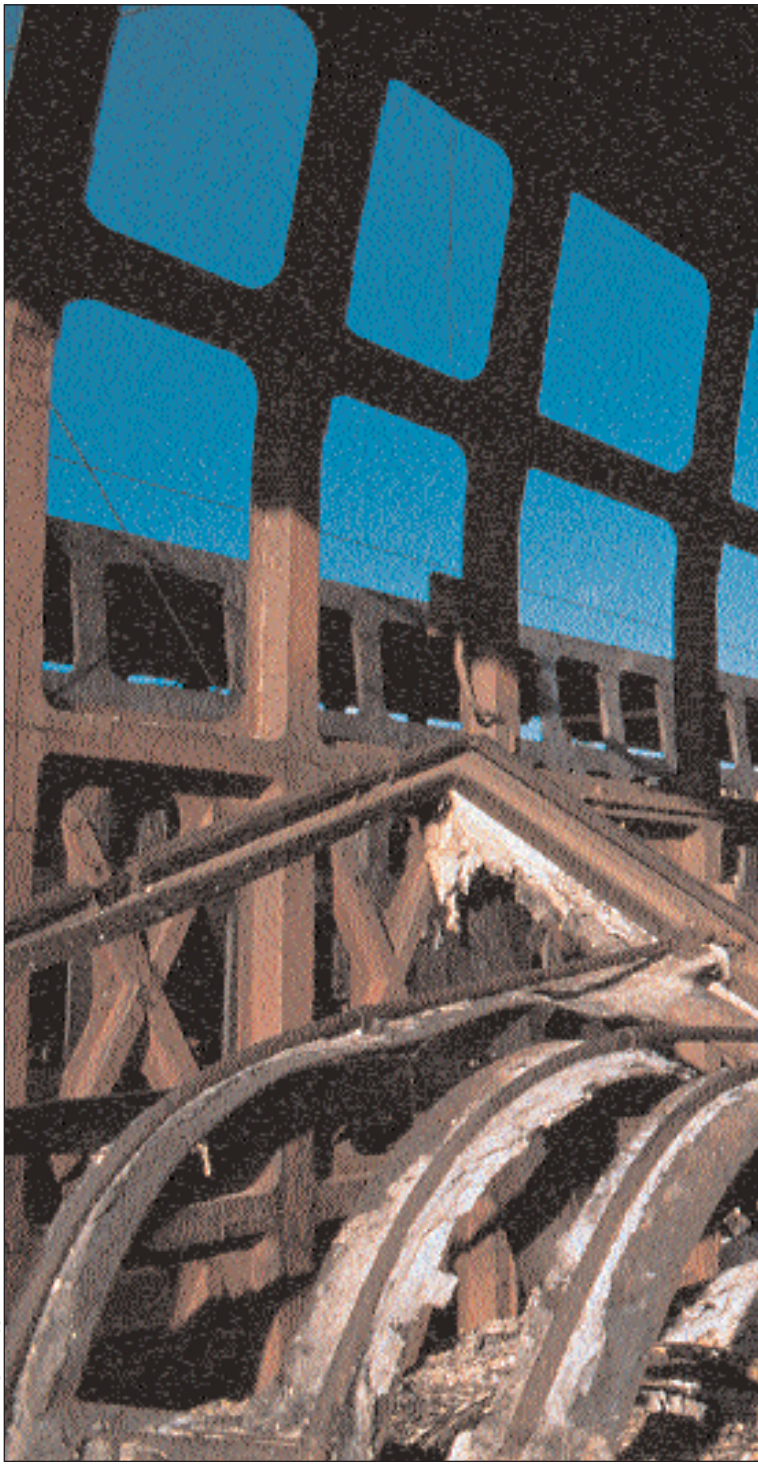

Photo: P.H.e Segretain-Sygma

Ed Comeau and Alisa Wolf

The Chunnel—the underwater tunnel beneath the English Channel—has been called the eighth wonder of the world, an engineering feat that defies convention. Connecting Pas de Calais, France, with Folkestone, England, the 31-mile (50 km) tunnel's design and construction was a model of cooperation, using standards from all over Europe and the United States. And before it opened on May 19, 1994, the Chunnel was exhaustively tested for safety, including extensive modeling and full-scale fire tests. When the fire scenario moved out of the laboratory and into real life on November 18, 1996, however, the ensuing emergency defied the models. The tunnel had to be shut down for weeks for repairs.

According to some of the U.K. responders interviewed during NFPA's four-day fire investigation, the actual fire scenario could never have been modeled. If it had, no one would have believed it—there were so many system and procedural failures that no one could have anticipated. Yet, say these same responders, many of the systems that were in place were effective. In fact, they credit them with preventing any deaths or critical injuries among those on board the stricken train. None of those who responded were injured or killed, either, even

The first major incident in the world's largest underwater tunnel tested safety features and procedures. An NFPA fire investigation examines how well they worked.

though 150 firefighters from England and France rotated shifts throughout the night and the next morning to extinguish the intensely hot blaze.

Security guards spotted the fire before the shuttle, which was traveling from France to England, entered the tunnel. By the time the control center received their report, however, the shuttle was already inside. Adding to the problem was another train, which was sent in after the fire was reported. Suffice it to say, the incident got off to a bad start.

The cause of the fire hasn't been determined, and it's still being investigated by French authorities, Eurotunnel, and the Channel Tunnel Safety Authority, so many conclusions about the incident will have to await their findings. We can, however, look at the firefighting response, the incident management procedures, and the high-tech engineering that, together, put out the fire and protected lives.

Chief Fire Officer Jeremy Beech of the Kent Fire Brigade gave NFPA and two investigators from the Metropolitan Fire Brigade of Melbourne, Australia, access to investigation resources, which included interviews with the responders, U.K. and French command officers, and Eurotunnel officials.

Safety features

A service tunnel was built between the two running tunnels going north and south between Folkestone and Pas de Calais. The service tunnel has no rails; rather, vehicles dedicated to maintenance and emergencies run on rubber tires. The three parallel tunnels are connected every quarter mile (375 m) by 270 cross passages that allow for quick evacuation of passengers and access to the shuttles by firefighters and other emergency personnel.

Fire detection systems include clusters of ionization and optical smoke detectors, infrared and ultraviolet flame detectors, and carbon monoxide (CO) detectors, spaced 1 mile (1.6 kilometers) apart. Cross-zoned detection is used to reduce the potential for false alarms. And all of the systems are monitored in four locations: the two Fire Emergency Management Centers in England and France, and the Railway Control Centers, also in England and in France.

A 10-inch (250 millimeter) diameter water main runs the length of the service tunnel. Water from four aboveground feeds supply the main, two from the United Kingdom and one from France, each with a 211,000-gallon (800 m^3) water supply, as well as low- and high-pressure pumps. The system can support four hose lines discharging a total of 120 m^3/hr simultaneously.

At each cross passage, 5-inch (125 millimeter) branch lines connect to the water main. These branch lines extend into the running tunnels and supply hydrants spaced 137 yards (125 meters) apart.

Eight members of the municipal fire brigade staff each terminal. These teams are referred to as the first line of response (FLOR). If an incident occurs in the tunnel, all 22 firefighters can respond through the entire length of the tunnel.

Photo: "PA" News

The remains of a truck, which was one of many vehicles destroyed in the fire, is brought out of the Pas de Calais end of the tunnel.

The train

The Eurotunnel fire started on a truck that was being hauled through the south tunnel for the 35-minute trip from France to England on a heavy goods vehicle (HGV). A typical HGV pulls 28 trucks on "carry wagons." The drivers, along with the chef de train and a steward, ride in a club car at the front of the shuttle. HGVs carry trucks of up to 44 tons, which roll onboard on loader cars, of which there are four. These trucks are locked into place with wire bands, one truck each to a carry wagon. Investigators will determine whether these open wagons played a role in the fire spread.

Eurotunnel runs the "Le Shuttle" HGVs, as well as standard freight trains, through the Chunnel. These are distinct from the high-speed Eurostar passenger trains, which can carry hundreds of passengers at a time and up to 16,000 passengers a day through the Chunnel between the United Kingdom and France, according to *US & World News.* All trains use the same tunnels, however.

Alarm

Security guards at the French terminal reported seeing flames on the HGV at 8:45 p.m. U.K. time, as the shuttle entered the tunnel with 31 passengers and 3 crew members. The driver rode alone in the locomotive, and the steward and chef de train, who has overall charge of the train, rode with the passengers, most of them truck drivers, in the club car (see diagram). The security guards alerted the French Terminal Control Center, which then contacted the Railway Control Center (RCC) in Folkestone.

According to standard operating procedures, the first approach that should be taken when a train is on fire is to have it continue through

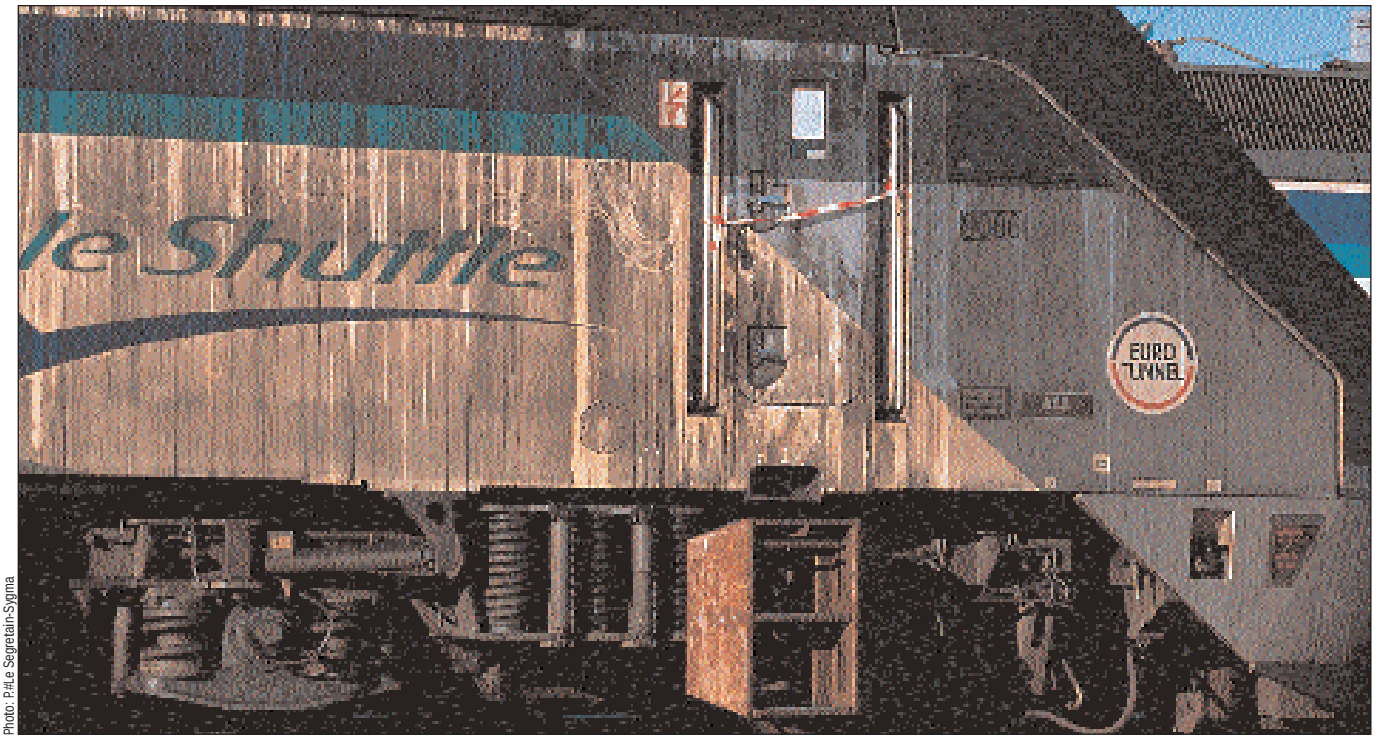

Photo: P.H.Le Segretain-Sygma

A typical Eurotunnel "Le Shuttle" pulls 28 trucks, weighing up to 44 tons, through the tunnel on "carry wagons," one truck per carry wagon.

the tunnel and extinguish the fire when it emerges from the tunnel. The stricken train was headed for the United Kingdom that night, and the RCC told the train driver to go ahead and follow this procedure.

Jurisdiction over the tunnel is divided between France and the United Kingdom. Upon receiving the alarm, the French sent their FLOR into the Chunnel. The U.K. FLOR was also notified. Anticipating that the train was coming through and that they'd have to deal with the fire then, the U.K. FLOR decided to sit tight.

That's when Dick Judge, leading firefighter for the U.K. FLOR, went into the fire emergency management center and saw that the carbon monoxide readings in the tunnel were at twice the dangerous levels. This tipped him off, he told NFPA, that something serious was going on in there. The U.K. FLOR began to respond into the service tunnel at 8:47 p.m., planning to proceed to the midpoint and stand by.

According to Eurotunnel officials, the shuttle driver learned of the fire by radio and was proceeding through the tunnel. At about 9:04, however, he reported a warning light on his control panel, indicating an abnormality in the train that could cause a derailment. Standard operating procedures required that the shuttle be stopped when such an alarm condition exists. Accordingly, the driver brought the train to a controlled stop next to a cross passage.

Discovery

About 10 minutes after they entered the tunnel, the U.K. FLOR was told that the train had stopped, that the French FLOR was evacuating it, and that the driver was locked in the cab. The U.K. FLOR wasn't sure whether they'd come upon the train facing forward, with the locomotive and club car in front, or backward, which would have put the passengers at the end of the train. On the return trip, the train may may either run a loop at the terminal or simply reverse direction, which is the procedure during high winds. U.K. responders worked out scenarios for both possibilities while continuing through the tunnel.

In fact, the HGV shuttle was facing forward, and the fire was in a truck loaded near the back. This didn't help in terms of smoke, however. Although the normal airflow would have been from the front of the train to the rear, the air movement was reversed when the train stopped, sending smoke to the front of the shuttle. This was due to the "piston effect" caused by the movements of the shuttle, the trains that preceded it, and a freight shuttle that unfortunately entered the tunnel behind it. The freight train's sole occupant, the driver, self-evacuated out of a cross passage door.

The fire had become more intense when the train stopped, and the locomotive lost power and was unable to move forward.

Meanwhile, the HGV driver reportedly couldn't see the marker on the wall because of the smoke, so he couldn't tell RCC where he was. Though sensors report information about the train's location to RCC monitors, the monitors show only a section of track. Subsequently, the responders found the train approximately 12 miles (19 km) into the tunnel, lining up with a cross tunnel at marker 4131.

Once the shuttle stopped, the chef de train unfortunately opened an exterior door on the club car, and smoke billowed in. To his credit, he kept his head, according to news reports, instructing people to keep calm and to cover their mouths with wet paper towels to avoid inhaling fumes.

First response

The French FLOR arrived on the scene at 9:15 p.m. and took command, evacuating all 34 passengers and crew into the service tunnel.

Photo: "PA"News

A worker rests in the Chunnel in the aftermath of the fire. The heat of the blaze had caused pieces of concrete to fall from the tunnel's ceilings and walls, creating a sloping surface of debris in the tunnel walkways, as seen here in the background.

Eight people suffering from smoke inhalation had to be taken from the service tunnel in ambulances specially designed for Chunnel rescues. Two people, the driver and a pregnant woman, were more seriously injured and were transported by helicopter to Lille. A shuttle in the north running tunnel was stopped and the uninjured passengers were placed onboard and transported to Folkestone. All the victims, who suffered from smoke inhalation, completely recovered.

The U.K. FLOR arrived at 9:30 p.m., while the French FLOR was treating the injured. At the scene, U.K. and French officers conferred. There was some problem communicating because of language barriers, but the U.K. FLOR was able to get the gist of what had happened from the French. Compounding the problem of getting information was the fact that the shuttle crew members were among those suffering severely enough from smoke inhalation to be unable to tell responders what they knew.

U.K. and French officers decided that the French would continue to treat victims while the U.K. responders evaluated conditions in the south running tunnel. The officer in charge of the U.K. FLOR advised the RCC that he was in charge of an entry team, according to operating procedures. It was very important for engineering management system personnel, who were in charge of ventilation control, to know from whom to take orders.

At 9:40, the U.K. FLOR entered the tunnel at the 4131 marker, and an entry control team stayed at the cross passage door. The entry team team had portable radios, as well as a charged hose line and a thermal imaging camera. The control team connected a portable radio into a tunnel system that would allow them to keep in contact with the entry team.

Going in

The entry team was greeted by thick smoke that had been pushed toward the front of the train by the piston effect. The team reported that the entire train was covered with soot and verified that all passengers and crew had been removed. Team members then moved toward the end of the car to evaluate conditions.

The supplementary ventilation system, designed to control the direction and volume of airflow during an emergency, was operating at this time because smoke conditions were beginning to improve. It blew air from west to east to offset the piston effect and direct the smoke toward the back of the train—that is, toward the French terminal.

The U.K. entry team walked east, toward the rear of the shuttle, reached a bend in the tunnel, and lost radio contact, probably because the fire had damaged the tunnel's radio system. They continued for about 2,000 feet (600 meters), and at marker 4163, they began to observe damage to the tunnel fittings, including fallen pipework and brackets on the walkway and dangling cables. They also saw the fire. As they proceeded toward the flames, they noticed more damage and debris on the walkway. At 1,000 feet (300 meters) past marker 4163, the entry team turned back to the cross passage door and went back to the service tunnel to report its findings.

At this point, a French command officer, Commandant Michel Rouaix, assumed incident command. The fire was declared a binational incident, which allowed the U.K. to respond according to pre-established procedures.

Second line of response

After reporting on the tunnel conditions, the U.K. FLOR officer called the U.K. fire emergency management center and asked about the second line of response (SLOR), assuming that the teams were staged and ready to go. This wasn't the case, however. The SLOR from the Kent Fire Brigade wasn't notified until 10:02 p.m. Kent Fire Brigade resources were immediately dispatched to the terminal.

By 10:19, the U.K. SLOR had responded with 10 firefighters and two command officers. They moved down to marker 4163 to join up with French responders. The U.K. command officer, Bill Welsh, met with Rouaix, and they began developing a strategy for combating the fire. They decided that the French FLOR would attack the fire from cross passage 4163, and the U.K. FLOR would attack closer to the fire, from cross passage 4201. This strategy would allow French firefighters to attack from upstream and the U.K. firefighters from the middle.

The air pressure in the service tunnel was being maintained at a higher level than that in the running tunnel, resulting in a very high airflow through the open cross passage door into the running tunnel. This airflow was so strong that when the door was manually opened, personnel had to brace themselves to make sure that none of their equipment was loose, as it would have blown into the tunnel.

The ventilation system in the running tunnel had also been increased and was blowing from the U.K. side on the west toward the

French side on the east. This air pressure, coupled with the airflow from the cross passage, created a "bubble" about 3.2 feet (1 meter) into the running tunnel inside which a responder could stand in relative comfort and safety. Passing beyond this boundary meant facing intense heat and smoke, which required full protective gear. Even so, the crews came back after 8 to 10 minutes "looking like lobsters," according to Welsh, letting him know just how hot it was near the fire.

Firefighters also had to dodge pieces of concrete falling from the tunnel ceilings and walls. They were advised not to look up in order to avoid injuries. This falling debris collected on the shuttle roofs, which ultimately collapsed into V shapes. The debris also collected on the tunnel walkways, creating a sloping surface that was difficult to walk on. It, too, was intensely hot, according to firefighters whose soles were burned from standing on them. Because of this difficult access, only one hose line each could be used on either side of the shuttle. U.K. responders trained a third hose line on the inside of the shuttle, but the trucks on the carry wagons made it difficult to advance this line.

Additional Kent Fire Brigade resources were brought to the scene by loading the apparatus and their crews on HGVs and transporting them in the undamaged tunnel.

The U.K. firefighters reported problems with the water supply during the first two hours, a situation Eurotunnel engineers corrected at 3:00 a.m. by reconfiguring the water distribution system. The problem might have been caused by an overloaded system. At one point, there were a total of eight hose lines operating on a system that was designed to accommodate four. A broken water line was also found in the tunnel, beyond the end of the rear locomotive, which contributed to water shortages. Firefighters reported that water was coming out of this pipe

Photo: "PA" News

The burned-out interior of the Chunnel shows damaged concrete walls and ceilings eight days after the fire.

shortages. Firefighters reported that water was coming out of this pipe at such high pressure that it hit the opposite tunnel wall.

By 5:00 a.m., most of the fire had been extinguished. A "fire out," or stop message, was given at 11:15 a.m. By U.K. estimates, firefighters used more than 200 breathing apparatus cylinders.

Damage

Eight trucks were destroyed in the blaze, and the rear loader and locomotive was damaged. The tunnel itself was significantly damaged. The fire's heat dislodged the concrete liner. According to reports, as much as 16 inches of concrete were spalled away in some areas, leaving only 1 to 2 inches of liner between the tunnel and bedrock. Fiberglass insulation used in the tunnel was also released into the air, irritating the responders' skin. All of the utilities and track in the immediate area of the fire were destroyed.

Smoke spread east through the south tunnel and got into the north running tunnel through crossover doors that were closed, but not sealed.

In addition, the engineering management system failed at some point, probably because the fire burned through cabling in the running tunnel. This meant that the control centers didn't get important information on a number of engineering systems that failed during the fire. Engineers were also unable to monitor the status of the cross passage doors and determine how many were open and how many were closed, information that affects decisions about configuring the supplemental ventilation system.

Ventilation is critical

The most critical lesson that emerged from this incident was the importance of ventilation. A plan for controlling ventilation must be established and implemented quickly to limit fire spread. In this incident, the supplemental ventilation system was activated promptly, providing significant protection to the firefighters in the tunnel. The

Tunnel Stats Sidebar

Length of tunnel	50.45 kilometers	31.35 miles
Diameter of running tunnels	7.6 meters	5 feet
Diameter of service tunnel	4.8 meters	16 feet
Average depth beneath seabed	45 meters	148 feet
Distance between cross passages	375 meters	1,200 feet
Hydrant spacing within the running tunnels	125 meters	410 feet
Travel time	35 minutes	
Speed of shuttle	140 km/hr	
Number of wagons on an HGV shuttle	28	
Number of loaders	4	
Number of locomotives	2	
Number of club cars	1	
Substantial damage between markers	4172 and 4220	480 meters*
Severe damage between markers	4180 and 4209	290 meters*
Very severe damage between markers	4180 and 4201	210 meters*
Extreme damage between markers	4186 and 4191	50 meters*

*Source: Kent Fire Brigade

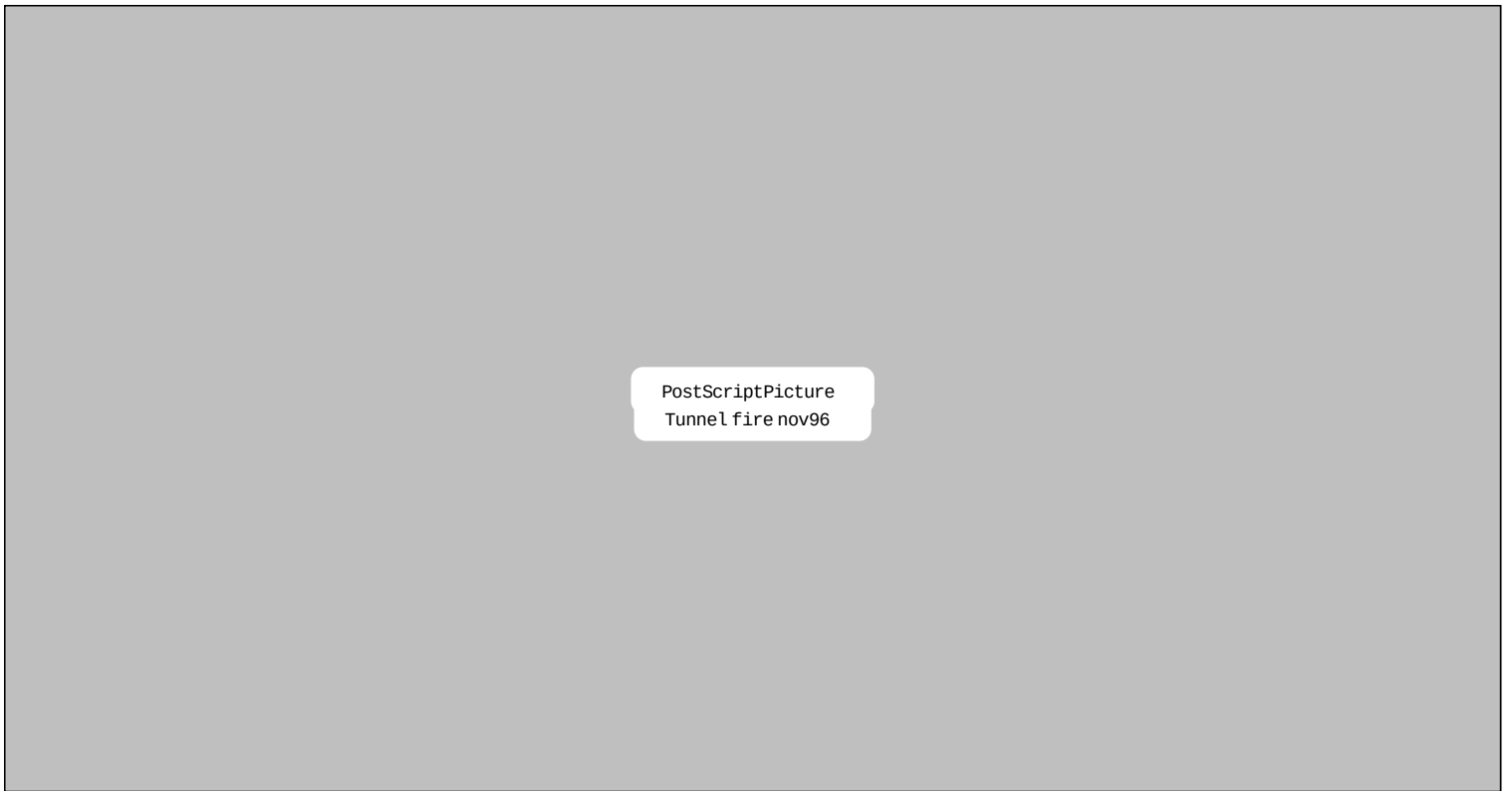

Chart: Geoffrey Sims, Tony Garrett, Helen Smithson, David Hart, Laura Sylvester, The Times, London

air bubble created by forceful cross ventilation allowed personnel a small working area safe from fire but close to the fire scene. Just outside the bubble, however, the force of the ventilation created a blowtorch effect. As a result, responders could spend only a limited time fighting the fire before the next rotation took over.

Vital communications

The second critical lesson is the importance of a strong communications systems. Responders trying to coordinate activities were stymied by the existing communications system, which was overwhelmed early in the incident. The radio system had only five channels, none of which were dedicated to fireground operations. It had to do, however, until a special system could be set up in the service tunnel. Reportedly, communications difficulties also existed between the two incident command centers at either end of the tunnel. Cellular phones provided backup.

Within the tunnel itself, a system was in place to allow firefighters to plug a portable radio into a socket at a cross passage door. An antenna system would allow the now hardwired portable radio to communicate with portable radios in the tunnel. Unfortunately, this system failed when the first U.K. entry team turned a corner in the tunnel, probably because the fire had damaged the system in the running tunnel.

Finally, the procedure for notifying responders from the Kent Fire Brigade broke down for some unknown reason. The hour that elapsed between the first report of fire and the Kent notification delayed the U.K. back-up response.

The need for water

This fire also demonstrated the need for large quantities of water for an extended period of time. The number of hose lines that were used exceeded the design capacity of the system. If a decision had been made to use master streams, there wouldn't have been enough water to do so.

Since crews were able to operate in the fire area for only 8 to 10 minutes, an extensive number of people were also needed. Provisions were made to rotate crews and bring in additional people on shuttles in the undamaged north running tunnel. This apparently worked well. Again, there were no reported injuries from either country's force.

Personnel from both countries emphasized the value of having participated in planning during the design phase of the Chunnel. This allowed them to get to know each other and learn how each organization operated, helping them work more effectively together during the actual emergency.

Aftermath

As a result of the fire, the Chunnel was completely shut down for 15 days. Passenger traffic on Eurostar trains resumed on December 4, and on Monday, January 6, 1997, the Channel Tunnel Safety Authority authorized the shuttling of buses. As *Journal* goes to press, trucks are still not being transported in the Chunnel. In the meantime, ferries, the Chunnel's competition, have been filling the void.

The cause of the fire is still undetermined.

A full NFPA fire investigation report is being prepared on this incident. To get a copy sent when it's completed, call (617) 984-7473 or E-mail a request to investi-