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INFORMATION FOR INTERVENTION TEAMS IN ROAD TUNNELS

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ABSTRACT

This document aims at providing information rather than recommendations to the various intervention teams—notably fire crews acting in tunnels—especially during fires. Fire-extinguishing techniques which are specific to firemen are not covered here.
The document presents intervention objectives, the first of which is to save user lives. It gives brief information about people's survival conditions, and conditions they are faced with. It goes on to examine the various steps of intervention procedures, starting with the initial alarm and its transmission to the intervention teams. The next step is the access to the tunnel. The last step is progression inside the tunnel as far as the event location, and dealing with it. Visual conditions—an essential parameter—are examined for various cases of mastered or non-mastered longitudinal airflow. Various recent intervention technique developments in very special tunnels (Fréjus Tunnel and Mont-Blanc Tunnel) are reported on briefly.

Lastly the document recommends the implementation of training exercises, sets out their general framework, and presents the Fréjus Tunnel training centre for intervention techniques.

MOTS CLES

TUNNEL / ROUTE / INTERVENTION / SECOURS

1. INTRODUCTION

Road tunnel disasters in recent years have shown up close links between the technical aspects of engineering structures and vehicles, individual and collective behaviour, user patterns, operating organisation and the organisation of safety services. Safety in road tunnels, as in all risk activity sectors, requires an overall approach to prevent and deal with serious situations. But above all, these disasters have led to a better understanding of safety objectives. It has become much clearer that the main priority is to save people, the drivers and passengers of vehicles who are present in the tunnel. Apart from some rare exceptions, emergency services take several minutes to get to the scene.
During this timespan, so precious for the survival of users, people have to make their own way out of the tunnel.

This document sets out the various stages of interventions in tunnels, together with recently developed means for improving and better ensuring the treatment of events. The evacuation of people is covered in general terms but also in specific terms for tunnels seen as having particularly sensitive safety problems.

2. SAFETY OBJECTIVES IN TUNNELS

The priority objective when ensuring safety in road tunnels is to guarantee, as far as possible, the lives of users. With this in mind, safety measures have to be taken that provide them with protection and enable their evacuation.

These arrangements also have to enable the intervention of emergency services to attain this fundamental objective. Controlling the fire should not be seen as a priority objective unless it enables lives to be saved. The task of emergency services is thus double: ensuring users' safety and controlling the fire.

This means that emergency teams have to understand:

• on the one hand those people whose job it is to take users in hand and get them to safety. For this they need suitable training. This is fairly new, and results from the experience of major disasters in recent years

• on the other hand, those people whose job it is fight the fire, a more traditional mission for which they have been trained.

3. EVENTS TO BE DEALT WITH IN TUNNELS

Events that disrupt tunnel use and require outside intervention services are:

• breakdowns

• accidents with or without fire, with or without injured or dead, whether the transport of dangerous materials is involved or not

• spontaneous fires

The most critical events are fires with aggravating circumstances (fire at the back end of a traffic jam, the presence of numerous coach passengers, the presence of dangerous materials, etc.).

4. SURVIVAL CONDITIONS FOR PEOPLE

Fire creates conditions that imperil the lives both of users and rescuers. The presence of smoke means that people lose their sense of direction and cannot find emergency exits. Stress can cause users to be incapable of taking logical decisions to escape. They need to be guided and helped.

Detailed studies carried out in France into tunnel dangers have developed scenarios showing that users perish in fires from the effects of carbon monoxide and too high a level of radiative heat flow.

Fire fighters are specially equipped and can withstand harsher radiative heat flow conditions. They may have individual breathing apparatus to counter the effects of carbon monoxide.

Thermal engines are sensitive to oxygen levels—indeed, when oxygen levels drop below 14% they begin to lose power. Their complete stoppage may jeopardise occupants. This type of condition occurred in the Mont Blanc Tunnel disaster.

5. DEGREES OF FIRE

A fire can be characterized by its thermal power that changes over time and that depends on the seat of the fire (LVs, HGVs, dangerous materials, etc.). The power curve as a function of time has three zones:

0. in the first zone power grows more or less quickly
1. the second zone is levelling off and of variable length
2. the third zone falls off until extinction takes place

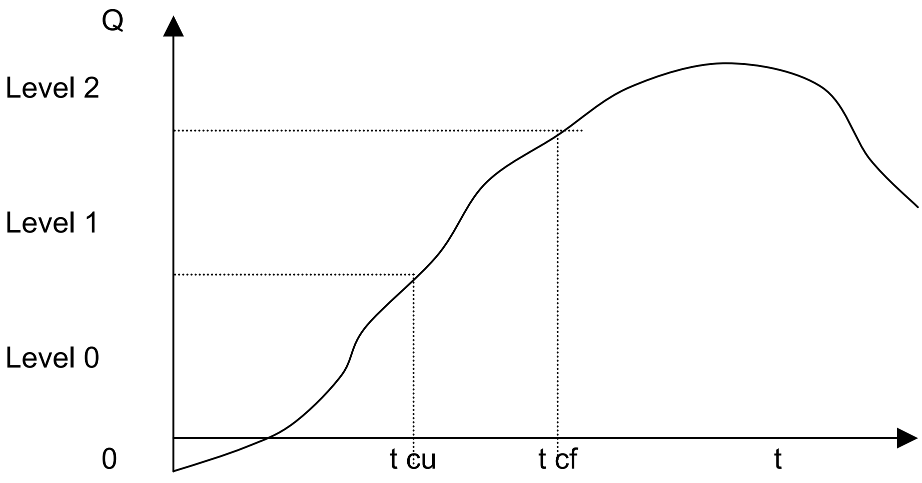

Figure 1 – Development of power (Q) of a fire as a function of time (t)

Depending on the power, three fire levels can be defined for the intervention teams:

0. Level 0 fire that lasts from the start of the fire until a t cu (Temperature Critical for Users) time is reached. During this period, users are able to get out of the tunnel by their own means and the emergency services can help them.

1. Level 1 fire lasts from the t cu time to t cf (Temperature Critical for Firemen). The conditions are such that only firemen can intervene and control the fire. On the face of it there are no more users to be saved.

2. Level 2 fire lasts beyond t cf. The fire is no longer controllable and firemen cannot intervene.

6. RECEIVING AN ALERT

Given the kinetics of fire spread, it is essential to detect an event as swiftly as possible so as to be able to take the right decisions to deal with it.

The basic principles governing actions to be undertaken when the alarm is given are:

- the zone must be protected by suitable signing
- the emergency services must be alerted
- the consequences of the event must be dealt with

The management rules to be respected are set out in a document whose name varies from country to country (PIS in France, for Intervention and Safety Plan). It is drawn up by the operator and lays down the actions to be implemented in a number of basic situations.

The fire brigade intervenes, following procedures set out in a document that has been approved by the Authority responsible for high-level safety (PSS in France, for Specific Safety Plan). If there are a lot of victims an additional, special procedure is instigated (the Red Plan, in France). These Plans specify actions to be adopted in such a way that coordination between the various intervening services is ensured.

It is important to clearly specify which Authority is responsible for operations. During the first phase, while the emergency services are not yet at the event, the operator will take all decisions. Later on it is important to be clear about who will give orders to the other services, including to the operator.

Once the alert has been given various immediate actions have to be carried out:

- Suitable signing, adapted to the event, must be put in place

When there is a fire the tunnel must be closed to traffic in order to limit the number of people present in the tunnel, as they could become potential victims.
Inside the tunnel, vehicles upstream from the fire must be stopped while those downstream must be able to get out.

Both tubes of a twin-tube tunnel must be closed. The fireless tube can thus be used as a safe access for the emergency teams. If there are communication galleries between the two tubes, users fleeing the accident tube thus arrive in a traffic-free, safe tube where there is no risk of causing another, panic-provoked, accident.

At chosen points along the road leading towards the tunnel, vehicles have to be detoured.

It is thus necessary to have traffic lights available at the tunnel portal, inside the tunnel, and on the access roads leading to the tunnel. Signing may be backed up with barriers that can be lowered when the lights change to red. In long tunnels barriers are installed inside the tunnel. These barriers must not hamper access by the emergency services.

Users must be informed about the cause of the closure so that they understand and respect the signing. At each traffic light there is a variable message sign that could show for example: "Tunnel closed: Fire".

If there is a radio broadcasting system that can be picked up by the general public, messages should be put out.

• The emergency services must be alerted

Wherever the alert comes from it must go through to the person who will take decisions and not transit through a series of different departments beforehand, wasting time and risking loss of information if there are transmission problems.

• In-tunnel devices must be deployed

As a preventive measure the automatic tunnel management system may, for example, switch the traffic lights to flashing amber, turn on speed limit signs, put up a warning message on the variable message signs, start up the ventilation to a certain speed or switch it off, depending on the circumstances.
These actions can be corrected as time goes on and the situation to be dealt with becomes more precisely understood.

Management of the ventilation system when there is a fire requires prior drawing-up of precise instructions.

7. INFORMATION ABOUT THE EVENT TO BE DEALT WITH

To provide an efficient intervention the emergency teams need information about the event to be dealt with, whatever it may be:

- exact location (tube, direction of traffic flow, position in the tube)
- type of event: breakdown, accident, fire
- number and type of vehicles involved
- type of fire: LV, HGV, coach, dangerous materials (DM)
- possible risks: product not classed as DM that may give off toxic gases or with high calorific power in case of fire
- number of users and injured present in the tunnel
- direction of air flow in the tunnel
- behaviour of smoke and fumes
- conditions of access

It is however vital to distinguish priority information to be given to decide what type of help should be called upon in the initial stages:

- type of event
- location of the event
- presence of smoke (if there is a fire)
- conditions of access

The exact location is of considerable importance. Drills carried out have shown that in a significant number of cases emergency teams mistook the tube or the tunnel portal, thereby wasting precious time.

These details should be given when the emergency services are alerted; they can then be completed and updated by radio during access to the tunnel. One solution that was envisaged and is now possible is to send the in-tunnel video surveillance images to the intervention vehicles. In this way the intervention teams can get a precise idea of the event to be dealt with and consequently be prepared.

8. CONDITIONS OF ACCESS TO THE SCENE OF THE EVENT

It is evident that rescue services must get to the scene of the event as rapidly as possible. In the case of a light vehicle (LV) fire the rescue services will control it very easily. For a heavy goods vehicle (HGV) fire, if the rescue teams arrive between 10 and 20 minutes after the start they will not be able to master it in most cases. Sometimes they cannot even approach it sufficiently to be able to do anything about it.

Two access phases can be distinguished:

8.1. Access to the tunnel itself

By this we mean a tunnel portal that may have a parking area reserved for rescue services, an outlet from an emergency exit or a communication gallery between tubes, etc.

The emergency services need to have road maps of the various routes and access conditions to the tunnel—especially in urban areas where the network is generally complicated, particularly near tunnel portals. These maps must be easy to read but at the same time full of data—vehicle clearances, service portal, need for a special key, break in safety barrier line, etc.—either as paper maps or on-board computerized files. They must be very regularly updated by observation and after drills.

The event itself or the closure of the tunnel leads to traffic disturbances that hamper access for the rescue teams. In some cases there are several access routes and a choice has to be made. The rescue teams must be in constant radio contact with the tunnel Control Centre (if there is one) to have reliable information about the itinerary.

Access roads need to be open at all times. Ongoing road-works may modify them and this has to be taken into account. When there is snow in winter access roads need to be practicable; the snow has to be cleared away.

The presence of toll points and their barriers should in no way slow down safety services.

Interventions against the usual traffic flow are of course possible, but should be undertaken extremely carefully.

In most cases, there are parking areas reserved for the rescue teams at tunnel portals or in their immediate vicinity. These areas are thus not affected by smoke and fumes coming out of the tunnel, they generally have an emergency telephone, a water supply and sometimes control boxes to vary road signing and tunnel ventilation. On these areas rescue teams can stop and obtain further information, finish kitting up and complete the intervention team before going into the tunnel, and load equipment. They can also be used for installing an operational command post if required.

When there are emergency services at both ends of the tunnel, each group must send in a team. Indeed, one of the teams may get blocked by a traffic jam or by a smoke-filled zone with zero visibility for example. The first team to arrive at the trouble spot will take charge of operations.

8.2. Access to the actual scene of the event in the tunnel

Once they arrive on the scene of the event the rescue teams have to assess the situation and request modifications in the treatment of the situation, or reinforcements if necessary. Dealing with a broken turbo on a lorry for example is different from dealing with a fire, but it is not possible to distinguish between them from the Control Centre.

Various problems are encountered when progressing through the tunnel:

• an event causes a traffic jam upstream that makes access difficult unless there is an emergency hard shoulder. If the road pavement is wide enough, rescue vehicles can work their way through lines of cars but progress will be fairly slow. A single badly positioned vehicle will block their way.

• when fires occur visibility is reduced and may even be inexistent. Only specially equipped vehicles will be able to intervene. The risk of intervening in zero visibility without special equipment is to create a new accident that may ruin the chances of a successful intervention.

Dealing with smoke from a fire occurs in various situations depending on whether the tunnel is fitted with a mechanical ventilation system:

• without a system

If there is no mechanical ventilation system and the traffic stops, the air flow direction and speed result from the combined effects of meteorological vagaries and the chimney effect that is dependent on the tunnel slope and the strength of the fire.
The emergency services can intervene by the side that has no smoke but the choice of one portal rather than another to access the fire is uncertain and can only be decided at the time of the event.

• with a system

If there is a Control Centre the firemen can ask it to generate specific conditions to enable them to intervene. The person directing the Control Centre will know how to direct ventilation to obtain the required effect. This may sometimes be impossible.
If there is no Control Centre, control boxes only available to firemen are stored at tunnel portals, enabling ventilation adjustments.

• survival conditions of the intervention teams are not ensured.
One of the worst cases that the emergency teams can encounter is a fire at the tail end of a jam thereby creating a second jam upstream.

Fighting fires and saving people are not covered in this document, as these activities are part of the specific tasks carried out by firemen.

9. EVACUATION AIDS

Various devices have been installed to enable people to move about in a smoke-filled atmosphere:

9.1. Marker posts

Smoke from a fire may completely block out lighting placed high up in tunnels. To enable both users and firemen to find their way in smoke it is planned, in France, to fit tunnels with luminous markers consisting of permanently lighted posts about 1 metre above ground level, about 10 metres apart, on each side-wall. The luminous part of these markers is made up of LEDs; one of the advantages of LEDs is their very long life. Older markers with incandescent lamps require too much maintenance.

9.2. Ariadne's thread

To improve the signing of the way leading to emergency exits in certain tunnels, an "Ariadne's thread" is implemented, mainly for users. This device can be seen in various forms.
Either:

- a 20 to 30 cm wide line painted on the side-wall,
- or a sort of hand-guide standing out from the side-wall.

The general specifications are: green, placed at a height of about one metre, on the side of the emergency exits.
Emergency exit pictograms may sometimes accompany the Ariadne's thread.
This arrangement has not been recommended for all French tunnels. It only concerns long tunnels that are seen as sensitive, from a safety standpoint.

9.3. Fixed guideline

Firemen working on a hazardous mission in a smoke-filled zone—as in a cellar fire—are linked to a reference point by a liaison cord whose length may vary from 1.25 to 6 metres. The aim of this personal liaison is to be able to return to the entry point. Fire brigades have now requested this same type of safety measure in tunnels. The solution, known as a fixed guideline, consists of placing a cable about one metre above ground level on a side-wall about 10 cm out from the side-wall face, throughout the length of the tunnel to serve as a reference point. Each fireman is then equipped with a liaison cord that is hooked at one end onto his belt and the other to the cable using a simple snap clasp. The fireman can then move all along the cable, providing that the cable is attached to the wall by a special device that allows the clasp to slide along without a hitch. It is not possible to have a continuous fixed guideline throughout the length of the tunnel because of the safety recesses, for example, but the cable can have 90° elbow curves.

10. SPECIAL VEHICLES

French regulations require the permanent presence of a rescue team at each end of two-way tunnels longer than 5,000 metres, that do not have a low traffic level and have no direct communications with the outside.
These teams have fire-fighting vehicles and equipment and rescue facilities for the injured; they can intervene rapidly from either side of the event.
In these tunnels, a motorized vehicle is necessary—specially equipped if need be—to drive in the safety gallery or the shelter accesses to be able to evacuate the injured, even on stretchers.

10.1. Intervention vehicles

These regulations have given rise to the development of special vehicles for the Fréjus, Mont Blanc, Toulon and Somport tunnels. A special vehicle is being studied for the East Tunnel of Autoroute (Highway) A86 West in its reduced-clearance section.
More or less dedicated vehicles for certain tunnels were designed in the past, but they did not reach the level of those currently being developed.
A few railway tunnels have also been, or will be, fitted with special intervention vehicles.

10.1.1. Mont Blanc Tunnel

The vehicle was named after the Roman god Janus, represented by two opposing faces. Janus was the god of Doors and—like them—had two faces.
The Mont Blanc Tunnel (a two-direction two-lane tube, 11,600 metres long) has three vehicles adapted to the geometry of the tunnel. This is why they have two driving cabins and guiding wheels that enable U-turns—with no manoeuvring—within the width of the 7-meter road pavement.
They can also advance in either direction depending on prevailing conditions. The driving cabin can be decided by toggling a command switch.
Two people, a driver and a team leader, occupy the "leading" cabin whence a water cannon placed on its roof and commanded by a joystick can be put into action. One person—a driver—is in the other "fleeing" cabin to drive in the other direction if need be.

These people have to be equipped with individual breathing apparatuses before and during their intervention in the tunnel. During the trip they are connected to fixed bottles of compressed air, thus ensuring 4 hours of autonomy. These bottles also maintain the high pressure in the cabins.
To be able to steer in the smoke, the front end of each vehicle is fitted with a thermal camera and flat monitoring screen inside the cabin.
In addition to the water cannon with a flow of 1,500 litres/min. already mentioned, the vehicle has a horizontally stored hose with nozzle, with a flow of 500 litres/min. It is all driven by a 40-bar pump operated by an auxiliary thermal motor, or else it can work from an electric mains supply, and is connected to a 4,000-litre water tank of and 500 litres of emulsifier.

The motor of the vehicle may be fitted with a tube that can be connected to one of the tunnel's fresh air vents for its air supply.
The cabin is protected by sprayed water, as are the tyres. The tyres are specially designed to withstand temperatures up to 80°C; the vehicle can continue to move even with a blown tyre.

The front end of each vehicle has a winch and blocks for pushing vehicles

10.1.2. Fréjus Tunnel

An intervention vehicle called Titan, specially adapted to the dimensions of the Fréjus Tunnel (a two-lane two-way tube, 12,870 metres long) is stationed at each portal.
It has only one cabin with three seats but has four-wheel drive and four-wheel steering. It may be called upon to intervene on the tunnel's steeply sloping, sometimes snow-covered, access route, which is why it needs to have four-wheel drive. Four-wheel steering enables U-turns inside the tunnel where the drivable width is 9 metres, and also the reversing out of the vehicle. To make driving easier the gear-box is automatic. The front end is fitted with a swivel "catcher" to push vehicles.

Driving in a smoky atmosphere is made easier by a thermal CCTV camera that sends images back into the cabin onto a flat control screen. The camera is fitted to the front of the vehicle in a special box that protects it from the effects of heat. It can also be fitted at the rear. With this device it is possible to drive at 50-60 km/hr in smoke.

A detector at the front and another at the rear of the vehicle give an indication of the distances to obstacles encountered. The tyres have a limited-collapse system that allows driving on flat tyres. The cabin is protected by a water spray ramp. The windscreen is covered with a shielding film.

The vehicle's fire-extinguishing equipment includes tanks for water and emulsifier, a pump, and 82-metre hoses on electric drums at front and rear.
The vehicle is fitted with a very special innovation that consists of air stored in ten 50-lire bottles at 300 bars. This air is used to maintain high pressure in the driving cabin and to feed the masks of the three individual breathing apparatuses built into the seats and most of all to feed the engine—which is the biggest consumer. The air flow that feeds the engine from this source is managed and optimised by a computer that takes into account the level of ambient oxygen and the power required.

A 4WD is stationed at each portal in cases where access to the event is difficult.

10.1.3. Toulon Tunnel

The vehicle made available to the firemen of the Town of Toulon to intervene in the three-kilometre Toulon Tunnel (a one-way, two-lane tube of 2,969 metres) is similar to those of the Mont Blanc Tunnel, with two cabins. All four wheels of the vehicle are traction and steering. The two cabins have a total capacity of 6 people with individual built-in breathing apparatuses.
The vehicle has the fire-fighting equipment of a vehicle of the fire-engine-tonne type meeting French norms.
At the front of each cabin there is a thermal camera to help driving.
The engine does not have an autonomous supply of compressed air but it is possible to connect a pipe to a fresh air supply in the tunnel.

10.1.4. Somport Tunnel

An intervention vehicle is scheduled at each portal of the Somport Tunnel (a two-direction tube, 8,597 metres long). These vehicles will be similar to those at the Fréjus Tunnel.

11. EVACUATION VEHICLES

11.1. An in-tunnel evacuation vehicle

For the Fréjus Tunnel a special vehicle has been developed to evacuate people remaining in the tunnel after a serious event. Its purpose is to pick up people who have not got to one of the shelters that are some 1,500 metres apart in the tunnel. It is a sort of mobile shelter that can transport 10 people standing, 10 sitting plus three firemen, including a driver. The bench seats have been designed to accept stretchers. One vehicle is stationed at each tunnel portal.

The vehicle has two driving cabins, one at each end, since it cannot do a U-turn inside the tunnel, because of its length. It behaves like an ordinary vehicle. The wheels under the cabin are for steering (master cabin) whereas those beneath the rear cabin (slave cabin) are driving wheels. Everything switches around when the direction changes. Notably, the vehicle's lighting system automatically changes to conform with highway code requirements.

Survival equipment includes forty 50-litre bottles of air at 300 bars. Sixteen bottles are for creating high pressure inside the vehicle, to feed 20 masks, plus three safety masks and the three individual breathing apparatuses of the firemen. Twenty-four bottles are available to feed the engine if need be, thus enabling three sorties into the tunnel to be able to evacuate a coachful of passengers.

The central cell has a sliding door on each side for rapid loading of people. The sides of the vehicle are painted in the same way as the sidewalls of the tunnel and thus have a green line of the Ariadne's thread type (previously mentioned in this document) whose job is to show the way and the side of the tunnel where the shelters are. Arrows and increasingly bigger and bigger "emergency exit" signs lead to the access door of the shuttle. An "emergency exit" sign is shown on the access door itself.

Driving aids (automatic gear-box, infra-red CCTV, obstacle detector, flat tyre driving, etc.) and the air-feed system for the engine are identical to those on the intervention vehicle developed for the same tunnel.

The vehicle was put through its paces in an exercise, with satisfactory results. In particular it can hold 40 people if need be.

11.2. Vehicles for evacuation from galleries

When tunnels are long and have emergency or evacuation galleries vehicles are required that can very swiftly evacuate people from them. These people have usually—as a first step—taken refuge in a shelter that they cannot leave to get to a safe place except with the protection of rescue teams.

Unlike the Gothard Tunnel, the Fréjus Tunnel does not yet have a safety gallery. The evacuation of people who have taken refuge in shelters—some 1,200 to 1,500 metres apart—takes place through a fresh-air ventilation shaft situated in the false ceiling of the tunnel. To get these people into safety quickly, there is a 4WD vehicle with a trailer at each shelter outlet in the gallery. There are 10 altogether, eight in the tunnel, plus one at each portal. The vehicle and trailer can take 6 to 8 people, plus the driver.

The 4WD can do a U-turn in the gallery. This is not the case for the trailer that has to be detached and re-attached from the other side. The trailer has a double steering axle, enabling it to set off in the other direction.

In the case of the Mont Blanc Tunnel the ventilation shafts are located under the road pavement. Fresh air ducts serve the evacuation gallery for people taking refuge in the shelters. An electric vehicle, adapted to the geometry of the shaft, is stationed at each portal, at the entrance to the gallery. These vehicles are designed to evacuate—in addition to the driver—three able-bodied or reduced mobility people or one injured person on a stretcher. As they cannot turn around inside the gallery they have to be able to operate in both directions.

12. SPECIAL PRECAUTIONS

12.1. Variable ventilation conditions

Meteorological conditions may vary at certain times of the day and with them the direction of the air in the tunnel. An example is the change of wind direction in tunnels near the sea under the influence of land winds and sea winds.

When a special wind like the Foehn starts to blow, the mechanical ventilation in a two-way tunnel may not be able to control air direction.

12.2. Breakdowns

One of the dangers lying in wait for intervention teams is a breakdown or deficiency in the system that ensures their safety.

The most insidious is undoubtedly the breakdown of the system that enables interventions by cooling down the atmosphere or the intervention vehicle by spraying water in the form of rain or mist without any operational safety guarantee. A breakdown for whatever reason or simply because the water supply is exhausted will mean that these people will be exposed to conditions in which survival is no longer possible and where they will perish. In certain extreme cases moreover the usefulness of such interventions is very questionable as they expose the intervention teams to considerable risks when it is clear that the conditions are such that there is nobody left to save and that saving the structure of the tunnel is not a major objective.

As has already been said, it may happen that—in a major fire—the level of oxygen in a tunnel is insufficient to enable the internal combustion engines of the emergency services to operate correctly.

12.3 Vehicles running on LPG

In Italy for example some 90% of cars run on LPG (liquefied petroleum gas). In principle this type of vehicle is not banned from road tunnels. In the Mont Blanc Tunnel drivers have to notify their use of LPG when going through the toll gate.

An explosion is possible when such vehicles catch fire. The emergency services must therefore take precautions when dealing with such cases. In France these precautions go by the name of the "Lyons directive" because of a burning LPG vehicle that exploded, severely injuring two firemen in a Lyons suburb. This text states that firemen should take up position at least 50 metres away and work on the front of the vehicle so as to be protected from the effects of an explosion of the tank, situated at the rear of the vehicle. The aim of their intervention is to cool down the whole vehicle so as to avoid an explosion resulting from the effect of the heat produced by the fire. Fire-fighting means therefore need to be able to go beyond 50 metres. In the case of a two-way tunnel it is also necessary to intervene from either side.

13. DRILLS

The emergency services need to be very familiar with the tunnel or tunnels they are likely to intervene in. Visits have to be organised so that the technical features of structures can be understood in calm conditions.

Drills enable the testing of operating instructions and safety intervention programmes, and their application by the various safety teams—especially the emergency services. Drills are necessary because each tunnel has a different structure, different equipment and organisation and existing rescue arrangements. Procedures that are rarely implemented get forgotten. Staff change as time goes by and it is important for them to train in realistic situations rather than have to react for the first time in a serious situation. This is important when a tunnel is brought into service.

Drills may only concern some of those involved—under the sole responsibility of the site owner or with the police and firemen or under the authority of the person responsible for general safety for evacuation exercises with large numbers of injured.
Their programmes can be very varied but the first one to be carried out is to test the closure of the structure and the coordination of the different services involved. This may be done in a real situation, as for example when there is a closure for works. The reaction time of each participant should be noted to see whether these times can ensure good safety and whether the situation can be improved. It is not necessary to have a fire but some smoke in the tunnel enables the emergency services to become familiar with moving about in a reduced-visibility atmosphere.
A minimum of one drill, large or not so large, per year should be the minimum. More may of course be organised if it is felt necessary.
Each drill should be carefully written up, with recommendations if necessary.

14. SPECIFIC TRAINING

Interventions in tunnels require specific training that goes well beyond that of traditional training for firemen.

With this in mind Fréjus Tunnel has set up a Tunnel Intervention Techniques Training Centre (CFEFIT).

To start with, the tunnel's safety agents are volunteer firemen, living locally, with a first-aid certificate and a heavy goods vehicle driving licence.

The progressive training and recycling programme includes basic knowledge of the tunnel itself, the intervention and safety plans, individual breathing apparatuses and medically supervised drills on moving walkways and endless ladders.

This programme is completed by drills in a maze and a tunnel simulator.

The maze is used to train for interventions in variable situations in an unknown environment. To achieve this it is fully adjustable and temperature, visibility and lighting conditions can be modified.

The tunnel simulator is 13 metres long, 7 metres wide and 2.8 metres high. It includes all the features of a tunnel, i.e. four safety recesses with emergency call phones, hydrants and shelters. To better simulate situations there are sound effects. A model is used to produce a car fire or the evacuation of an injured person. The real novelty is that it is possible to simulate a lorry fire, a surface fire and a ceiling fire. The aim of the latter is to simulate the phenomenon of blazing gas at ceiling level. LPG is used for these fires.

All this is managed by a PC and it is possible to set up various scenarios. Temperature, oxygen and carbon monoxide levels, and explosiveness are constantly monitored. Trainees can be observed on the PC via thermal cameras, one of which is fixed and the other mobile and manipulated by the accompanying instructor. Conversations are picked up by built-in equipment in the trainees' helmets and sent back to the PC.

General safety is ensured by opening of doors, swift smoke-clearing and switching on of maximum lighting.

This simulator is designed to be adapted to a variety of uses so that people from other tunnels or safety services can come and be trained.

A final five-day test with two firemen validates the training of 12 people.

CONCLUSION

The large number of victims in recent tunnel disasters has led to profound modifications in the ways of considering their safety. Existing regulatory texts in various countries have been modified. The European Union has a planned Directive concerning minimum safety requirements applicable to trans-European road tunnels.

New equipment that has been recently developed thanks to technological progress has been integrated into these rules. Other equipment has since been developed in response to new imperatives while some has been put forward and it had to be decided whether these developments really did contribute to improved safety and were not redundant when compared with existing equipment. Lastly, some devices are still being assessed because they are based on physical phenomena that are not yet fully understood. This document has presented some newly developed and implemented dispositions and equipment that are now operational in certain "sensitive" tunnels that should result in improved safety in tunnels in general.

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