APPENDIX N° 2

to inter-ministry circular n° 2000- 63 of 25 August 2000
relating to the safety of tunnels in the national highways network

TECHNICAL INSTRUCTION RELATING TO SAFETY MEASURES IN NEW ROAD TUNNELS
(DESIGN AND OPERATION)

CONTENTS

PREAMBLE

The purpose of this instruction is to specify the safety measures which must be applied to new road tunnels for the protection and evacuation of users and action by the emergency services in the event of an incident or accident, and to limit the consequences of such an event. By incident or accident is meant here any event due to accidental circumstances which might place users of the tunnel in danger: incidents having a serious effect on the tunnel's technical systems, road traffic accidents, fire, release of hazardous materials, etc.

This text is not concerned with construction rules relating to the mechanical strength and durability of structures, nor the provisions and equipment necessary to ensure tunnel operation in the context of normal functioning.

Although the safety measures described in this instruction are designed to apply to incidents or accidents once they have occurred, it is not possible to place too much emphasis on the importance of measures of a preventive nature designed to limit their number and severity, regardless of whether these measures relate to the design of the structure or its future operation. The measures which are to be applied in these two fields must also be regarded as a whole.

Effectively, future conditions for the operation of a structure must be adapted to the characteristics of the tunnel, its equipment and traffic, and vice versa. These shall constitute a fundamental factor which must be taken into consideration at a very early stage.

Although design and operation must comply with the provisions applicable to routes in the open air, they must also take into account the special features associated with the underground nature of the structure.

With regard to general design, choices about number of tubes and their one-way or two-way nature must be taken having regard to all pertinent parameters relating to safety (total traffic, heavy goods traffic, the system for the authorisation of the carriage of hazardous goods, congestion risks, geometrical and line characteristics, gradients, protection and safety facilities, devices for the detection of incidents and stopped vehicles, safety equipment, operating measures, etc.). In general, tunnels must have two one-way tubes if they are to accept heavy goods traffic in excess of a total of 4000 vehicles per day in both directions, as a yearly average. In any event, as indicated below in this instruction, non-urban tunnels more than 500 metres long and urban tunnels more than 300 metres long must include safety exits which are connected to the exterior at regular intervals.

Similarly designers should consider the possibility of replacing a long structure by several shorter structures, in particular in the case of cut-and-cover tunnels which can often be interrupted at regular intervals by open sections or partial cover which can allow smoke to escape in the event of fire (e.g. "acoustic baffles").

As far as geometrical characteristics and equipment are concerned, specific problems, such as for example the transition between an open air stretch and the much darker and more enclosed environment underground, or again the restriction on visible distance produced by side walls and roof, must be investigated very closely. In this respect the reader is invited to refer to the specialist documents produced by the Tunnel Design Centre (CETU), and in particular the pilot tunnel documentation, without forgetting the documents relating to all highways, in particular those produced by the Highways and Motorways Design Department (SETRA).

In the remainder of this instruction it will be assumed that all necessary measures of a preventive nature will have been taken earlier. This being the case, its provisions will relate to the following fundamental objectives in the event of incidents or accidents:

- the detection of abnormal situations and their communication to users (monitoring and detection equipment, signalling equipment, emergency telephone stations, etc.),
- means for the protection and evacuation of users and access by emergency services (emergency exits, shelters, lay-bys, emergency lighting, ventilation, etc.),
- fire detection and control (reaction to fire and fire resistance, extinguishing systems, emergency service communication facilities, smoke extraction, etc.).

However, to assist use of the document the measures which have to be applied have been classified according to their nature: civil engineering, equipment, fire behaviour, operation. This should not mean that the role of any one of a set of complementary measures designed to achieve the same objective should be lost sight of.

While it is always possible that the provisions in this text may not be implemented strictly if it can be demonstrated that the proposed measures ensure at least an equivalent level of overall safety, for example by strengthening some aspects in order to compensate for a choice of lesser performance from others. If no recognised methods for demonstrating that compensatory measures ensure at least an equivalent overall level of safety exist, the measures adopted in similar circumstances may be used as a basis.

Most of the safety devices and equipment are to be incorporated along the length of a tunnel in a repetitive module approximately 200 m long, or as multiples of 200 m in some cases.

In the remainder of this document a number of terms are used with the special meanings defined below.

Light traffic tunnel : the tunnel in which the envisaged traffic in each direction ten years after it has been placed in service is less than both an annual average of 2 000 vehicles per day and 400 vehicles at peak times (30th heaviest hour in the year). When assessing these criteria heavy goods vehicles are to be counted as five vehicles.

Urban tunnel : a tunnel located within an urban unit of more than 20 000 inhabitants as defined by the INSEE (see 1990 general population census - Composition of urban units by communes) and fulfilling at least one of the following conditions:

- envisaged traffic in one direction more than 1 000 vehicles per traffic lane at daily peak times ten years after commissioning,
- risk of traffic backing up into a tunnel because of the existence of a crossroads at grade a short distance away from a tunnel exit, or any other arrangement of a permanent nature (route through a heavily built-up area, etc.),
- the existence in the tunnel of exchangers, arrangements for pedestrians, for bicycles, for common or public transport, etc.

Tunnels located within urban units of less than 20 000 inhabitants in which there is a risk of frequent congestion shall also be regarded as urban tunnels.

Non-urban tunnel : a tunnel which does not meet the conditions requiring it to be regarded as an urban tunnel.

1 - SCOPE OF APPLICATION

For the purposes of this instruction all covered roadways, regardless of how they are constructed, bored or immersed structures, cut-and-cover structures, which does not permit the circulation of air, partial roofing offering an open surface to the exterior of less than 1 m^2 per linear metre of traffic lane are regarded as tunnels.

With exception of the following paragraph, this instruction applies to projects for the construction of road tunnels more than 300 m long which are open to public traffic. In the case of tunnels made up of several tubes, it shall apply when one of the tubes exceeds this length. In this case the length limits included in the remainder of the text shall apply separately to each tube.

The examination of safety problems and adoption of the necessary measures must not be dispensed with in the case of construction projects which do not fall within this scope of application. These may be based on this text, particularly in the case of successive tunnels where there is difficulty of access, partial roofing which has a surface area open to the exterior which is a little larger than above, or tunnels authorised for vehicles carrying hazardous goods. Tunnels between 200 and 300 m long must in any case have two emergency recesses (described in section 2.4), preferably located outside the tunnel, which will be equipped with an emergency telephone and extinguishers (described in sections 3.4 and 3.5). If they are urban these tunnels must also be provided with a water supply point at each end (as described in section 3.5).

With the exception of chapter 6, the following text applies to tunnels where the authorised overhead clearance for signalling is more than 3.50 m. Chapter 6 deals with the special case of structures with lower clear heights.

Chapters 2 to 6 apply directly to tunnels which are prohibited to hazardous goods traffic (vehicles which are required to display special markings in accordance with the amended order of the 5 December 1996 relating to the transport of hazardous goods by road, known as the "ADR order"). Chapter 7 describes additional measures which must be taken where hazardous goods traffic is authorised.

2 - CIVIL ENGINEERING PROVISIONS

2.1 - Roadways and walkways

2.1.1 - Emergency vehicle access widths

If traffic is one-way, the transverse profile must be designed to permit access by emergency vehicles, including in the normal traffic direction, when there are stopped vehicles on the nominal number of traffic lanes. If necessary use may be made of an emergency stopping lane or a lower level lane associated with an accessible walkway. No special provisions need however be provided in the following two circumstances:

- if there is direct communication with the exterior (as described in section 2.2.1),
- if there is access to a second tube, which can be accessed at least by pedestrians (described in section 2.2.2.a), and also if the traffic can easily be interrupted in the second tube so as to allow emergency vehicles to pass through.

2.1.2 - Walkways

A walkway must be provided alongside each direction of traffic movement so that users in distress who have had to leave their vehicles to reach safety equipment or to exit from the tunnel remain outside the lateral traffic clearance.

This walkway, which shall be raised to a maximum of 0.25 m, shall not be separated from the roadway by a kerb or any other device of more than this height. It shall also have the following minimum widths beyond the lateral traffic clearance:

- 0.60 m at ground level,
- 0.75 m at a height of 1.50 m above ground level.

2.1.3 - Roadway surfacing

Draining wearing courses are prohibited within tunnels more than 50 m from the ends. If such a wearing course is used in the tunnel approaches, the change shall be made in a covered area so as not to create a singularity in terms of skid resistance or spray at the tunnel entrance or exit in the event of rain.

2.2 - Arrangements for the evacuation and protection of users and emergency access

Arrangements for the evacuation and protection of users and emergency access shall constitute an essential safety feature. In urban tunnels these arrangements shall be provided on a systematic basis and access shall be provided approximately every 200 m; a shorter spacing is to be used in tubes which are frequently congested and which have more than three lanes. In non-urban tunnels these arrangements are to be provided where lengths exceed 500 m and the spacing will be approximately 400 m. In the case of light traffic tunnels it is recommended that the same requirements be complied with; adaptation may however be envisaged depending upon difficulty of construction.

The type of arrangements are to be selected in the following decreasing order of preference:

- direct communication with the exterior wherever this can be provided under reasonable conditions,
- communication between tubes, when there are two tubes, and this communication can be provided through an intermediate airlock,
- parallel safety tunnel if this is otherwise justified,
- shelters with access-ways protected from fire if none of the above arrangements can be used.

The doors located between these facilities and the tunnel must remain closed when not in use. They must be capable of being opened by any user who has need to enter the facilities.

Ventilation for facilities for the evacuation and protection of users and emergency access is dealt with in section 3.2.3, lighting in section 3.3 and fire resistance in section 4.3.2.

2.2.1 - Direct communication with the exterior

In the case of tunnels where the roadway is less than 15 m from the ground surface, particularly in cut-and-cover structures, the facilities for the evacuation and protection of users and emergency access shall consist of direct communication with the exterior.

Accessible to pedestrians only, these communication facilities must have a minimum width of 1.40 m and a height of 2.20 m. They are to be separated from the tunnel by an airlock having a floor surface area of at least 5 m^2. The doors shall leave a clear space at least 0.90 m wide and 2 m high, and shall all open in the direction away from the tunnel. Communication facilities and airlocks must allow for the passage of a stretcher 0.70 m wide and 2.30 m long. The two doors of the airlock must be capable of being opened simultaneously in order to permit a stretcher to pass through.

Communications must not be accessible to unauthorised persons from the exterior.

In the case of tunnels where the roadway is more than 15 m from ground level, the provision of direct communications with the exterior is not compulsory and shall be compared with the arrangements described in section 2.2.2.

2.2.2 - Facilities underground

Where there is no direct communication with the exterior, the facilities for the evacuation and protection of users and emergency access shall be provided in accordance with the following requirements:

a) Tunnels with two tubes

Communication between the tubes represents a satisfactory arrangement for the evacuation of users provided that a single door does not provide access from the tube in which the incident or accident occurred and a traffic lane in the other tube (through which traffic may still be passing). In addition to these communication facilities, whenever possible an airlock having a surface area of at least 15 m^2 is to be provided between the two tubes. If this is not possible (e.g.

tube separated by a single concrete wall), one of the arrangements described below for single tube tunnels is to be adopted.

Section 2.3.1 indicates the special circumstances in which communications between the tubes must be accessible to emergency vehicles and the requirements applicable to them.

Communications which are designed for pedestrians shall be at least 1.80 m wide so that fire-fighting equipment (in particular hose reels) can pass through, and be 2.20 m high. Doors are to allow free passage of 1.40 m and are to have a minimum height of 2 m. They are to open in the direction away from the tunnel and towards the communication facility. If a change in level between the tubes makes it impossible to take a hose reel through (when stairs are present), communications between the tubes and their doors shall comply with the minimum dimensions described in Section 2.2.1 for direct communications with the exterior. Under normal circumstances the communication facilities will be closed off so as to prevent air and smoke from passing from one tube to another.

b) Single tube tunnels

Where only one tube is present it will be necessary to have either a safety tunnel or shelters connected to the exterior of the tunnel by an access-way which is protected against fire.

Safety tunnel parallel to the tunnel

A safety tunnel parallel to the tunnel is only to be constructed if this is justified for technical reasons (e.g. pilot tunnel). Communications between the tunnel and the safety tunnel are in principle to be accessible only to pedestrians. Whenever possible they are to be equipped with an airlock. The safety tunnel, the communication facilities and the airlocks where present are to have at least the characteristics specified in section 2.2.1 for direct communication with the exterior.

Shelters (previously known as refuges, especially in circular 81-109 of 29/12/1981)

Whenever none of the preceding arrangements apply, shelters are to be built to offer users a safe place while they await evacuation. Each shelter shall have a surface area of at least 50 m^2, a minimum width of 4 m, a minimum height of 2.20 m, and a mean height of 2.50 m. The entrance shall be equipped with an airlock having the characteristics described in section 2.2.1 for airlocks in direct communication with the exterior.

Shelters must be connected to the exterior of the tunnel by an access-way which is protected from fire and intended for emergency purposes. This must also be capable of evacuating persons sheltering in a shelter. They must not however be able to use them without being guided by emergency or operating personnel. The access-way will not have to be fitted out as a safety tunnel. It shall have a minimum height of 1.50 m for a width of 1.40 m, and a height of 2 m for a width of 0.9 m (located within the previous width of 1.40 m). Its floor must be capable of supporting at least a distributed load equivalent to 2.5 kPa over its entire surface area. This requirement shall not prevail over other requirements associated with operating needs. A ventilation shaft may be used for this purpose provided that fresh air can be gently blown through it while a fire is in progress (this method of ventilation must remain compatible with the emergency scenarios adopted). Fresh air delivery shafts which can be reversed to extract smoke are ruled out for this application. Communications between these access-ways and shelters may have characteristics which are smaller than for the communications described previously, but they must permit a stretcher having the dimensions indicated in paragraph 2.2.1 to pass through.

Use of specialist motor-driven emergency equipment

In tunnels more than 5000 m long which are not light traffic tunnels, the safety tunnel parallel to the tunnel or the access-ways providing access to the shelters must be capable of being used by the motor-driven equipment appropriate to their geometry described in section 5.1.2.

2.3 - Facilities for use by emergency vehicles

Facilities for use by emergency vehicles must be capable of being used by a one tonne tank/pump truck which is 8 m long,
2.50 m wide and has a turning cycle diameter between walls of 19 m.

2.3.1 - Facilities within a tunnel

In tunnels more than 1000 m long, provision must be made at approximately every 800 m for the passage of emergency vehicles from one tube to the other if there are two tubes and if this arrangement is possible, or for them to turn round in other circumstances.

In tunnels where two tubes or communication tunnels between the tubes are provided in accordance with section 2.2.2.a, this is to be ensured by making some of the communication facilities accessible to emergency vehicles.

Tunnels which are accessible to emergency vehicles shall have a minimum width of 5 m between side walls. They shall have a trafficable width of at least 3.5 m and a height of 3.5 m over this width. Their gradients shall not exceed 15 %. They shall be equipped with doors leaving a free space of at least 3.50 m wide by 3.50 wide high. The geometry of the ends of these tunnels and their doors shall permit an emergency vehicle as described above to pass through without reversing. Doors of smaller dimensions, leaving a free width of 0.90 m and a height of 2 m are also to be provided for the passage of pedestrians. These doors are to be closed in normal circumstances to prevent air and smoke passing from one tube to the other.

If communication tunnels between the tubes have not been provided in accordance with section 2.2, communication facilities shall be provided for the sole use of emergency vehicles (in the general case of cut-and-cover structures where there is direct communication with the exterior these shall consist of single doors provided in the central upright). It shall only be possible for these to be opened by emergency or operating personnel.

The above provisions shall not apply if the two tubes are one above the other or are on very different levels.

In the case of tunnels in which there is a single tube, or two tubes without any possibility of communication for vehicles, provision shall be made for emergency vehicles to turn round with maximum reversing under a height of 3.50 m. This may be achieved by constructing reversing tunnels whose dimensions will depend on the trafficable width of the tunnel and the existence of any widening at that point.

2.3.2 - Arrangements at the ends

A location 12 m long and 3 m wide for parking an emergency vehicle shall be provided outside, close to the ends, on the right hand side of the entering lane or lanes, outside the traffic lanes.

In addition to this, in all tunnels having two tubes an arrangement enabling emergency vehicles to move from one roadway to another shall be provided externally, close to each end.

In the case of single tube tunnels facilities are to be provided externally, close to the ends, for emergency vehicles to turn round.

If the above arrangements cannot be provided in the immediate vicinity of the ends, they are to be placed as close as possible.

2.4 - Emergency recesses

Emergency recesses are designed to hold various items of emergency equipment, in particular emergency telephones and extinguishers. It is strongly recommended that they be fitted with doors which can reduce inside noise levels and protect equipment from dirt. Even in circumstances where they are fitted with doors and under slight positive pressure, recesses must not be designed for the protection of users from the effects of a fire. All steps are to be taken to prevent users from being misled in this respect.

Emergency recesses are to be provided at approximately every 200 m within a tunnel, and close to each end. The latter are preferably to be located outside the tunnel. If lay-bys are provided, a recess is to be provided in each one, or in its immediate vicinity if this is impossible.

Recesses are to be located on the right hand side of each traffic lane:

- on a single side if the traffic is one-way,
- on both sides and opposite each other if the traffic is two-way.

So that users can make use of emergency telephones and the extinguishers provided in the recesses without any difficulty these are to have the following minimum dimensions:

- width : 1.5 m,
- depth : 1 m,
- height : 2 m over their entire surface area.

These dimensions may be adapted in relation to other emergency equipment which has to be installed and special circumstances. In particular if fire-fighting equipment (risers or hydrants) is installed, the provisions relating to clearance spaces specified by standard NFS 62-200 must be complied with. Recesses are to be accessible from the roadway without any change in level higher than that of a footway kerb (see section 2.1.2).

Unless it is impossible, recesses must not project beyond the line of side walls. If exceptionally they do project, special arrangements designed to protect drivers and users of the recess in the event of an impact are to be provided; in addition to this the minimum passage widths for the footway specified in section 2.1.2 are to be maintained alongside the recess.

If emergency recesses are fitted with doors, these must not project into the lateral clearance for vehicle traffic including the emergency stopping lane, if present, when they open.

Emergency recesses are separate from the facilities for the evacuation and protection of users and emergency access described in section 2.2, but this does not rule out them being located close together. Emergency recess equipment may possibly be installed in front of the access doors to such facilities.

2.5 - Fire-fighting recesses

Fire-fighting equipment whose water supply is dealt with in section 3.5.2 must preferably be located in recesses which are separate from emergency recesses. This requirement shall be compulsory in situations where the latter are provided with doors.

The dimensions of fire-fighting recesses shall comply with the requirements relating to clearance volume specified in standard NFS 62-20 relating to fire-fighting equipment - fire-fighting risers and hydrants - installation requirements. Preferably recesses and their equipment should not project beyond the line of side walls. If exceptionally they do project, special arrangements designed to protect drivers in the event of impact are to be provided; in addition to this the minimum passage widths for walkways specified in section 2.1 are to be maintained alongside the recess.

Fire-fighting recesses are only to be located on one side.

2.6 - Helipad

Where a tunnel is more than 3 000 m long and access to the area is difficult, an area which can be used as a helipad is to be found, if possible, at each end in the case of a two-way tunnel.

2.7 - Arrangements to prevent the passage of smoke from one tube to the other

In tunnels with two tubes, if a fire breaks out in one tube the smoke produced must not invade the other tube.

All precautions are to be taken to prevent this in the separations between the tubes (in particular leaktight walls and passages through them) and at the ends (e.g. a wall between traffic directions or offsetting the ends, to be provided for at the design stage).

Where measures such as those described above cannot be applied at the ends, operating instructions for ventilation in the event of fire are to be designed to avoid any risk of drawing smoke from one tube into the other.

2.8 - Lay-bys

In the case of tunnels more than 1000 m long which are not light traffic tunnels, where the width available for vehicles will not permit traffic on the nominal number of lanes alongside a stopped vehicle, lay-bys are to be provided approximately every 800 m, and this distance is to be adjusted according to gradients.

2.9 - Accessibility for handicapped persons

It is not desirable that handicapped persons who can only move in a wheelchair should leave their vehicle without assistance in a tunnel with normal traffic. Such a manoeuvre is in fact hazardous because it involves getting out onto at least one traffic lane. This hazard does not arise in lay-bys; it is therefore also necessary that the emergency recesses located in lay-bys should be designed to permit access by handicapped persons.

In order to be able to gain shelter in the event of a serious accident or fire, handicapped persons using wheelchairs must be capable of passing through the airlocks between the tunnel and the direct communications to the exterior (described in section 2.2.1), enter communication facilities between tubes (section 2.2.2.a), gain access to the parallel safety tunnel or shelters where present (section 2.2.2.b), without the help of a third party. It is not however required that these handicapped persons should be able to use these various communication facilities as far as their exits without help. They must be able to communicate with the exterior using emergency telephones located in these facilities (as described in section 3.4).

3 - EMERGENCY EQUIPMENT

3.1 - Electricity supply

Electricity sockets are to be provided in emergency recesses. These are to comprise at least one 1P + E + N mains socket with a minimum rating of 2.5 kVA and one 3P + E + N power socket with a minimum rating of 12 kVA.

3.1.1 - Uninterruptible back-up supply

So that users can reach safety and rescuers can act in the event of an incident or accident occurring when there is cut in the external power supply, essential safety equipment shall be powered by an uninterruptible power source (generally a charger - battery - DC/AC converter unit) having an independence time of at least half an hour in the event of failure of the external power supply. In particular this shall apply to the following items of equipment where the design provides for them:

General equipment such as:

- emergency lighting and marker lights (described in section 3.3),
- lighting of facilities for the evacuation and protection of users and emergency access (described in section 3.3),
- signage and marking of safety equipment (described in section 3.7),
- pollution sensors and anemometers,
- systems for the collection, local processing and transmission of information,
- equipment involved in maintaining the functioning of monitoring and control rooms.

Traffic management equipment such as:

- signalling devices (stop signals, lane allocation signals, variable message panels, etc.),
- closed-circuit television, automatic incident or fire detection,
- radio-communications relay equipment,
- barriers closing off the tunnel and traffic lanes.

If the tunnel is equipped with shelters but does not have an uninterruptible power supply (as discussed above), the lighting and ventilation of shelters and their access-ways and all other equipment necessary for their use shall be powered by an uninterruptible power source having an independence time of two hours.

3.1.2 - Uninterruptible power supply

In all tunnels equipped with ventilation equipment the power supply system is to be maintained in the event of a mains power cut (e.g. using a dual supply provided by connections from different terminals on the distributor or through the installation of an electricity generating unit having an independence time of at least four hours) even in the event of partial failure of the equipment (e.g. by doubling up transformers in order to ensure mutual support).

This power supply must be capable of restoring equipment powered by the interruptable supply (described in section 3.1.1) to operating status. It shall ensure that the ventilation for shelters and their access-ways and that the equipment for extracting smoke from a single tube (even if the tunnel has two), and the equipment required for maintaining excess pressure in the water system, operate at full power, and that two of the electrical power sockets located in the emergency recesses operate simultaneously. It need only provide reduced power for the remainder of the ventilation system, and for the basic and additional lighting systems.

In the case of tunnels which have no ventilation system, two situations need to be considered:

- The level of service for the route on which the structure is located is not compatible with closure of the tunnel in the event of a power cut. The electricity supply must then be maintained as above in order to ensure that all equipment remains in operation, especially the basic and additional lighting systems, whose power may be reduced.
- Closure of the tunnel can be accepted in the event of a mains power cut. There is no need to provide for any measures other than the uninterruptible power supply mentioned above.

3.2 - Ventilation

3.2.1 - Ventilation to maintain air quality

This text is only concerned with incident or accident situations and does not lay down measures necessary to ensure air quality in normal operation.

Ventilation must ensure that for users a pollution level of 150 ppm of carbon monoxide and an absorption coefficient per unit length, K, of 9.10^{-3} m^{-1} is not exceeded at any point in the tunnel following an accidental traffic stoppage. Its dimensioning must take into account the number of vehicles which are likely to be present in the tunnel, having regard to operating measures designed to close off access as soon as an accident is detected.

3.2.2 - Smoke extraction ventilation in the event of a fire

The objectives of smoke extraction ventilation in the event of a fire are as follows:

- to enable users to see to their own safety, by giving them more opportunity to see the exits or shelters provided for them and to get to them,
- once the emergency services have arrived, to assist their activities to help users who have been unable to gain safety and to fight a fire.

The provisions below are to be implemented in the light of these objectives. However the thermodynamic factors involved when a fire breaks out are very complex. As a consequence, these provisions will not always guarantee that the results desired, e.g. layering of smoke, will be strictly achieved.

Arrangements to ensure smoke extraction will be required for tunnels in excess of the following lengths:

- 300 m in the case of urban tunnels,
- 500 m in the case of non-urban tunnels which are not for light traffic (this limit may be raised to 800 m provided that the absence of smoke extraction is compensated for by increasing the arrangements for the evacuation and protection of users as described in section 2.2),
- 1000 m for light traffic tunnels.

In some circumstances where no suitable smoke extraction system is available, an exception may be made to the above limits provided that the compensatory measures are applied especially to the facilities for the evacuation and protection of users in the spirit of what has been said in the preamble to this text. Likewise, the requirements relating to smoke extraction systems below may be adjusted, or other principles of smoke extraction may be adopted, provided that an at least equivalent level of safety is achieved, if necessary by using particular compensatory measures.

The following provisions are based on a fire of the size of a heavy goods vehicle having the following characteristics:

- thermal capacity 30 MW (of which it can be assumed that one third is dissipated by radiation from the source),
- smoke output of 80 m^3/s when stratified (this flow, measured at the temperature of the smoke, represents the sum of the flows of combustion products and gas which is drawn into the source but not burnt).

When applying these provisions, adverse conditions due to atmospheric effects which are not exceeded less than 5% of the time may be taken into consideration as an order of magnitude which is unfavourable but not exceptional. The determination of these shall be subject to specific investigation, without specifying any accuracy, which might be misleading in this field.

The way in which smoke extraction is achieved will depend on the ventilation system installed. The provisions below correspond to two main families of systems:

- longitudinal ventilation systems are designed to create an air flow having the same velocity throughout the entire length of the tunnel, or in successive sections separated by extraction and/or air injection devices. This is generally achieved through jet fans or accelerators suspended from the crown.
- semi-transverse and transverse systems which provide for the injection and/or extraction of air at regular intervals in the tunnel. In the semi-transverse system there is no suction in normal operation, but only fresh air injection. In the transverse system it is also possible to extract polluted air in normal operation. In the event of a fire, smoke extraction is achieved through the use of a duct only used for smoke extraction or normally used for the extraction of polluted air, or by direct discharge to the open air, or again by reversing the air flow in fresh air ducts.

Whenever possible the longitudinal system is to be preferred to semi-transverse and transverse systems in non-urban one-way tunnels.

a) Smoke extraction requirements for longitudinal ventilation

Principle and dimensions

The principle of this type of smoke extraction consists of pushing the smoke towards a tunnel exit. The system must be capable of ensuring a mean air flow velocity of at least 3 m/s in the section of tunnel upstream from the fire.

In one-way tunnels the normal direction of smoke extraction is the direction of vehicle traffic. However, the direction in which the fans blow can be reversed; this exceptional operation will not be taken into account when dimensioning the installation.

In two-way tunnels, the system must be capable of ensuring the air flow velocity specified above in both directions. However, if the emergency services can reach the two ends equally quickly, it will be sufficient for the system to ensure the above velocity in the direction in which it is most easy to achieve it.

The dimensioning velocity must be capable of being achieved with vehicles stopped in the tunnel, the number of which will depend on the time to closure in the event of fire.

Except in two-way tunnels where the specified velocity only has to be achieved in the direction in which it is easiest to achieve it, the "chimney" effect which causes smoke to rise towards the upper end of the tunnel if it is not horizontal must be taken into account where it is unfavourable, as well as atmospheric effects which are favourable but not exceptional.

A reduction in fan performance when operating in hot air must be taken into account, as also loss of the fans which will be destroyed by heat (see section 4.4.2.a). In tunnels more than 800 m long dimensioning will be based on calculation of these two effects. In tunnels less than 800 m long it is not generally possible to comply strictly with the condition above. These two effects can then be taken into account by increasing the thrust deriving from the abovementioned paragraphs by a figure of 30% in tunnels less than 500 m long and by 50% in other circumstances.

Situation where the use of longitudinal ventilation is possible

Non-urban one-way tunnels

The longitudinal ventilation system can be used for smoke extraction up to the maximum length for application of this system to ensure air quality, and as a maximum up to a length of 5 000 m. This length may be increased by providing massive extraction systems at least every 5 000 m, dimensioned as described in the paragraph below.

Urban one-way tunnels

Because of the risk of downstream congestion it is recommended that the longitudinal ventilation system should not be used for lengths of over 500 m. It may however be used up to lengths of 800 m if all conditions for controlling the longitudinal flow of air in the event of a fire are fulfilled (as described below in the section on use in the event of fire).

This applicable lengths may be increased by providing massive extraction systems every 500 m or 800 m as appropriate. These extraction systems are to be dimensioned so that they can remove all the air flow arising from the direction of the fire, including the smoke produced by it, and the drawn-in air originating from the other direction and flowing at a minimum speed of 1 m/s.

In circumstances where massive smoke extraction is used, monitoring of the longitudinal air flow is of special importance. Insufficient velocity upstream from the fire will in fact result in the back-flow of smoke onto users who are likely to be blocked by the fire, whereas an excessive velocity will result in smoke being carried beyond the massive extraction system. This air flow velocity control therefore requires control which has been investigated in advance. System dimensioning and the instructions for its use must be established on the basis of an investigation of scenarios.

Non-urban two-way tunnels

Where the traffic is not light, the system may be used for lengths up to 1 000 m. It can however only be used provided that it reinforces the arrangements made for the evacuation and protection of users.

Where traffic is light, the longitudinal system can in principle be used for lengths up to 1 500 m. Depending on the special circumstances of the tunnel it is however possible for it to be used beyond this length, if necessary with compensatory measures, if alternative ventilation arrangements do not offer a better guarantee.

Urban two-way tunnels

The longitudinal system is to be prohibited for smoke extraction from this type of tunnel.

Use in the event of fire

A distinction must be made between several circumstances when using longitudinal ventilation in the event of a fire.

Non-urban one-way tunnels:

The ventilation must be started up as soon as possible under conditions which will make it possible to achieve at least 3 m/s in the direction of traffic movement.

Urban one-way tunnels:

If the tunnel is not more than 500 m long, or if the distance between two massive extraction units does not exceed this amount, ventilation must be started up as in the case above (if massive extraction units are present, this applies to the section in which the fire has occurred).

If this is not the case, use of the ventilation must be adapted to the traffic circumstances at the time when the fire breaks out. If the tunnel is not congested, ventilation is to be applied as in the case above. If congestion is present, initially the ventilation must insofar as is possible maintain a reduced air flow (of the order of 1 to 2 m/s) in the direction of traffic movement so as to limit the back-flow of smoke towards users stopped upstream from the fire, while maintaining some layering of the smoke so as not to impede the evacuation of users who might be upstream; during a second stage, once the latter have reached a place of safety, ventilation can be changed to conditions which will provide at least 3 m/s in the direction of traffic flow.

The use of ventilation in the two stages when congestion is present is difficult, and must only be used in tunnels equipped with high-level equipment and operating systems (preferably degrees D3 or D4 of monitoring and supervision as described in section 5.1.1, unless automated systems are used with, in all circumstances, very thorough maintenance of the equipment). If an automatic system is used, the system must include fire detection and congestion detection means so as to start ventilation under the appropriate conditions during the initial stage of a fire. In all circumstances application and monitoring of these conditions will require the sufficient provision of anemometers. Start-up of the second stage will require human action (and may be initiated by the emergency services when they arrive on site).

Non-urban two-way tunnels:

Initially efforts must be made to restrict the longitudinal air flow as much as possible in order to maintain the best possible smoke stratification and permit users to be evacuated; in a second stage fire-fighting may require that the ventilation operate under conditions sufficient to push all the smoke from one side of the source of fire (longitudinal air velocity 3 m/s).

The use of ventilation in two stages requires human action or an automatic device incorporating fire detection to initiate the appropriate ventilation conditions for the initial stage of the fire. In addition to this, use and monitoring of this system will require the sufficient provision of anemometers. Start-up of the second stage requires human action in all circumstances (this may be initiated by the emergency services when they arrive on site).

The above provisions or equipment are essential whenever operation of the ventilation system is necessary to maintain air quality apart from in fire situations. If they are not provided the ventilation must be shut down during normal periods and only activated by emergency or operating personnel when they are on site.

b) Requirements for smoke extraction using semi-transverse or transverse ventilation

Smoke extraction objectives and necessary conditions

In the event of a fire the required objectives for ventilation systems are to maintain natural stratification of the smoke in the crown of the tunnel as far as possible in order to retain a layer of pure air close to the roadway, and to extract smoke using an extraction system located at roof level. Smoke extraction from the reference fire specified above must be capable of being achieved over a distance of the order of 400 m in an urban tunnel and 600 m in a non-urban tunnel.

These objectives are made more difficult by the presence of a longitudinal air flow which can be controlled in such a way that smoke stratification is maintained as far as possible. In order to do this the longitudinal air velocity alongside the fire must be as small as possible. This can be achieved by several actions: the piston effect of vehicles which are still moving, the chimney effect due to the gradient of the tunnel, differences in atmospheric pressure between the ends, differences between the air flows extracted and the air flows injected.

In areas which might contain users it is necessary to ensure a certain level of fresh air input (longitudinally from parts of the tunnel which are smoke-free, or transversely by blowing from ducts). Nevertheless, maintaining natural smoke stratification involves not blowing fresh air to the roof, where smoke is present, and not blowing fresh air in at the base of side walls, except under reduced flow. Using blocks of ventilation of limited length and in sufficient number, in which the flows (extraction and fresh air input) can be controlled independently, makes it easier to deliver fresh air to users in the event of a fire and offers possibilities for controlling the longitudinal air flow.

If fresh air blower blocks are more than 800 m long, provision must be made for the possibility of blowing fresh air into the lower part of the tunnel under all circumstances. This imposes a requirement for blower outlets at the base of the side walls and means for delivering fresh air to the duct feeding them at all times.

If the use of accelerators to help control the longitudinal air flow is envisaged, all precautions must be taken to prevent these from being started up in the smoke-filled zone, or in the vicinity and direction of the latter, which would have the effect of almost immediately destroying the smoke stratification.

The control of longitudinal air velocity during a fire requires continuous action which has been investigated in advance. The nature of the ventilation system will therefore depend on fire scenarios being taken into account in combination with the various factors mentioned above.

The start-up of smoke extraction requires a human presence at all times, or an automatic system which includes fire detection.

Ventilation systems must be designed to ensure that the breakdown of any unit only puts part of the overall system out of service; several fans operating in parallel on the same circuit, or emergency fans which can be connected to several circuits, or again mutual support between fans in two successive blocks.

Requirements relating to the control of longitudinal air flow

The requirements specified for smoke extraction below depend on whether or not it is possible to control the longitudinal air flow. The air flow is to be regarded as being under control for the purposes of smoke extraction when the following conditions are fulfilled. In all circumstances these must be checked in the event of unfavourable but not exceptional atmospheric conditions, and bearing in mind the effects of a fire on the air flow, in particular any "chimney" effect.

Non-urban one-way tunnels:

The system must be capable of maintaining the air flow in the direction of traffic movement upstream from the fire. Thus the air flow will remain in a direction favourable to the users stuck behind the fire. If it is weak, smoke could rise towards them, but in the form of a stratified layer at roof level which can be extracted by the smoke extraction system. If strong, all the smoke will be pushed downstream from the fire and the destruction of stratification will not create a hazard to users.

Urban one-way tunnels:

As in the previous case, the system must be capable of maintaining air flow in the direction of traffic movement upstream from the fire. At the same time the air flow velocity must be capable of being limited to 2 m/s in the vicinity of the fire so as to limit destratification of the smoke and enable any people who may be blocked downstream from the fire to be evacuated. When the system is put into use efforts should be made to restrict the air flow to 1.5 m/s whenever possible.

(Urban and non-urban) two-way tunnels:

The ventilation system must be capable of limiting the mean velocity of the longitudinal air flow in all sections of the fire zone to 1.5 m/s.

The conditions for control of the longitudinal air flow described in the foregoing paragraphs must if possible be satisfied for urban tunnels more than 1 500 m long, and in any event for urban and non-urban tunnels over 3000 m long.

In the case of shorter tunnels control of the longitudinal air flow is more difficult, mainly because of the limited number of ventilation blocks. The above conditions need not then be satisfied, but the extraction flow must be increased as a compensatory measure as specified below where there is no control over the longitudinal air flow. In this situation it is however desirable that operating instructions for the ventilation system in the event of a fire which aim to approach the abovementioned conditions whenever possible should be envisaged and implemented.

Smoke extraction systems

There are two types of smoke extraction system: openings which are open at all times, or smoke vents which open under remote control. In the remainder of this section, when openings which are not under remote control are grouped into independently controlled blocks not more than 400 m long in the case of urban tunnels and 600 m long in non-urban tunnels these will be regarded in the same way as smoke vents which are opened under remote control.

When the tunnel has a human presence offering rapid and accurate control at all times (degrees D2, D3 or D4 of attendance and monitoring as specified in section 5.1.1), it is recommended that smoke should be extracted using smoke vents in the roof which are opened under remote control. This system is in fact the most effective if it is correctly used, because it makes it possible to concentrate extraction close to the source of the fire. The smoke vents are to be spaced approximately 50 m apart in urban tunnels and no more than 100 m apart in non-urban tunnels.

Ducts equipped with remote-controlled extraction smoke vents suffer from leaks which can be considerable if they are too long. This requires that precautions be taken in both the design and the construction and maintenance of smoke vents. In addition to this, where the length of a block is more than 800 m, the extraction flow must be increased to take these losses into account, especially after a number of years operation, as well as leaks from the ducts. Efforts should be made to avoid ducts more than 3000 m long between the first and the last smoke vent. If this is not the case, special attention must be paid to dimensioning the extraction flow so as to incorporate all losses which are foreseeable in the long term, and maintenance which should include inspections which are more frequent the longer the ducts.

If operating conditions do not allow rapid accurate action in the event of a fire, remote-controlled smoke vents should generally not be used and permanently open extraction openings should be used. If the duct on which these openings are fitted is used for extraction only, these are to be spaced between 50 m (urban tunnels) and 100 m (maximum for non-urban tunnels) apart. If on the other hand the duct is used to deliver fresh air under normal circumstances and for smoke extraction in the event of a fire, smaller openings which are closer together may be used in order to obtain a more uniform distribution of fresh air.

Smoke extraction flow when remote-controlled smoke vents are used

In all circumstances the extraction flow must be increased in comparison with the flow of smoke produced by the fire in order to take into account the inevitable entrainment of fresh air by the extraction system.

Where the air flow is regarded as being under control, as defined above, an increase of one third in the smoke flow produced by a fire is to be adopted for roof-mounted smoke vents. In the case of the reference fire (which produces 80 m^3/s of smoke, this results in a minimum extraction flow of approximately 110 m^3/s. Smoke vents which are not located in the roof, but laterally at the top of the side walls, are less effective and should only be accepted against a larger increase in the extraction flow, and thus require specific analysis with reference to design.

In all circumstances it is recommended that the nominal mean velocity of the extracted air be limited to 15 m/s when passing through the smoke vents. This is to be determined by dividing the minimum extraction flow required by the total surface area of the open vents.

The extraction flow is to be distributed over a maximum length of 400 m in urban tunnels and 600 m in non-urban tunnels.

Where the system makes it impossible to regard the longitudinal air flow as being under control, some compensation is to be provided by increasing the extraction flow. This will be equal to at least the flow of smoke from the reference fire (80 m^3/s) increased by a flow (m^3/s) equal to one and a half times the transverse internal cross-section of the tunnel (in m^2). Thus, for example, for an internal cross-section of 50 m^2, the extraction flow is to be at least 155 m^3/s. This flow takes into account both the increase required to take into account the entrainment of fresh air by the extraction system and the compensation intended to allow for insufficient control of the longitudinal air flow.

Smoke extraction flow when vent openings are not under remote control

Where openings are not under remote control, the extraction flow which would be necessary with remote-controlled vents (110 m^3/s if the longitudinal air flow can be regarded as being under control, the smoke flow increased by one and a half times the internal cross-section of the tunnel if not) must be provided over every length of 400 m in urban tunnels and 600 m in non-urban tunnels. This flow represents the minimum which it is necessary to establish, even if the tunnel is less than 400 m long in the case of urban tunnels or 600 m long in the case of non-urban tunnels.

c) Use of smoke extraction

Whatever the type of ventilation installed, operating instructions must specify the smoke extraction conditions which are to be implemented in the event of fire. It is recommended that smoke extraction be controlled for pre-programmed operating conditions in order to respond during the first few minutes after the alert. These are to be initiated by the operator if human resources permit this (degrees D2, D3 or D4 of attendance and monitoring as defined in section 5.1.1), or automatically if not. Subsequently control should be capable of being manual, with priority over the automatic system. Control should preferably be exercised on the control unit, if present. If there is no control unit, cabinets containing a manual control are to be provided at the ends of the tunnel.

In all circumstances it is desirable that the appropriate ventilation conditions for smoke extraction should be operational within a few minutes of the moment when the order is given. Compliance with this condition must be substantiated in the design. Because of this some systems which are too slow to react may be rejected. It may possibly burden the operation of ventilation under normal conditions so that changeover to the conditions required for smoke extraction can take place within a sufficiently short time.

The conditions which are implemented when the alert is given must insofar as possible be corrected as soon as conditions in the tunnel have stabilised (particularly when the entrainment effects due to the movement of vehicles have disappeared), and subsequently in accordance with any changes in circumstances (growth of the fire, weather effects) and needs (evacuation of users, fire-fighting).

3.2.3 - Ventilation of facilities for the evacuation and protection of users and emergency access-ways

a) Communications between tubes

The airlocks provided in the communication facilities between tubes must be provided with a ventilation system providing them with an excess pressure of approximately 80 Pa with respect to the tube in which an incident or accident has occurred.

b) Safety tunnel parallel to the tunnel

Whenever in use the tunnel is to be ventilated and the communication airlocks (or the tunnel itself in the absence of airlocks) is to have an excess pressure of approximately 80 Pa in comparison with the tunnel.

c) Shelters

Shelters are to be equipped with a specific ventilation system. Air quality is to be maintained at all times by renewing the volume in the shelter three times per hour.

While a shelter is occupied, the ventilation must be automatically reinforced to ensure an overall output of 2500 m^3/h for a floor surface area of 50 m^2. It must be possible to achieve this simultaneously in at least three shelters. Air circulation is to be in the shelter-airlock-tunnel direction so as to maintain an excess pressure of approximately 80 Pa in relation to the tunnel in the atmosphere in the shelter.

Whenever in use, the access-ways used to provide access for the emergency services and for the evacuation of persons sheltering in shelters is to be ventilated in such a way as to ensure air quality.

When in use, the ambient air temperature in a shelter or an access-way must be kept below 40°C for the period of time specified for the evacuation of shelters (see section 4.2.2). This condition is to be checked for a 200 MW fire under the conditions of the most unfavourable fire location and tunnel ventilation (including non-functioning of the smoke extraction system).

The ventilation of shelters and their access-ways is to be designed according to the principle of system redundancy: at least two fans operating in parallel, or an emergency fan.

3.3 - Lighting

This text does not relate to the artificial lighting of tunnels except insofar as its safety role in the event of an incident or accident is concerned. This does not have any effect on the arrangements which are necessary to ensure that drivers have adequate visibility in normal operation.

To enable users to evacuate the tunnel in the event of an electricity power cut, emergency lighting ensuring a minimum level of lighting over the roadway and walkways of an average of 10 lux, and 2 lux at any point, is to be provided. This lighting is not compulsory in light traffic tunnels.

In order to provide marker lights in circumstances where smoke from a fire masks the overhead lighting (and if there is an electricity power cut in light traffic tunnels which are not equipped with emergency lighting), illuminated markers (or marker lights) are to be located at a height of approximately 1 m approximately every 10 m along the side walls. These are to be permanently lit.

The arrangements for the evacuation of users and emergency access are to be provided with lighting which will ensure a minimum average lighting level of 10 lux and 2 lux at all points when these facilities are in use. Comfort lighting ensuring a mean level of 150 lux shall be ensured in the shelters when these are in use. The access-ways providing emergency access to the shelters and used for the evacuation of persons sheltering in them shall be provided with marker lights.

3.4 - Emergency telephones

Emergency telephones shall be placed in the emergency recesses specified in section 2.4 and in the facilities for the evacuation and protection of users specified in section 2.2.

Emergency telephones located in the facilities for the evacuation and protection of users must be capable of being used by handicapped persons who use wheelchairs. It is recommended that the same should apply to the emergency telephones located in the emergency recesses located in lay-bys, where present (see section 2.9).

Shelters are also to have a separate sound system (loudspeaker).

3.5 - Fire-fighting facilities

3.5.1 - Extinguishers

Two standard portable extinguishers having a recommended unit capacity of 6 kg and at least 13A and 183B performance are to be located in the emergency recesses mentioned in section 2.4. It is recommended that water-with-additive extinguishers should be used.

3.5.2 - Water supply

The provision of a water supply is not compulsory in non-urban tunnels less than 500 m long. In other circumstances, unless different arrangements are agreed by local authorities, a water pipe is to be installed.

Fire-fighting equipment of the riser or hydrant type delivering 120 m^3 at a pressure of 0.6 MPa are to be installed approximately every 200 m. In the case of a tunnel in which there is a change in level, a range of 0.4 to 0.8 MPa shall be accepted. The delivered flow from a hydrant must be 60 m^3/h. Two water delivery points must be capable of being used simultaneously. The recesses in which fire-fighting equipment is located are described in section 2.5.

The piping must not be of plastic. All systems are to be protected against the effects of frost.

Where pressurisers are fitted, the required flow is to be capable of being achieved in the event of one of these breaking down. In tunnels more than 1000 m long which are not used by low levels of traffic, the supply must be capable of being maintained at at least half capacity if there is a local fracture in a pipe.

The water pipe may be replaced by offtakes from the public distribution system.

Dry risers may be used, provided that they open less than 60 m from a fire hydrant. The lengths feeding dry risers must not be longer than 800 m.

3.6 - Fire detection

In tunnels where there is no permanent human supervision (degrees D1, D2 or D3 of attendance and supervision as described in section 5.1.1), an automatic fire detection system is required whenever the ventilation system which is used in the event of a fire is not that which is automatically brought into use in the event of serious tunnel pollution.

The detection system must automatically start up the ventilation applicable in the event of a fire and set off an alarm in the unit providing round-the-clock monitoring (see section 5.1.1).

Where the ventilation is of the longitudinal type, section 3.2.2.a specifies the circumstances in which this equipment is necessary.

Where the ventilation is of the transverse or semi-transverse type, fire detection will always be necessary where there is no permanent human supervision (degrees D1, D2 or D3 of attendance supervision).

In tunnels where there is permanent human supervision (degree D4), the usefulness of an automatic fire detection system must be investigated in relation to the size of the tunnel and the amount of traffic, particularly heavy goods traffic, and the existence of other equipment which might perform a similar function (especially automatic incident detection).

3.7 - Signage, signalling systems and tunnel closure devices

In a tube which is normally a one-way tube, if two-way traffic is permitted under certain operating conditions, the signage and the signalling system must allow for this type of traffic, at least in simplified form.

3.7.1 - Signage for emergency facilities

Signs or permanently illuminated signs shall be provided to draw the attention of users to the safety facilities available for their use such as emergency telephones, extinguishers, facilities for the evacuation and protection of users, and lay-bys. When radio frequencies intended for users are retransmitted within the tunnel (see section 3.8) appropriate signs shall be placed before the entrance to make users aware of them and to encourage them to listen to one of them.

3.7.2 - Signage and means for stopping traffic

In all circumstances signs which can be used to prohibit access to the structure when necessary must be provided some 50 metres in front of each entrance, a distance which is to be adjusted in relation to site constraints (visibility of signs on approach, visibility of the end of the tunnel from the stopping point, etc.). This distance is necessary in order to allow access and manoeuvering space for the emergency services. The stop signals (including advance signals) must be incorporated into the overall traffic management system for the route on which the tunnel is located so that users can be diverted to other routes well before the entrance.

In the case of tunnels more than 800 m long, whether supervised at all times or not (degrees D3 or D4 of attendance and supervision as described in section 5.1.1), this signage is to be supplemented by a remote-controlled physical closure device (barrier) and by a variable message panel which will inform users of the reasons for closure. The signage must if necessary be reinforced in order to limit the risk of accidents due to the closure of a barrier.

Within tunnels more than 1000 m long, whether or not they are permanently under supervision (degrees D3 or D4 of attendance and supervision), lights are to be located at approximately 800 m in order to stop users travelling in the tunnel at the time when the alarm is given. Every light is to be associated with a variable message panel informing users of the reasons for the stoppage.

If there is no permanent supervision (degrees D1, D2 or D3), a signal system priority control box is to be provided for the police force for use as necessary. In principle this is to be located on the right hand side in the inward direction or at the side of the emergency stopping lane if there is one, at the ends of the tunnel or in their immediate vicinity.

3.7.3 - Lane allocation signalling

In the case of tunnels more than 800 m long, whether or not there is permanent human supervision (degrees D3 or D4 of attendance and supervision) which have more than one lane in each direction, the signage is to include lane allocation signals ahead of the structure (at least two lines), and again at the entrance, and then within the tunnel with a spacing of the order of 200 m in urban tunnels and 400 m in non-urban tunnels, a spacing which may be reduced in order to ensure continuity of sign readability.

3.8 - Relaying of radio communications

In order to provide continuity of communications for emergency vehicles, particularly between the site of an incident and the outside of the tunnel, underground radio communication relays are to be provided for tunnels more than 500 m long in the case of urban tunnels and 800 m long in the case of non-urban tunnels.

In the case of tunnels with a light traffic flow, the relaying of emergency services radio communications may be replaced by two fixed telephone lines providing communication between emergency recesses, including those located at the ends.

If radio broadcast stations are relayed, and if there is a control unit, it must be possible to interrupt these relays in order to broadcast safety messages to users. In order to permit this, and whether permanent or non-permanent human supervision is present (degrees D3 or D4 of attendance and supervision defined in section 5.1.1), at least one frequency intended for users is to be relayed in tunnels more than 800 m long in the case of urban tunnels and 1000 m long in the case of non-urban tunnels which do not have low levels of traffic. It is nevertheless preferable that a larger number of frequencies should be relayed.

3.9 - Other equipment

The following equipment may be provided, depending upon the hazards presented by a tunnel and its traffic, and the manner in which it is operated (see part 5):

- lifting rings, depending on local breakdown and response facilities,
- recess, emergency exit and shelter door opening and extinguisher removal alarms,
- television monitoring system,
- automatic incident detection,
- alarm pushbuttons with an indication that the call has been received,
- relaying of mobile phone communications (so that users can provide rapid warning and if necessary obtain information in the event of an incident or accident).

A television monitoring system covering the entire interior of the tunnel and its immediate surroundings and an automatic incident detection system are obligatory when permanent or non-permanent human supervision is provided (degrees D3 or D4 of attendance and supervision defined in section 5.1.1). A television supervision system may also be necessary in the absence of human supervision where the unit responsible for operation has to take decisions which require knowledge of the conditions obtaining in the tunnel (degree D2 of attendance and supervision).

In the event of an alarm which might be the consequence of an incident or accident, television pictures showing the zone from which the alarm originated must be recorded automatically in order to permit subsequent analysis of any incident or accident. This is a minimum requirement: a system which includes the systematic recording of all images and their conservation for a few minutes in normal circumstances and for an indefinite period in the event of an alarm will obviously offer the best possibilities for subsequent analysis. Information reaching any centralised technical management unit, where present, and instructions given by this unit, or generated by it, should be recorded for the same purposes.

4 - FIRE BEHAVIOUR

4.1 - Reaction of materials to fire[1]

The construction materials used for the main structures and secondary structures in a tunnel, with the exception of roadway components, must have a classification of M0 from the point of view of reaction to fire. This class is also necessary for materials constituting drainage systems, including slotted channels and drains. The only exception relates to lightweight roof units in which case class M2 is permitted: the local loss of some of these units does not represent any disadvantage to safety provided that fire propagation risks are limited; it may even have advantages for the evacuation of smoke.

The materials used for internal linings must be classed M0 when they are located on the crown. Materials of class M1 are permitted for the lining of side walls provided that they are specially justified in respect of lack of fire propagation risk under the conditions of use in the tunnel.

Class M1 shall be permitted for various items of equipment within a tunnel, in particular cable tracks. Cables running within a tunnel must be of category C1 if they are not placed in cable tracks which are protected against the effects of fire. Cables running in facilities for the evacuation and protection of users and emergency access (described in section 2.2) and those located in fresh air delivery ducts must also be of category C1; in addition to this they must comply with the requirements of article 4 of the order of 21 July 1994 if they run alongside each other or in a vertical or semi-vertical position over more than ten or so metres (e.g. fresh air delivery shafts).

4.2 - Principles of fire resistance[2]

This text specifies the minimum fire resistance requirements to ensure the safety of persons, including the safety of emergency services engaged in their work. The principal may decide on higher levels of resistance in order to ensure better protection for the tunnel and to limit repairs and closure time after a fire.

4.2.1 - Temperature/time graphs

Temperature/time graphs are to be used as appropriate for justification of the fire resistance of structures and certain items of equipment.

Fires in which the temperature rise is relatively slow, but which may be long-lasting, are characterised by the standard temperature/time graph specified in Appendix XI to the order of 3 August 1999 (graph identical to the one in standard ISO 834). Fire resistance requirements in relation to this graph are expressed in the remainder of this text by the letters CN followed by the resistance time in minutes (e.g. CN 120 means suitability using the standard graph for 120 minutes).

A fire in a heavy goods vehicle may show a much faster temperature rise than this graph, particularly if it involves very combustible and liquid or easily liquefiable goods, even if these are not classed as hazardous for the purposes of transport. Such fires are characterised by a so-called "supplemented hydrocarbons fire" graph which reaches 1200°C in less than ten minutes and approximately 1300°C twenty minutes later. The following equation can be used, for example:

$$\Theta = 1\,280\,(1 - 0.325\,e^{-0.167\,t} - 0.675\,e^{-2.5\,t}) + 20$$

where : Θ is the temperature of the gases in degrees Celsius,
t is the time in minutes.

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[1] The reaction of a material to fire is its ability under specified conditions to contribute to the fire to which it is exposed, in particular as a result of its own decomposition. The classification of construction materials and fittings on the basis of their reaction to fire is the subject matter of the amended order of 30 June 1983. The classification of fire behaviour (and in particular reaction to fire) of electrical conductors and cables is the subject matter of the order of 21 July 1994.

[2] The fire resistance of a component is its ability to maintain all the properties necessary for use, under specified conditions and for a specified length of time, despite the outbreak of a fire. The fire resistance of materials, construction components and structures is the subject matter of the order of 3 August 1999.

Fire resistance requirements in respect of this graph are subsequently expressed by the letters HCM followed by the resistance time in minutes.

When two periods corresponding to two different temperature/time graphs are specified, justification is to be provided independently using each graph for the period specified for it (e.g. CN 240 HCM 120 means two separate justifications, one using the standard graph for 240 minutes, the other using the supplemented hydrocarbons fire graph for 120 minutes).

4.2.2 - Objectives and resistance levels

The fire resistance required from structures and equipment is designed to achieve the following main objectives:

- protection of users who have entered the evacuation facilities (with the exception of shelters, which are dealt with in the next paragraph) for the time required for them to reach the exit, which is set at 60 minutes because of the fact that handicapped persons needing external help to get out may be present,
- protection of users sheltering in shelters, if provided, allowing them to be evacuated by the emergency services during the time period for the evacuation of shelters, set at 120 minutes,
- no endangering of the emergency services, especially the fire service, during the time for emergency action, set at 120 minutes,
- maintenance of electricity supply and communications on either side of the fire for the maximum duration of the fire,
- prevention of any flooding or any break-in by the surrounding ground into the tunnel in a catastrophic way during the maximum duration of the fire,
- protection of any structures or buildings which are nearby or on the surface for the same maximum duration of the fire.

Subject to an agreement between the various local services involved, the above set times may be reduced to take into account special conditions applying to action by the emergency services or the configuration of the site (e.g. handicapped persons using wheelchairs can exit from accessible evacuation facilities without external help, which can reduce the time necessary to reach the exit to 15 minutes). This could result in amendment of the time period for application of the level N1 or N2 requirements specified below to the project in question. In all circumstances the maximum duration of a fire is fixed at 240 minutes for the standard graph and 120 minutes for the supplemented hydrocarbons fire graph.

As far as structures are concerned, so that these objectives can be met without unnecessary additional cost, four levels of fire resistance corresponding to increasing requirements are specified below. The details of their application to the individual circumstances of structures are described in section 4.3. The fire resistance of equipment is considered in section 4.4.

Level N0

This level corresponds to verification that there will be no risk of progressive collapse in the event of a local failure: the loss of one element should not result in a transfer of load which is likely to cause other parts of the structure to fail. Conversely, it is not required that measures should be taken against the risk that the loss of one element will result in an increase in temperatures in other parts of the structure, and that this heating may subsequently bring about their failure.

This level constitutes the minimum requirement which must be satisfied by any structure. It must be complied with while the fire is in progress and after the fire, while it is cooling down. Structures which comply with the higher resistance levels described below must also comply with this requirement.

This level applies when a local failure alongside the fire has no harmful consequences for the safety of users or the emergency services who are likely to be present in other areas where the temperature is lower.

Level N1

This level corresponds to requirement CN 120. In the great majority of fires, but not in the case of the most violent, it ensures that the structure in question will offer resistance for the time required for emergency action. This applies to the elements of a structure which contribute to action of the emergency services in an important way, when this function is not in any event dimensioned for the maximum fire possible.

Level N2

This level corresponds to the HCM 120 requirement. It applies to installations which must be preserved regardless of the violence of the fire for the periods required for the evacuation of shelters and action by the emergency services.

Level N3

This level corresponds to the CN 240 HCM 120 requirement. It applies to installations which must resist the most violent fire throughout the maximum duration of the fire.

4.2.3 - Evidence of fire resistance

The fire resistance of structures and equipment is to be proven by performing tests, by reference to prior tests, by calculation or by a combination of these various means in accordance with the provisions of the order of 3 August 1999.

Evidence from calculation is to be based on the methods indicated in article XII of that order. Elements whose fire resistance can only be determined by test shall be proven using the methods indicated in that order. Where the HCM graph is specified:

- in the case of evidence from calculation, it will be appropriate to use this under the conditions described for the hydrocarbons fire graph in document XP ENV 1991-2-2, and in particular using the same coefficient for heat transfer by convection α_c ,
- in the case of proof by tests, these are to be performed by developing the thermal effects induced by the HCM graph, the procedures and application protocols being adapted from those specified in standard EN 1363-2 for the hydrocarbons fire graph.

Given the present state of digital modelling, calculation cannot be used alone to provide evidence for a concrete structure where there is a risk that the latter may burst. This risk is always present when the HCM graph is used and may exist when the CN graph is used for high performance concretes.

Verification for reinforced concrete must consider the temperature resistance of the reinforcement, its covering, cracking, the consequences of expansion and possible bursting of the concrete. Joints must not reduce the fire resistance of the whole. In the case of ventilation ducts, the temperatures which are likely to obtain within these must be taken into account. The manner in which false ceilings are attached must provide a guarantee against any risks of brittle fracture and progressive collapse, including after the fire has been put out.

Where there is no standardised or officially accepted test procedure or method of calculation, users of this text are invited to contact the Tunnels Design Centre to obtain information about procedures or methods which may have already been used in similar cases or which are in the process of development.

4.3 - Fire resistance of structures

4.3.1 - Main structures

Unlined bored tunnels are not subject to any particular requirements as regards fire resistance.

The main structure of other tunnels must satisfy level N0 when local failure alongside the source of the fire will have no harmful consequences for the safety of persons likely to be present in other areas. In other circumstances described below, a higher level of fire stability must be confirmed.

Level N1

Fire stability level N1 applies to the structures supporting a roadway or an area which is accessible to pedestrians located above it.

Level N1 also applies when the structure is necessary in order to maintain the stability of another tube or the part separating it off, when there is also direct communication with the exterior. The structure must then have a fire stability or a fire-stop capability respectively of this level.

In all the above circumstances it will be necessary to provide measures to prohibit traffic on the supported roadway or in the second tube within a short time. If this is not possible, or if the response strategy requires that the second supported roadway or the second tube is preserved, a higher level of fire resistance will be required.

Stability level N1 shall also apply if local failure of the structure is likely to cut a ventilation duct or longitudinal cables in respect of which the maintenance of continuity alongside the fire is important for action by the emergency services, but which does not constitute one of the situations described below which justify the application of level N2.

Level N2

Level N2 applies when the structure is required to maintain the stability of another tube or the separation from it in circumstances where there is no direct communication with the exterior. The structure must then have a fire stability or a fire-stop capability respectively of this level.

Fire stability level N2 shall also apply if local failure of the structure is likely to cut a ventilation duct or longitudinal cables which are required for the use of shelters and access-ways providing access to them from the exterior.

Level N3

Fire stability of level N3 is required in the case of immersed tunnels, as well as tunnels located below the level of the water table which run comparable flooding risks in the event of local collapse. This also applies if local failure of the structure is likely to result in a catastrophic break-in to the tunnel by the surrounding ground, is likely to cause serious damage at the surface or is likely to imperil another structure.

Where the tunnel is adjacent to an inhabited or occupied structure, or located beneath it, the fire-stop capability of intermediate walls or slabs and the fire stability of the parts of the tunnel constituting the loadbearing structural elements for the buildings above is to be ensured to level N3.

4.3.2 - Secondary structures

Only the most frequently encountered situations are considered below. There are many special situations which require specific investigation. Where different levels might apply to the same element of a structure on the basis of the various provisions in sections 4.3.1 and 4.3.2, the more severe provisions shall apply.

a) False ceilings and walls separating off ventilation ducts

False ceilings and walls separating ventilation ducts from a tunnel, like all ventilation duct walls, must comply with level N0 where loss of continuity alongside the fire has no harmful consequence to the safety of persons likely to be present in other parts of the tunnel. In the other circumstances described below a higher level of fire stability must be confirmed.

In the case of ducts where continuity alongside a fire is important for the work of the emergency services, but which play no role in ventilation or the evacuation of shelters, walls which are common with the tunnel shall have a fire stability level of N1. In addition to this, where these walls include no openings communicating with the tunnel, whether permanent or not, these shall have a fire-stop capability of this level.

In the case of ducts which are used for the ventilation of shelters, walls which are common with the tunnel must have a fire-stop capability of level N2. Those which are used as access-ways to gain access to shelters are dealt with in c) below.

In all circumstances, if other components of the tunnel contribute to the stability of a duct they must have fire stability of the same level as indicated above for the duct walls which are common with the tunnel.

Where ducts are likely to be used to extract smoke, walls which are common with other ducts or installations are to have a fire-stop capability of 120 minutes with respect to the most unfavourable temperatures which might obtain on either side.

b) Plant rooms and ventilation units

If plant rooms, especially ventilation units, are located alongside, above or below a tunnel, the dividing walls or slabs must be investigated from the dual point of view of the risk to the tunnel of a fire occurring within the plant room and the risk of loss of the functions provided in the room as the result of a fire occurring in the tunnel.

With regard to the risk of a fire occurring in the room, the elements dividing it off from the tunnel are to have a fire-stop capability of level N1.

With respect to a fire occurring in the tunnel, elements dividing off the room are to have a minimum fire-stop capability of level N1. Level N2 shall apply if loss of the room is likely to affect the operation of equipment, especially ventilation equipment, which is necessary for the use of shelters and the access-way providing access to them from the exterior. Level N3 shall apply if loss of the room is likely to interrupt the continuity of electricity supply or telecommunications alongside the fire.

If a room communicates directly with the tunnel, the construction elements sealing off communication must have a fire-stop capability of the same level as is specified above for the wall. If there is an airlock, the full fire-stop capability is to be provided by the airlock.

c) Facilities for the evacuation and protection of users and access by the emergency services

Airlocks and walls separating the tunnel from direct forms of communication with the exterior (described in section 2.2.1) must have an overall fire-stop capability of CN 60.

Where communications are provided between the two tubes of a tunnel (as described in sections 2.2.a and 2.3.1), and if the two tubes have a common wall, doors and/or closures obstructing communication are to have a fire-stop capability of the same level as the wall. If the two tubes do not have a common wall, the construction elements obstructing communications must have a fire-stop capability of level N2 between the two tubes. When an airlock is provided, these full fire-stop capabilities are to be provided by the airlock between the two tubes.

Where a safety tunnel is provided, the construction elements obstructing communications with the tunnel are to have an overall fire-stop capability of level N2. The same shall apply for any walls which are common with the tunnel.

Where shelters are provided, the walls separating them from the tunnel and the airlocks providing communication with the latter shall have an overall fire-stop capability of level N2.

For every shelter an access-way offering access from the exterior of the tunnel must be capable of being used for two hours in the event of a fire occurring at any point in the tunnel. If it is necessary to pass alongside the fire and if the access-way includes walls or slabs which are common with the tunnel, these shall have a fire-stop capability of level N2. In addition to this the maximum temperature of the face of the wall which is not exposed to the fire must not exceed 60°C during the time specified for shelter evacuation (see section 4.2.2). If other elements of the tunnel contribute to the stability of the access-way, they must have fire-stop capability of the same level N2.

d) Slab supporting the highway

Where traffic moves on a slab supporting the highway, this must meet the requirements of level N0 if it does not act as a boundary for spaces located beneath which are subject to a higher resistance capability by virtue of the foregoing sections.

All steps must be taken to prevent the propagation of a fire beneath the roadway (especially flow of burning liquids).

If there is another level used by traffic beneath the slab, this shall satisfy the requirements specified in section 4.3.1 in respect of structures which are necessary in order to maintain the stability of another tube and the separation from it. The situations of a fire beneath the slab and above it shall then be considered separately.

4.3.3 - Protection against fall of equipment suspended from the roof

The emergency teams working under stratified hot smoke overhead must be protected against the fall of any hazardous elements. With this object means for the suspension of heavy equipment located overhead, accelerator fans, variable message panels, beams carrying equipment, and their supporting structures must withstand a temperature of 450°C for 120 minutes. This shall be substantiated using the standard fire graph up to the time when this temperature is reached, and this temperature will then be maintained until the end of the specified period.

4.4 - Operation of equipment under hot conditions

4.4.1 - Electrical power supply and transmission equipment

Although there is no point in ensuring that all the equipment in a tunnel is fire resistant, it is essential that the continuity of electricity supply and transmission equipment be maintained alongside a fire.

The main arteries ensuring connections between electricity supply points and transmission cables must be protected from the direct effects of fire by being laid in sleeves embedded in the walkway or roadway, in ducts or in service ducts, with additional fire protection if necessary, so that they can function under the conditions of level N3.

The power circuits for emergency lighting specified in section 3.3 are to be protected against the direct effects of fire, or are to be constructed using cables of category CR1 (as defined by the order of 21 July 1994). However a heavy goods vehicle fire may produce temperatures which are higher than this level of resistance. As a consequence the power supply is to be provided on the basis of the block principle. Block lengths must not exceed approximately 600 m.

Marker lighting is also to be powered on the block principle. Block lengths shall not be longer than approximately 100 m.

Connection boxes shall have the same fire resistance as the main circuits to which they are connected. Branch cables shall have the same fire resistance as the equipment which they serve. Failure in a branch must not result in loss of the main circuit to which it is connected.

4.4.2 - Ventilation equipment

a) Longitudinal ventilation

Where ventilation is longitudinal, the accelerator fans located in the immediate vicinity of a violent fire will not be able to withstand the heat.

Section 3.2.2.a makes a distinction between two situations when taking their loss into account at the design stage:

- where this is considered on an arbitrary basis, the accelerator fans must withstand at least 200°C for 120 minutes and be located as several sets so that they are not all destroyed simultaneously,
- where their loss is taken into account as a basis of calculation, the system must be designed to ensure the specified longitudinal air flow for 120 minutes. This must be achieved regardless of the location of the fire, bearing in mind that all accelerator fans which are subjected to temperature conditions exceeding their fire resistance level will be out of service.

Where fans are installed in order to ensure massive extraction, these must be capable of operating for 120 minutes at a temperature of 200°C.

b) Transverse or semi-transverse ventilation

In the case of semi-transverse or transverse ventilation a distinction must be made on the basis of whether the fans are or are not likely to be subjected to very high temperatures:

- In the general case, extraction fans located at the end of a duct must be capable of operating at a temperature of 200°C for 120 minutes. If however there are smoke extraction vents nearby, it will be necessary to ensure that this temperature is not likely to be exceeded at the fans. If this is not the case these must withstand 400°C for 120 minutes (at the time when this text was written there were no fans meeting this requirement: until such time as such equipment is available, a resistance time of 60 minutes at 400°C may be adopted).

- The extraction fans specified at each end in some cut-and-cover situations must be capable of operating at 400°C for 120 minutes (likewise a resistance time of 60 minutes may be adopted for as long as equipment having 120 minutes resistance is not available).

Smoke extraction vent operation must be ensured under the following conditions:

- for a period of 15 minutes
  . only opening at a temperature of 400°C in the tunnel and 20°C in the duct
- for a period of one hour
  . opening and closing at a temperature of 200°C in the tunnel and in the duct,
  . only opening at a temperature of 400°C in the tunnel and 200°C in the duct.

When air flow transparency (large dimension opening placing the tunnel atmosphere in communication with the open air) is provided for with a mechanised opening and closing system, and this must play a part in the event of a fire, it must be capable of operating open for one hour with a temperature of 400°C in the tunnel.

4.4.3 - Relaying of radio communications

In order that a fire should not result in the loss of radio communications over an excessively great distance, the system is to be constructed on the block principle. Blocks are not to be more than 500 m long in the case of urban tunnels and 800 m in non-urban tunnels.

5 - OPERATION

By operation is meant all the tasks which are required in order to ensure continuity and safety in tunnel operation. Depending upon circumstances this may include all or some of the following functions:

- traffic management (in particular supervision by personnel in a control post and possibly in the tunnel, action in the event of need using signage and if necessary personnel on site),
- technical management (in particular inspection and maintenance of civil engineering structures, monitoring/control systems and equipment maintenance).

As indicated at the start of this text, the operating conditions of a tunnel are fundamental to its safety. The needs resulting from this must be included at a very early stage in design. In addition to this, operation must be appropriate for the specific characteristics of a tunnel, its traffic, its equipment and the highway system of which it forms a part.

5.1 - Forms of operation

Operation must be organised in such a way and have the facilities necessary to ensure the prevention of accidents (not dealt with in this text) and the safety of persons in the event of an incident or accident. Personnel involved in operation must receive the necessary training in order to achieve these objectives.

5.1.1 - Degrees of attendance and supervision

Depending upon the needs resulting from the characteristics of a tunnel and its traffic, attendance and supervision in the control room shall be provided on the basis of one of the following four degrees, providing an increasing quality of response.

Degree D1 - Mere attendance

At the least, the emergency telephone calls at any automatic alarms will be received by a facility offering round-the-clock attendance. This facility may be separate from the operator and alert the latter and the emergency services in the event of need.

Degree D2 - Attendance with response capability

This degree applies in circumstances where, although human supervision of the tunnel is not necessary, action requiring human initiative must be taken in the tunnel in the event of an alarm. This for example might constitute starting up the smoke extraction system or activating a sign which depends on the circumstances of the event occurring in the structure.

Additional equipment, and the corresponding training, must then be provided to those providing attendance. The additional equipment may include video images which are automatically displayed if an alarm is set off, and possibly simplified monitoring/control systems which make it possible to initiate the necessary action.

Degree D3 - Non-permanent human supervision

The amount of traffic or the characteristics of the tunnel may make it desirable for there to be human supervision at certain times. By human supervision is meant here at least the active presence in a monitoring/control station of a person equipped with means for displaying the interior of the tunnel and its surroundings, for receiving alarms and for initiating the application of appropriate means to deal with any abnormal situation. This supervision may be remote and common to several infrastructure units or an entire route. Where supervision is not permanently available the facilities described for degrees D1 or D2 must be implemented by the facilities providing attendance for the remainder of the time.

Degree D4 - Permanent human supervision

The need to provide the permanent human supervision described above must be assessed on the basis of the characteristics of the tunnel and the traffic. In any event, permanent human supervision is compulsory for urban tunnels more than 1000 m long and for non-urban tunnels more than 3000 m long which carry more than low levels of traffic. It may prove necessary for shorter tunnels, especially where traffic is heavy or includes a high proportion of heavy goods vehicles.

Single control for equipment

Whatever the degree of attendance and supervision, the tunnel safety equipment must only be controlled from a single monitoring/control station at any time. This shall not rule out the possibility of the existence of several stations, provided that they are not operational simultaneously.

5.1.2 - Emergency facilities

The need for emergency facilities specific to a structure has to be considered in the light of the size of the tunnel and the amount of traffic, and its distance from public emergency services. In any event the permanent presence of a safety team at each end of the tunnel is compulsory in the case of two-way tunnels more than 5000 metres long which are not light traffic tunnels and which have no direct communication with the exterior in accordance with the provisions in section 2.2. These teams are to be provided with vehicles and equipment which will enable them to fight fires and attend to those injured. In the event of an alarm they must be capable of leaving for an incident or accident, wherever it occurs, within a few minutes, arriving from both ends.

In these tunnels at least one motor-driven vehicle (specially adapted if necessary) which is capable of using the safety tunnel or the access-ways to the shelters specified in section 2.2.2.b must be kept available at each end. These vehicles must be capable of evacuating users, including on stretchers of the dimensions described in section 2.2.1.

5.2 - Compulsory documents

The documents specified in this paragraph must be drawn up in advance of commissioning and then be kept up to date as frequently as necessary in order to take into account actual observed operating conditions, the lessons learnt from exercises and the analysis of actual accidents and incidents (see section 5.3), and all changes in a tunnel, its operation, its traffic, environment, etc.

5.2.1 - Control of traffic

The control of traffic within a tunnel, or on the route including the tunnel, must in particular specify types of prohibited vehicles, maximum permitted speeds and any minimum spacings between vehicles. Consistency between the traffic regulations applicable to the route and the measures specific to the tunnel must be ensured.

5.2.2 - Operating instructions

Operating instructions shall specify the operation and methods of use of security equipment and actions taken by operating personnel. They shall in particular specify the ventilation conditions which are to be applied and the links which are to be maintained with the emergency services, especially in the event of an incident, accident or fire. If two-way traffic can be accepted as an exceptional measure in a tube which is normally one-way, the instructions are to specify the circumstances in which this situation may be accepted, the arrangements of all kinds which must then be made, including informing the authority responsible for policing. The instructions shall also cover the situations where equipment or operating personnel are not available, in which the tunnel must be closed to traffic because user safety is not adequately ensured.

The operating instructions shall be prepared by the operator.

5.2.3 - Response and safety plan

The response and safety plan is to be prepared by the operator jointly with external emergency services (gendarmerie, police, fire service, emergency medical assistance centre, etc.).

The response and safety plan must in particular lay down:

- the organisation commanding and co-ordinating the operator’s facilities, distinguishing different levels of responsibility,
- internal and external monitoring and warning facilities (display of instructions, method of transmission, accident definition code, etc.),
- general response instructions, distinguishing between normal and ordinary operations and those requiring action by parties other than the operator,
- the nature of the facilities committed in each case,
- the steps which are to be taken with regard to the control of traffic within the structure and access-ways and clearing routes,
- the ordinary facilities designed to keep track of events, decisions and actions occurring in the course of operation.

5.3 - Maintenance of safety levels

The civil engineering and equipment are to be maintained so that they can fulfil their functions whenever necessary. The skills of those responsible for operation and emergencies shall be maintained and improved by ongoing training and the organisation of exercises. In addition to this significant incidents or accidents occurring in the tunnel are to be recorded and analysed, and the lessons from these are to be taken into account in order to improve operation and if necessary equipment.

5.3.1 - Exercises

The operator is to organise an internal exercise designed to test operating instructions and their implementation by personnel at least once a year, and to take any corrective action which proves necessary (updating of instructions, training of personnel, etc.).

A report shall be drawn up after each exercise. It shall summarise the circumstances and the progress of the exercise; it shall draw lessons from it and propose any further action if necessary.

These provisions shall not pre-empt exercises organised by the police authority responsible for safety in the context of a Special Emergency Plan.

5.3.2 - Feedback of experience

The operator will prepare a report on significant incidents and accidents as they occur in the tunnel and shall analyse these in order to establish whether any adjustments in current safety measures or additional measures are necessary. The following in particular shall be included:

- all accidents involving injury, i.e. those giving rise to at least one injured party (requiring medical attention or hospitalisation, even for a short time) or a fatality,
- all fires, including fires in vehicles which began to burn inside the tunnel but were able to exit without assistance,
- any other events, including physical accidents and technical incidents which resulted in non-scheduled closure of the tunnel.

Appendix 1 to this text lays down the procedures for information feedback.

5.4 - User information

User information cannot always be restricted to the signage and signalling systems mentioned in section 3.7. If justified by the length of the tunnel, its specific characteristics and the amount of traffic, additional steps must be taken such as the provision of variable message panels, information panels, the provision of explanatory notices about the tunnel, its equipment, action to be taken under normal circumstances and in the event of incidents or accidents, etc.

6 - SPECIAL CASE OF URBAN TUNNELS HAVING AN AUTHORISED GAUGE OF 3.50 m OR LESS

The provisions in this section relate to urban tunnels and take into account the fact that the transport of hazardous goods is normally prohibited in small gauge tunnels.

Given the novelty of this type of structure, the requirements below may be amended in the future in order to take into account acquired experience.

Small gauge tunnels more than 500 m long are subject to a special recommendation (Recommendations for the design of small gauge urban tunnels - RECTUR) which suggests that only three gauges should be adopted: 2 m, 2.70 m and 3.50 m.

From the point of view of action by the emergency services, the 3.50 m gauge does not give rise to any problems which differ from those for normal gauge tunnels. In fact all emergency vehicles, including fire-fighting vehicles, can gain access.

With a gauge of 2.70 m the underground portion is accessible to emergency vehicles serving asphyxiated and injured parties, but will not allow action by standard fire-fighting vehicles. An underground section having a gauge of 2 m is not accessible to any of the emergency vehicles normally in use, except ambulances based on light vehicles without any change in height. In the two latter circumstances specific arrangements must be investigated and suggested for the action of emergency services, dimensioned in relation to the severity of the hazards present. The equipment on specific emergency vehicles must be compatible with that on conventional emergency vehicles.

As in the case of urban tunnels having a gauge in excess of 3.50 m, provisions to ensure smoke extraction will be necessary when the length of the tunnel exceeds 300 m.

In the event of a fire, the users of underground tunnels having a gauge of 2.70 m or less will not benefit from any smoke stratification, nor from a volume above the useful space which will allow for the temporary accumulation of hot gases before they spread to the entire section. In the case of larger gauges up to 3.50 m, smoke stratification remains problematical and the layer of pure air below it is in any event not very deep. This being the case, the method of smoke extraction must be appropriate for the special conditions of the structures and the operator must be able to act on ventilation equipment very quickly.

Nevertheless, the restricted size of the vehicles, and thus possible fires, makes it possible to reduce some of the characteristics in these installations. The special provisions relating to fire risks are dealt with in sections 6.1 and 6.2 below.

With the exception of these aspects, the safety devices and in particular arrangements for the evacuation and protection of users and emergency access shall have the same objectives and comply with the same rules as indicated for other tunnels in this text.

Because of the difficulties of response in the event of an accident and the limitations applying to smoke extraction, tunnels having a gauge of 2.70 m or less must carry one-way traffic in normal operation. Two-way traffic may only be accepted under normal operation in tunnels of gauge over 2.70 m and up to 3.50 m in exceptional circumstances and subject to analysis of all safety measures.

If the project includes a reduction in characteristics other than the height gauge (e.g. the absence of a walkway, as specified in RECTUR for operating level TU1, or a larger spacing between facilities for the evacuation and protection of users and emergency access), equipment and operating levels must be increased. A special investigation will be necessary in such circumstances.

6.1 - Smoke extraction ventilation in the event of a fire

a) Tunnels having an authorised gauge of 2.00 m or less

In the case of gauges not larger than 2.00 m, the dimensioning of smoke extraction equipment is to be based on a fire producing a heat output of 8 MW (of which it can be assumed that one third is dissipated by radiation at the location of the fire). This is equivalent to two or three light vehicles (depending on their size).

Because there is no stratification, the only possibility for smoke extraction consists of pushing the smoke in the direction of traffic movement away from the fire. With this object the ventilation equipment must be capable of ensuring a mean air flow velocity of 2 m/s under the conditions described in section 3.2.2.a.

It is also appropriate that massive extraction systems capable of extracting the total air flow originating from the direction of the fire, as well as the entrained air from the other direction flowing at a minimum speed of 1 m/s, should be provided on the downstream side.

b) Tunnels having authorised gauge of over 2.00 m up to 3.50 m

If the gauge is in excess of 2.00 m but does not exceed 3.50 m, the fire used for dimensioning purposes will produce a heat output of 15 MW (of which it can be assumed that one third is dissipated by radiation at the location of the fire) and a smoke output of 50 m^3/s where this is stratified (this flow, measured at the temperature of the smoke, represents the sum of the flows of the combustion products and the gases which are drawn into the fire and not burnt). It corresponds to the largest vehicles, which in this case are vans.

In the case of one-way traffic, smoke extraction will normally be provided in the manner described in section 6.1.a above. The system must however be capable of ensuring an air flow velocity of 2.5 m/s.

In a tunnel of gauge between 2.70 m and 3.50 m carrying two-way traffic, smoke extraction is to be provided by remote-controlled extraction vents which must be located in the roof, accompanied by monitoring of the longitudinal air flow as described in section 3.2.2.b. The system must be capable of ensuring an extraction flow of 70 m^3/s distributed over a maximum length of 200 m.

In the same situation of gauges between 2.70 m and 3.50, the latter form of smoke extraction may be used for one-way traffic where this appears to be more appropriate for safety, with the reservation that all necessary evidence should be produced regarding level of operation and the monitoring of longitudinal air flow in particular.

6.2 - Fire resistance

The provisions specified in chapter 4 apply subject to the provisions indicated in this section.

All the times specified in section 4.2.2 shall be reduced to 60 minutes. The definition of fire resistance level N0 is unchanged. Levels N1, N2 and N3 are all defined by CN 60.

The requirements in sections 4.2.3, 4.3.1, 4.3.2 and 4.4.1 shall apply without change with this new definition of the levels. However, when a tunnel is adjacent to an inhabited or occupied structure, or located beneath it, the fire-stop capabilities of the dividing walls or slabs and the fire stability of the parts of the tunnel constituting components of the load-bearing structure for the buildings above must be ensured to the following levels:

- CN 240 in the case of tall buildings,
- CN 180 in the case of establishments which are open to the public and establishments which are classified in accordance with the law of 19 July 1976 because of the fire hazard,
- CN 120 in other circumstances.

The mechanical integrity of heavy equipment suspended from the roof at a temperature of 450°C, required by section 4.3.3, need only be ensured for 60 minutes.

The provisions of section 4.4.2 relating to the operation of ventilation equipment under fire conditions will only be required for a period of 60 minutes. The temperatures which such equipment must withstand are to be adjusted in relation to the strength of the reference fire and the tunnel characteristics.

7 - TUNNELS AUTHORISED FOR VEHICLES CARRYING HAZARDOUS GOODS

7.1 - Scope and field of application of this chapter

This chapter relates to tunnels having a gauge in excess of 3.50 m which are authorised for vehicles carrying hazardous goods subject to special compulsory marking. It specifies the provisions and safety equipment which is to be provided, supplementing that specified in chapters 2 to 5.

Not necessarily all vehicles carrying hazardous goods will be authorised to use a tunnel. In this part a distinction is made between two situations and these are subject to requirements which may be different:

- access authorised to all vehicles carrying hazardous goods (in this case there is no prohibition sign at the entrance to the tunnel),
- access prohibited to vehicles carrying explosive or readily flammable materials (panel B18 is then used; its precise significance is specified in article 19 of the amended order of 5 December 1996 relating to the transport of hazardous goods by road, known as the "ADR order").

Other circumstances are however possible: the most appropriate provisions must be assessed for each of these with reference to the requirements specified for the two above circumstances in this chapter.

Where the provisions which follow are of an optional nature, the degree of sensitivity of the tunnel in question must be borne in mind:

- authorisation or non-authorisation of vehicles carrying explosive or readily flammable materials,
- authorisation or non-authorisation of vehicles carrying significant quantities of toxic gases,
- volume of traffic in hazardous goods, based on the most adverse events (explosion of flammable gases, fire of flammable liquids, intoxication by toxic gases or liquids, etc.),
- the number of persons which may be present within the tunnel at any one time (traffic, length, risks of congestion),
- the number of persons which may be present outside close to the tunnel at any time (up to approximately 500 metres in the case of some types of accident),
- the general characteristics of the tunnel (length, transverse profile, smoke extraction facilities, possibilities for the rapid evacuation of users, etc.),
- operating procedures and emergency response,

- conditions applicable to hazardous goods traffic (e.g. declaration, escort, specified times).

7.2 - Civil engineering measures

7.2.1 - Facilities for the evacuation and protection of users of emergency access-ways

Special attention must be paid to facilities for the evacuation and protection of users and emergency access-ways, because these will be even more important when hazardous goods are present. In particular, in the case of non-urban tunnels which are sensitive in the meaning of section 7.1, the spacing between such facilities may be reduced.

7.2.2 - Transverse gradients

Transverse gradients in roadways and walkways may help to ensure the satisfactory collection of hazardous liquids which may have been spilled in the event of an accident. A minimum transverse gradient of 2% is to be complied with over the traffic width of the roadway. Changes of direction and transverse cambered profiles are to be avoided whenever possible.

7.2.3 - Drainage system

In order to reduce the surface area of puddles of flammable or toxic liquids spilt after an accident, and the time for which these remain present on the roadway, a continuous slot gutter shall be compulsory.

This gutter shall drain to an underground main along independent sections of the order of 50 m long. A siphon is to be provided between the gutter and the main alongside each connection in order to stop flames. Liquid is to be present at all times so that the siphons are always in a position to perform this function. Siphon closure devices must be as leak-tight as possible. No connection is to be located at a distance of less than 10 m from fire-fighting equipment, an emergency recess, or access to a facility for the evacuation and protection of users and emergency access-way. If the transverse profile of the roadway is cambered, a gutter is to be provided on each side.

Each section of gutter is to be capable of accepting a volume of 5 m^3 in 1 minute. The siphons and the main are to be capable of draining a flow of 100 l/s.

All liquids collected from the roadway are to pass through the main. The main is to be connected via a siphon at each low point and at the exit from the tunnel to a leak-tight recovery pit designed to prevent environmental pollution. The system must be capable of recovering at least a minimum total volume of 200 m^3 (40 m^3 corresponding to the maximum volume of hazardous liquids transported in a vehicle and 160 m^3 corresponding to the volume of water used to control the accident).

7.2.4 - Obstacles

Insofar as is possible any change in the transverse cross-section of a tunnel which might constitute a rigid obstacle which might pierce a tank involved in an accident, or tear off its equipment, is to be avoided. If this is not the case, appropriate protective measures must be taken.

Likewise, tunnel equipment which projects outward with respect to the side walls must be capable of retracting easily in the event of an impact or be protected by adequate means.

7.3 - Safety equipment

7.3.1 - Smoke extraction ventilation

The provisions of section 3.2.2 apply without change when vehicles carrying explosive or readily flammable materials are prohibited. If these are authorised, the provisions of section 3.2.2 will only apply if no stricter provisions detailed in the remainder of this section apply.

The reference fire corresponds to a fire in a hydrocarbon tanker and has the following characteristics:

- heat output 200 MW (of which it can be assumed that one third is dissipated by radiation at the location of the fire),
- the smoke output, when stratified, exceeds 300 m^3/s in the immediate vicinity of the fire and is of the order of 200 m^3/s beyond 50 to 100 metres from the fire (these flows, measured at the smoke temperature, represent the sum of the flows of the combustion products and the gases which are drawn into the fire or flame envelope and are not burnt).

In the case of one-way tunnels it is generally possible to provide a longitudinal ventilation system which is capable of driving all the smoke from the fire in one direction. Conversely, the quantity of smoke produced can only be extracted by a semi-transverse or transverse system at the price of considerable overdimensioning of the system, which may require a consequent increase in the cross-section which has to be excavated. Even with this, control of the consequences of a serious fire remains very uncertain. As a result, the longitudinal system is to be preferred for one-way traffic whenever possible. In the case of two-way tunnels, the general rule is to use a semi-transverse or transverse system. Nevertheless, in the case of two-way non-urban tunnels, a longitudinal system may be used in the circumstances and under the conditions described in section 3.2.2.a. Where the semi-transverse or transverse system is used, it is generally not dimensioned for the reference fire.

a) Requirements for smoke extraction using longitudinal ventilation

The mean velocity of the air flow which is to be achieved under the conditions described in section 3.2.2.a is 4 m/s. This velocity is however only required when adverse atmospheric conditions which are only exceeded during less than 10% of the time are present. A velocity of 3 m/s must be capable of being achieved in the presence of adverse atmospheric conditions which are only exceeded during less than 5% of the time.

b) Requirements for smoke extraction using semi-transverse or transverse ventilation

As a general rule, the provisions of section 3.2.2.b are to be applied without change. If the tunnel is of a sensitive nature in the meaning of section 7.1, strengthening of the other means to limit the consequences of a fire is to be provided:

- facilities for the evacuation and protection of users and emergency access,
- means providing rapid warning, such as a television monitoring system, automatic incident or fire detection, etc.,
- means to prevent entry to the tunnel.

In cases where extractors communicating directly with the open air can be installed in the roof (e.g. cut-and-cover structures), the extraction flow is to be increased and depending upon the nature of the sensitivity defined in section 7.1 may go so far as to make it possible to extract a flow of 300 m^3/s over a length of 400 m in urban tunnels and 600 m in non-urban tunnels.

7.3.2 - Detection and warning facilities

Where hazardous goods are present, an essential safety factor is the capability to very quickly detect any accidental event and give the alarm.

The following measures shall be taken in tunnels which are of a sensitive nature in the meaning of section 7.1:

- when permanent human supervision is not provided (degrees D1, D2 or D3 of attendance and supervision specified in section 5.1.1), and regardless of the nature of the ventilation system, it will be necessary to install an automatic fire detection system which provides the functions described in section 3.6,
- whatever the level of attendance and supervision, additional equipment at emergency telephones, user information facilities, etc., can be envisaged.

7.3.3 - Signage and means for closing tunnels

In the case of tunnels more than 800 m long, whether they are permanently supervised or not (degrees D3 or D4 of attendance and supervision defined in section 5.1.1), signalling, information and physical closure devices are specified in section 3.7.2 in order to prevent access to the structure in the event of need. Whenever a particular point in the route (crossroads, interchange, etc.) makes this provision realistic, these are to be supplemented by similar facilities provided at least 500 m in front of the end of the tunnel so as to protect users as much as possible from the effects of a serious accident occurring in the tunnel (especially explosion, release of toxic gas).

7.3.4 - Water supply

Fire-fighting equipment is to have a larger water reserve than tunnels in which hazardous goods traffic is prohibited. The necessary volume is 160 m^3.

7.3.5 - Other equipment

Depending upon the manner in which the tunnel is operated and its sensitive nature in the meaning of section 7.1, the advantage of installing the optional equipment specified in section 3.9 and a system for identifying hazardous goods present in the tunnel is to be considered.

7.3.6 - Flameproof equipment

The electrical equipment provided in recovery pits and electrical equipment rooms communicating with them are to be of the flameproof type.

7.4 - Fire resistance

The provisions of chapter 4 apply to the following requirements without reservation. These relate to section 4.4.2 and only apply to tunnels in which vehicles carrying explosive or readily flammable materials are authorised.

Operation of ventilation equipment under hot conditions

With longitudinal ventilation, when loss of the accelerator fans destroyed by heat is taken into account on a nominal basis (under the conditions specified in section 3.2.2.a), these are to withstand 400°C for 120 minutes (at the time when this text was written no accelerators satisfying this requirement were in existence; until such time as such equipment is available a resistance time of 60 minutes at 400°C may be adopted). The accelerator fans are to be placed in several sets so that they are not all destroyed simultaneously. When fans are installed in order to provide massive extraction, these must be capable of operating for 120 minutes at a temperature of 400°C (likewise a resistance time of 60 minutes may be adopted for as long as fans which are resistant for 120 minutes are not available).

In the case of semi-transverse and transverse systems, the extraction fans located at the end of a duct must be capable of operating for 120 minutes at a temperature of 400°C (as above, a resistance time of 60 minutes may be adopted as long as fans which are resistant for 120 minutes are not available). In the case of other ventilation equipment the provisions of section 4.4.2.b are to apply.

7.5 - Operation

Operating quality is even more important when hazardous goods traffic is authorised, and the provisions of chapter 5 may be strengthened according to the sensitivity of the tunnel in the meaning of section 7.1.

Of the particularly significant incidents or accidents in respect of which section 5.3.2 requires a report and analysis, by analogy with appendix IV to the amended order of 17 December 1998 incorporating Council Directive 96/35/EC of the 3 June 1996 concerning the appointment and professional qualifications of safety advisors for the transport of hazardous goods by road, rail or waterway, and until such time as European regulations are available, all events involving the transport of hazardous goods in which one of the criteria below are fulfilled are to be included:

- fatality or injury,
- leakage or loss of 200 kg of hazardous goods as net weight (in the case of class 7 - radioactive materials - any leakage or loss of load is to be included, regardless of its size),
- more than 250 000 F of material loss (including costs of restoring the tunnel and the environment),

- event for dealing with which special precautions have been adopted by the public authorities, such as the evacuation or confinement of the public, provisional closure of transport infrastructure, etc.

Regulations for the traffic of road vehicles carrying hazardous goods in tunnels shall be established by a circular cancelling and replacing circular no. 76-44 of 12 March 1976. This will describe applicable procedures and regulations. Depending upon circumstances, this text envisages the possibility of special operating measures such as:

- declaration of hazardous goods carried and movements with escort,
- mere declaration,
- prohibition of hazardous goods at peak times, or authorisation at off-peak times.

APPENDIX 1 :

Significant incident and accident reports

The purpose of this appendix is to specify the means for the feedback of information relating to significant incidents and accidents.

The list below summarises situations where reports are compulsory:

Whether traffic in hazardous goods is authorised or not

- accident involving at least one injured party (requiring medical attention or hospitalisation, even for a short period),
- accident involving at least one fatality,
- fire in a vehicle which began to burn in the tunnel but was able to exit without assistance,
- fire in a vehicle which burnt within the tunnel,
- any other event, including a physical accident or technical incident which required unscheduled closure of the tunnel.

Furthermore, where hazardous goods traffic is authorised:

- leakage or loss of more than 200 kg of hazardous goods as net weight (in the case of class 7 - radioactive materials - any leakage or loss of load will be taken into consideration, regardless of its size),
- more than 250 000 F of material loss (including the costs of restoring the tunnel and the environment),
- event for dealing with which substantial precautions have been taken by the public authorities, such as evacuation or confinement of the public, temporary closure of transport infrastructure, etc.

Other less serious incidents or accidents may be the subject of a similar report, on the initiative of the principal or the operator, and be forwarded in the same way.

The reports must be sent to the Prefect, the police authority responsible for safety if this is not the Prefect, and the Tunnels Design Centre (CETU) within a maximum period of one month after the event. A shorter period will apply if the importance of the event justifies it. Transmission to the CETU will be via an Internet site. Connection and input procedures are to be requested from the following address:

Centre d'Etudes des Tunnels	Telephone : 04 72 14 34 30
25 avenue François Mitterrand	Fax : 04 72 14 34 70
Case n° 1	E-mail address :
69674 BRON Cedex	incident.cetu@equipement.gouv.fr

At the time of connection the operator may obtain a copy of the information which he has acquired in the form of an IT file or on paper. Either of these media will be used for forwarding the information to the Prefect and the police authority responsible for safety if this is not the Prefect. These provisions will not rule out any further information if the Prefect or police authority responsible for safety has given the operator any instructions in this respect. The pages below provide an outline for the report as presented at the time when this appendix was drafted. This may be amended if necessary: the version which is to be used will be that available on line at the time of connection.

Furthermore, whenever an analysis report on the circumstances of an incident or accident and the consequences which can be drawn from it is established, a copy will be sent to the Prefect, the police authority responsible for safety if this is not the Prefect and the Tunnels Design Centre as soon as it is available. The latter copy shall be forwarded to the address above, if possible in electronic form.

EVENT DESCRIPTION RECORD

TUNNEL :

TYPE OF EVENT

Possibilities

1 - Breakdown of a vehicle in the tunnel
2 - Physical accident
3 - Bodily injury
4 - Fire following an accident
5 - Spontaneous fire
6 - Incident in tunnel installations
7 - Wilful damage
8 - Other, specify:

LOCATION

Date :

Time :

Tube :

RP + abs.

Location on the route by RP + Abscissa

If the incident involved tunnel installations, specify the location :

Possibilities: *control point, ventilation plant, transformer, tube, tunnel portal, etc..*

SEVERITY OF THE OCCURRENCE

Number slightly injured:

Number seriously injured:

Number of fatalities:

Damage to installations:

Possibilities

1 - None
2 - Slight over less than 10 m
3 - Severe over less than 10 m
4 - 10 to 50 m
5 - 50 to 100 m
6 - More than 100 m

CAUSES / CIRCUMSTANCES

Main cause : other :

Possibilities

In the event of an accident (whether or not followed by a fire):
1 - Broken down vehicle involved
2 - Construction work involved
3 – Oversize
4 - Other to be specified:_______

Followed by a fire: yes no

In the event of a breakdown:
5 - Fuel
6 - Mechanical
7 - Flat tyre
8 - Other, specify:________________

If the fire was spontaneous:
9 - Spontaneous fire in a vehicle which exited from the tunnel without help
10 - Spontaneous fire in a vehicle which burnt in the tunnel

If the incident involved tunnel installations:
11 - Lighting failure
12 - Ventilation failure
13 - Electricity supply failure
14 - Other, specify:______________

Direction of movement of the vehicle giving rise to the occurrence:

Possibilities: directions 1 or 2, gradient, not applicable

TRAFFIC DURING THE OCCURRENCE

Possibilities

1 - No restriction, flowing traffic
2 - No restriction, bottleneck
3 - One lane closed
4 - Alternate working
5 - Closure of the tube
6 - Closure of several tubes
7 - Other, specify:

In the case of possibilities 2 to 7 indicate the time (min):

Between the first alarm and implementation of the first traffic control measure:

Total duration:

(Until normal traffic re-established)

Number of vehicles stationary in the tunnel:

NUMBER OF VEHICLES INVOLVED

LV : 2 wheels :

HGV : Bus :

Other : Specify : ________

Hazardous goods:

Was a vehicle carrying hazardous goods involved?:

Possibilities

1 - None
2 - One
3 - Several
4 - Not known

Class of materials carried:

Possibilities: ADR classes; several classes; not known

Was a hazardous material released?

Possibilities
1 - No
2 - One
3 - Several
4 - Not known

If which, which was the main one?
(UN number)

MANNER OF DETECTION

and

Possibilities

1 - Operating staff in the tunnel
2 - Police in the tunnel
3 - Push-button
4 - Emergency telephone
5 - TV
6 - Automatic detection
7 - Other, specify:

FACILITIES USED

	In use	Time
Operating departments	_____	_____
Police force	_____	_____
Breakdown equipment	_____	_____
Excavating equipment	_____	_____
External fire service	_____	_____
Rescue	_____	_____
….	_____	_____
Other	_____	_____

If others, specify:

Possibilities: Yes, no, not known for each facility used (time in minutes between first alarm and arrival on site) :

EQUIPMENT USED

Operating lights	______
Barriers	______
Tunnel extinguishers	______
Tunnel fire system	______
Magnetic detector	______
….	______
….	______
Others	______

If others, specify:

Possibilities: Yes, no, or not known for each item of equipment used.

IN THE EVENT OF A FIRE	INFORMATION PROVIDED TO USERS	SAFEGUARDING OF USERS
Smoke extraction brought into use: ☐ ***Possibilities*** *1 - No* *2 - Automatic* *3 - Manual in accordance with instructions* *4 - Manual not in accordance with instructions* *5 - Other* *6 - Not known* Time : ☐ min (between first alarm and start of smoke extraction) Control of fire: ***Possibilities*** *1 - By users* *2 - By the operator* *3 - By external fire services* *4 - Extinguished spontaneously* Duration of fire min ☐	Equipment used to inform users: Stop lights at the tunnel entrance ____ Stop lights in the tunnel ____ Lane allocation signals ____ Variable message panels ____ Superimposition of radio message on public broadcasting frequencies ____ Tunnel loudspeakers ____ …. ____ Other ____ ***Possibilities: Yes, no or not known*** If other, specify: ☐ Messages provided for users if VMP, radio, etc., used Broken down vehicle ____ Obstacle on the roadway ____ Accident ____ Fire ____ Remain in your vehicle ____ Leave your vehicle ____ Evacuate the tunnel ____ …. ____ ***Possibilities: Yes, no*** ☐ Other message:	Action by users/use of: Lay-by ____ Vehicle U-turn in tunnel ____ Exit on foot from one end of the tunnel ____ Emergency exit to the exterior ____ Communication with the other tube ____ Safety tunnel ____ Shelter (refuge) ____ …. ____ …. ____ …. ____ …. ____ Other : ____ ***Possibilities** : Yes, no or not known.* If other, specify: ☐

Description and causes of the occurrence, comments, any other steps taken

Specify at least any points over which you had difficulty in filling in the above boxes or which seem to you to be of interest. Also, describe insofar as is possible:

- the initial situation
- the circumstances and their progress
- the alarm
- any exceptions to instructions
- the roles of the various parties involved, the conditions for emergency access
- the behaviour of users, spacing between stopped vehicles
- damage to the vehicles
- the extent of damage to the tunnel's structure and equipment
- the nature, quantity, packaging and role in the event of any hazardous goods involved, whether released or not
- steps taken after the occurrence

____

(*Continued on another sheet*)

APPENDIX 2 :

Summary tables

This appendix provides a number of tables summarising some of the provisions in the technical instruction. However this summary view suffers from an absence of completeness, and even accuracy: use of the tables will not dispense with a reading of the more detailed provisions in the technical instruction. If there is any inconsistency between the text of the technical instruction and this appendix, the former is to prevail.

Tables 1 to 5 below summarise the main types of civil engineering arrangements and equipment which have to be specified, and some operating provisions. They are independent of the system for the authorisation or prohibition of hazardous goods and have been drawn up for several tunnel situations having gauges of over 3.50 m (not all possible circumstances have been dealt with)

Table 1 :	Urban tunnel with two one-way tubes
Table 2 :	Urban tunnel with one two-way tube
Table 3 :	Non-urban tunnels with two one-way tubes and heavy traffic
Table 4 :	Non-urban tunnels with one two-way tube and heavy traffic
Tableau 5 :	Non-urban tunnels with one two-way tube and light traffic

Table 6 summarises the fire resistance requirements for the structures of tunnels of gauge in excess of 3.50 m.

The following abbreviations are used in these tables:

-	no requirement
Accep.	Accepted
w/	With
2-way	Two-way
Compens.	Compensatory measures
A.I.D.	Automatic incident detection
Degrees (att.)	Degrees of attendance and supervision described in § 5.1.1
Pref.	Preferably
Eqp.	Equipment
Mass. ex.	Massive extraction
Emergency routes	Facilities for the evacuation and protection of users and emergency access specified in § 2.2 of the technical instruction
Mand.	Mandatory
VMP	Variable message panel
Possib.	Possibility
If poss.	If possible
Sup.	Human supervision of the tunnel (permanent or not: degrees D3 or D4 defined in § 5.1.1, unless it is specified that it should be permanent: degree D4)
THD	Transport of hazardous goods (authorised)
EV	Emergency vehicles

Table 1 : URBAN TUNNELS WITH TWO ONE-WAY TUBES OF GAUGE > 3.50 m

URBAN 2 TUBES		300 m	500 m	800 m	1000 m	1500 m	3000 m	5000 m
CIVIL ENGINEERING ARRANGEMENTS								
EXCESS WIDTH / WALKWAYS	§ 2.1	Additional with or access by EV required or not depending upon access routes - compulsory footway on the right hand side						
EMERGENCY ROUTES	§ 2.2	Compulsory every 200 m (closer together in tubes with more than 3 lanes where congestion is frequent)						
if depth < 15 m	§ 2.2.1	Direct communication with the exterior compulsory						
others possib. if depth >= 15 m	§ 2.2.2	Communication between tubes if there is room for an air lock, safety tunnel or shelter (with access way protected from fire) if not						
ARRANGEMENTS FOR EV in the tunnel	§ 2.3.1	-	-	-	Communication between tubes every 800 m possible, if not possible. turning space			
at ends	§ 2.3.2	In front of each entrance, parking space on the right hand side and possibility for transfer from one tube to the other						
EMERGENCY RECESSES	§ 2.4	Every 200 m on the right hand side						
FIRE RECESSES	§ 2.5	Preferably separate from the safety recesses, every 200 m (on one side only)						
HELIPAD	§ 2.6	-	-	-	-	-	If access is difficult	
PREVENTION OF SMOKE RECYCLING	§ 2.7	Steps to be taken to avoid smoke from passing from one tube to the other, preferably as part of the civil engineering						
LAY-BYS	§ 2.8	-	-	-	Every 800 m if the number of lanes alongside a stopped vehicle is reduced			
SAFETY EQUIPMENT								
ELECTRICITY SUPPLY	§ 3.1	Sockets in emergency recesses + uninterruptible supply + uninterruptible power supply						
ORDINARY VENTILATION	§ 3.2.1	CO concentration < 150 ppm and K < 9.10^{-3} m^{-1} in the event of an accidental traffic blockage						
SMOKE EXTRACTION VENTILATION	§ 3.2.2	Compulsory						
- LONGITUDINAL general case	§ 3.2.2.a	Accepted	Accepted only with massive extraction every 500 m					
with appropriate operation/equipment		Accepted		Accepted only with massive extraction every 800 m				
- (SEMI-) TRANSVERSE	§ 3.2.2.b	Accepted						
control of air flow		-	-	-	-	If possible	Compulsory	
LIGHTING / MARKER LIGHTS	§ 3.3	Emergency lighting + marker lights every 10 m on each side						
EMERGENCY TELEPHONES	§ 3.4	In emergency recesses (every 200 m) + and in emergency access						
FIRE FIGHTING	§ 3.5	2 extinguishers in each emergency recess (every 200 m) + fire outlet or hydrant every 200 m						
FIRE DETECTION	§ 3.6	As appropriate (see also § 7.3.2 if THG permitted)						
SIGNAGE for safety equip.	§ 3.7.1	Compulsory (illuminated and permanent in the tunnel)						
stop at ends	§ 3.7.2	Compulsory 50 m in front of each entrance						
stop with barrier + VMP at the ends		-	-	Compulsory if sup.	Compulsory			
stop with VMP in tunnel		-	-	-	Every 800 m			
lane allocation	§ 3.7.3	-	-	Every 200 m if sup.	Every 200 m			
RADIO RELAY	§ 3.8	-	At least EV	EV + users if sup.	EV + users			
TV AND A.I.D. MONITORING	§ 3.9	Compulsory if there is human supervision (degree D3 or D4)			Compulsory			
OPERATING								
DEGREE OF ATTENDANCE/SUP.	§ 5.1.1	Degrees D1 to D4 authorised - choice depends on tunnel, traffic and THG			Permanent human supervision compulsory (degree D4)			
SPECIFIC EMERGENCY FACILITIES	§ 5.1.2	Needs to be assessed on the basis of tunnel, traffic, THG and distance from public emergency services						

Table 2 : URBAN TUNNELS WITH ONE TWO-WAY TUBE OF GAUGE > 3.50 m

URBAN 1 two-way TUBE		300 m	500 m	800 m	1000 m	1500 m	3000 m	5000 m
CIVIL ENGINEERING ARRANGEMENTS								
WALKWAYS	§ 2.1.2	Compulsory on each side						
EMERGENCY ROUTES	§ 2.2	Compulsory every 200 m (closer together if more than 3 lanes and congestion is frequent)						
if depth < 15 m	§ 2.2.1	Direct communication with the exterior compulsory						
others possib. if depth >= 15 m	§ 2.2.2	Safety tunnel or shelter (with access way protected from fire)						
ARRANGEMENTS FOR EV in the tunnel	§ 2.3.1	-	-	-	Turning spaces every 800 m			
at the ends	§ 2.3.2	Parking area on the right hand side with turning space in front of each entrance						
EMERGENCY RECESSES	§ 2.4	Every 200 m on either side and opposite each other						
FIRE RECESSES	§ 2.5	Preferably separate from emergency recesses, every 200 m (on one side only)						
HELIPAD	§ 2.6	-	-	-	-	-	If access difficult; at each end if poss.	
LAY-BYS	§ 2.8	-	-	-	Every 800 m if the number of lanes alongside a stopped vehicle is reduced			
SAFETY EQUIPMENT								
ELECTRICITY SUPPLY	§ 3.1	Sockets in emergency recesses + uninterruptible supply + uninterruptible power supply						
ORDINARY VENTILATION	§ 3.2.1	Concentration of CO < 150 ppm and K < 9.10^{-3} m^{-1} in the event of accidental traffic blockage						
SMOKE EXTRACTION VENTILATION	§ 3.2.2	Compulsory						
- LONGITUDINAL	§ 3.2.2.a	Prohibited						
- (SEMI-) TRANSVERSE	§ 3.2.2.b	Accepted						
control of air flow		-	-	-	-	If possible	Compulsory	
LIGHTING / MARKER LIGHTS	§ 3.3	Emergency lighting + marker lights every 10 m on each side						
EMERGENCY TELEPHONES	§ 3.4	In emergency recesses (every 200 m on each side) + along emergency routes						
FIRE FIGHTING	§ 3.5	2 extinguishers in each emergency recess (every 200 m on each side) + fire outlet or hydrant every 200 m (on one side only)						
FIRE DETECTION	§ 3.6	Compulsory if degree of att. D1, D2 or D3, possible if D4			Possible			
SIGNAGE for safety equip.	§ 3.7.1	Compulsory (illuminated and permanent in the tunnel)						
stop at ends	§ 3.7.2	Compulsory 50 m in front of each entrance						
stop with barrier + VMP at the ends		-	-	Compulsory if sup.	Compulsory			
stop with VMP in tunnel		-	-	-	Every 800 m			
lane allocation	§ 3.7.3	-	-	Every 200 m if degree of att. D3 or D4 and if there is more than one lane in each direction				
RADIO RELAY	§ 3.8	-	At least for EV	EV + users if sup.	EV + users			
TV AND A.I.D MONITORING	§ 3.9	Compulsory if there is human supervision (degree D3 or D4)			Compulsory			
OPERATING								
DEGREE OF ATTENDANCE/SUP.	§ 5.1.1	Degrees D1 to D4 permitted - choice depends on tunnel, traffic and THG			Permanent human supervision compulsory (degree D4)			
SPECIFIC EMERGENCY FACILITIES	§ 5.1.2	Needs to be assessed depending on tunnel, traffic, THG and distance from public emergency services						Compulsory at the 2 ends

Table 3 : NON-URBAN TUNNELS HAVING TWO ONE-WAY TUBES AND HEAVY TRAFFIC OF GAUGE > 3.50 m

NON URBAN 2 TUBES		300 m	500 m	800 m	1000 m	1500 m	3000 m	5000 m
CIVIL ENGINEERING ARRANGEMENTS								
EXCESS WIDTH /WALKWAYS	§ 2.1	Additional width for access by EV necessary or not depending upon emergency routes - compulsory footway on the right hand side						
EMERGENCY ROUTES	§ 2.2	-	Compulsory every 400 m					
if depth < 15 m	§ 2.2.1	-	Direct communications with the exterior compulsory					
others possib. if depth >= 15 m	§ 2.2.2	-	Communication between tubes if there is room for an airlock, safety tunnel or shelter (with protected access-way), if not					
ARRANGEMENTS FOR EM in the tunnel	§ 2.3.1	-	-	-	Communication between tubes every 800 m if feasible, if not, turning spaces			
at the ends	§ 2.3.2	Parking space on the right hand side in front of each entrance and possibility for transfers from one tube to the other						
EMERGENCY RECESSES	§ 2.4	Every 200 m on the right						
FIRE RECESSES	§ 2.5	-	Preferably separate from the emergency recesses, every 200 m (on one side only)					
HELIPAD	§ 2.6	-	-	-	-	-	If access is difficult	
PREVENTION OF SMOKE RECYCLING	§ 2.7	Steps to be taken to prevent smoke from passing from one tube to the other, preferably as part of the civil engineering						
LAY-BYS	§ 2.8	-	-	-	Every 800 m if the number of lanes alongside a stopped vehicle is reduced			
SAFETY EQUIPMENT								
ELECTRICITY SUPPLY	§ 3.1	Sockets in the emergency recesses + uninterruptible supply + uninterruptible power supply (compulsory only if there is ventilation)						
ORDINARY VENTILATION	§ 3.2.1	CO concentration < 150 ppm and K < 9.10^{3} m^{-1} in the event of an accidental traffic blockage						
SMOKE EXTRACTION VENTILATION	§ 3.2.2	-	Compulsory unless compens.	Compulsory				
- LONGITUDINAL	§ 3.2.2.a	-	Recommended					With mass. ex.
- (SEMI-) TRANSVERSE	§ 3.2.2.b	-	Longitudinal to be preferred wherever possible					
control of air flow		-	-	-	-	-	Compulsory	
LIGHTING / MARKER LIGHTS	§ 3.3	Emergency lighting + marker lights every 10 m on each side						
EMERGENCY TELEPHONES	§ 3.4	In emergency recesses (every 200 m) + along emergency routes						
FIRE-FIGHTING	§ 3.5.1	2 extinguishers in each emergency access (every 200 m)						
water supply	§ 3.5.2	-	Fire outlet or hydrant every 200 m					
FIRE DETECTION	§ 3.6	As appropriate (see also § 7.3.2 if THG authorized)						
SIGNAGE for safety equip.	§ 3.7.1	Compulsory (illuminated and permanent in the tunnel)						
stop at ends	§ 3.7.2	Compulsory 50 m in front of each entrance						
stop with barrier + VMP at the ends		-	-	Compulsory if there is human supervision (degree D3 or D4)			Compulsory	
stop with VMP in tunnel		-	-	-	Every 800 m if sup. (degree D3 or D4)		Every 800 m	
lane allocation	§ 3.7.3	-	-	Every 400 m if sup. (degree D3 or D4)			Every 400 m	
RADIO RELAY	§ 3.8	-	-	For at least EV	For at least EV; users if sup. (D3 or D4)		EV + users	
TV AND A.I.D. MONITORING	§ 3.9	Compulsory if there is human supervision (degree D3 or D4)					Compulsory	
OPERATING								
DEGREE OF ATTENDANCE/SUP.	§ 5.1.1	Degrees D1 to D4 authorised - choice depends on tunnel, traffic and THG					Permanent sup. compulsory (degree D4)	
SPECIFIC EMERGENCY FACILITIES	§ 5.1.2	Needs to be assessed depending on tunnel, traffic, THG and distance from public emergency services						

Table 4 : NON-URBAN TUNNELS HAVING ONE TWO-WAY TUBE AND HEAVY TRAFFIC OF GAUGE > 3.50 m

NON URBAN 1 two-way TUBE		300 m	500 m	800 m	1000 m	1500 m	3000 m	5000 m
CIVIL ENGINEERING ARRANGEMENTS								
WALKWAYS	§ 2.1.2	Compulsory on each side						
EMERGENCY ROUTES	§ 2.2	-	Compulsory every 400 m					
if depth < 15 m	§ 2.2.1	-	Direct communications with the exterior compulsory					
others possib. if depth >= 15 m	§ 2.2.2	-	Safety tunnel or shelter (with access-way protected from fire)					
ARRANGEMENTS FOR EV in the tunnel	§ 2.3.1	-	-	-	Turning space every 800 m			
at the ends	§ 2.3.2	Parking space on the right hand side in front of each entrance and turning space						
EMERGENCY RECESSES	§ 2.4	Every 200 m on each side and opposite each other						
FIRE RECESSES	§ 2.5	-	Preferably separate from the emergency recesses, every 200 m (on one side only)					
HELIPAD	§ 2.6	-	-	-	-	-	If access is difficult; at each end if poss.	
LAY-BYS	§ 2.8	-	-	-	Every 800 m if the number of lanes alongside a stopped vehicle is reduced			
SAFETY EQUIPMENT								
ELECTRICITY SUPPLY	§ 3.1	Sockets in emergency recesses + uninterruptable supply + uninterruptable power supply (compulsory only if there is ventilation)						
ORDINARY VENTILATION	§ 3.2.1	CO concentration < 150 ppm and $K < 9.10^{3}\ m^{-1}$ in the event of accidental blockage of traffic						
SMOKE EXTRACTION VENTILATION	§ 3.2.2	-	Compulsory without compens.		Compulsory			
- LONGITUDINAL	§ 3.2.2.a	-	Accepted with compensatory measures		Prohibited			
- (SEMI-) TRANSVERSE	§ 3.2.2.b	-	Accepted					
control of air flow		-	-	-	-	-	Compulsory	
LIGHTING / MARKER LIGHTS	§ 3.3	Emergency lighting + marker lights every 10 m on each side						
EMERGENCY TELEPHONES	§ 3.4	In emergency recesses (every 200 m on each side) + along emergency routes						
FIRE FIGHTING	§ 3.5.1	2 extinguishers in each emergency recess (every 200 m on each side)						
water supply	§ 3.5.2	-	Fire outlet or hydrant every 200 m (on one side only)					
FIRE DETECTION	§ 3.6	-	As applicable (see 7.3.2)	Compulsory if degree of att. D1, D2 or D3, possible if D4			Possible	
SIGNAGE for safety equip.	§ 3.7.1	Compulsory (illuminated and permanent in the tunnel)						
stop at ends	§ 3.7.2	Compulsory 50 m in front of each entrance						
stop with barrier + VMP at the ends		-	-	Compulsory if there is human supervision (degree D3 or D4)			Compulsory	
stop with VMP in tunnel		-	-	-	Every 800 m if sup. (degree D3 or D4)		Every 800 m	
lane allocation	§ 3.7.3	-	-	Every 400 m if degree of attendance D3 or D4 and if there is more than one lane in each direction				
RADIO RELAY	§ 3.8	-	-	For at least EV	At least EV; users if sup. (D3 or D4)		EV + users	
TV AND A.I.D. MONITORING	§ 3.9	Compulsory if there is human supervision (degree D3 or D4)					Compulsory	
OPERATING								
DEGREE OF ATTENDANCE/SUP.	§ 5.1.1	Degrees D1 to D4 authorised - choice depends on tunnel, traffic and THG					Permanent sup. compulsory (degree D4	
SPECIFIC EMERGENCY FACILITIES	§ 5.1.2	Needs to be assessed depending on tunnel, traffic, THG and distance from public emergency services						Compuls. at 2 ends

Table 5 : NON-URBAN TUNNEL WITH ONE TWO-WAY TUBE AND LOW TRAFFIC OF GAUGE > 3.50 m

LOW TRAFFIC 1 2-way TUBE		300 m	500 m	800 m	1000 m	1500 m	3000 m	5000 m
CIVIL ENGINEERING ARRANGEMENTS								
WALKWAYS	§ 2.1.2	Compulsory on each side						
EMERGENCY ROUTES	§ 2.2	-	Recommended every 400 m					
if depth < 15 m	§ 2.2.1	-	Direct communication with the exterior					
others possib. if depth >= 15 m	§ 2.2.2	-	Safety tunnel or shelter (with access-way protected from fire)					
ARRANGEMENTS FOR EV in the tunnel	§ 2.3.1	-	-	-	Turning space every 800 m			
at the ends	§ 2.3.2	Parking space on the right hand side in front of each entrance and turning space						
EMERGENCY RECESSES	§ 2.4	Every 200 m on both sides and opposite each other						
FIRE RECESSES	§ 2.5	-	Preferably separate from emergency recesses, every 200 m (on one side only)					
HELIPAD	§ 2.6	-	-	-	-	-	If access difficult; at each end if poss.	
LAY-BYS	§ 2.8	-	-	-	-	-	-	-

SEAFETY EQUIPMENT								
ELECTRICITY SUPPLY	§ 3.1	Sockets in emergency recesses + uninterruptible supply + uninterruptible power supply (compulsory only if there is ventilation)						
ORDINARY VENTILATION	§ 3.2.1	CO concentration < 150 ppm and $K < 9.10^{3}\ m^{-1}$ in the event of accidental traffic blockage						
SMOKE EXTRACTION VENTILATION	§ 3.2.2	-	-	-	Compulsory			
- LONGITUDINAL	§ 3.2.2.a	-	-	-	Accept. w/compens.	Prohibited (except special cicumstances, with compens.)		
- (SEMI-) TRANSVERSE	§ 3.2.2.b	-	-	-	Accepted			
control of air flow		-	-	-	-	-	Compulsory	
MARKER LIGHTS	§ 3.3	Marker lights every 10 m on each side						
EMERGENCY TELEPHONES	§ 3.4	In emergency recesses (every 200 m on each side) + along emergency routes						
FIRE FIGHTING	§ 3.5.1	2 extinguishers in each emergency recess (every 200 m on each side)						
water supply	§ 3.5.2	-	Fire outlet or hydrant every 200 m (on one side only)					
FIRE DETECTION	§ 3.6	-	-	-	Compulsory if degree of attendance D1, D2 or D3, possible if D4			
SIGNAGE for safety equip.	§ 3.7.1	Compulsory (illuminated and permanent in the tunnel)						
stop at ends	§ 3.7.2	Compulsory 50 m in front of each entrance						
stop with barrier + VMP at the ends		-	-	Compulsory if there is human supervision (degree of attendance D3 or D4)				
stop with VMP in tunnel		-	-	-	Every 800 m if there is human supervision (degree D3 or D4)			
lane allocation	§ 3.7.3	-	-	-	-	-	-	-
RADIO RELAY	§ 3.8	-	-	At least for EV (may be replaced by 2 fixed telephone lines); users if sup. (degree D3 or D4)				
TV AND A.I.D. MONITORING	§ 3.9	Compulsory if there is human supervision (degree D3 or D4)						

OPERATING		
DEGREE OF ATTENDANCE/SUP.	§ 5.1.1	Degrees D1 to D4 authorised - choice depends on tunnel, traffic and THG
SPECIFIC EMERGENCY FACILITIES	§ 5.1.2	Needs to be assessed depending on tunnel, traffic, THG and distance from public emergency services

Table 6

Fire resistance of structures

RESISTANCE LEVELS	Gauge > 3.50 m (§ 4.2.2 in the technical instruction)	Gauge ≤ 3.50 m (§ 6.2 in the technical instruction)
N0	No risk of progressive collapse	
N1	CN 120	CN 60
N2	HCM 120	CN 60
N3	CN 240 HCM 120	CN 60

MAIN STRUCTURES (§ 4.3.1 and 6.2 in the technical instruction)	
General situation as regards ground and environment (no risk of catastrophic collapse or flooding, nor serious risks on the surface or for other structures)	
- General situation (local failure without any consequence for the safety of users or emergency services which might be present elsewhere in the tunnel)	N0
- Risk to the supported route (pedestrian or roadway):	
general situation	N1
if it is essential to preserve the supported route	N2 or N3
- Risk to stability/separation of another tube:	
where there is direct communication with the exterior	N1
where there is no direct communication with the exterior	N2
- Risk of cutting ventilation ducts or cables:	
if they are important for emergency action	N1
if they are necessary for shelters and their access-ways	N2
Catastrophic risk of flooding or tunnel break-in	N3
Risk of severe damage on the surface, to another structure or to an inhabited or occupied structure	N3 (*)

(*) CN 240, 180 or 120 for a building, depending upon its type, if the gauge is 3.50 m or less

SECONDARY STRUCTURES (§ 4.3.2 of the technical instruction)	
False ceilings and walls separating ventilation ducts from the tunnel	
- General situation (local loss of continuity without consequences for the safety of users present elsewhere in the tunnel)	N0
- If continuity of the duct is important for emergency action	N1
- Ventilation ducts for shelters	N2
Other ventilation duct walls	
- General situation	N0
- Ducts used for smoke extraction	120 minutes (**)
Walls separating plant rooms and tunnel ventilation units	
- With regard to a fire occurring in the plant room	N1
- With regard to a fire occurring in the tunnel: general situation if there is a risk to the use of shelters and their access-ways if there is a risk to the continuity of electricity supply or communications in the tunnel	 N1 N2 N3
Facilities for the evacuation or protection of users and emergency access	
- Direct communication with the exterior	CN 60
- Communications between tubes: if there is a common wall between the tubes if there is no common wall	 ditto for the wall N2
- Safety tunnels, shelters and their access-ways	N2 (***)
Slabs supporting roadways	
- General situation	N0
- Slab bounding a space requiring higher protection	ditto that space

(**) With respect to the most unfavourable temperatures obtaining on either side

(***) With in addition a condition that the temperature of the surface which is not exposed to the fire should be less than 60°C.