COMPARED FIRE SAFETY FEATURES FOR METRO TUNNELS

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ABSTRACT

This paper presents the fire safety features for metro tunnels. After a short introduction showing the specificity of the metro transportation, it deals with the standard and usage.
A detailed analysis of structural conditions, safety equipment and response to fire is carried out, showing some differences between networks within the same country and between countries.

1. INTRODUCTION

Compared to the road and rail tunnels, the Metro is very different for the two other underground transportation modes. The scale of each network is a town and suburbs, and not a country like for road or rail transportation. Usually the metro concerns mainly urban sites and tunnels, sometimes suburban lines. So the Transport Authority is usually the Town and not a Country; for that reason the need for standard was less important.

1.1 Compared specificies

The fundamental difference between road or rail and metro tunnels results from the traffic nature which does not induce the same level of risk at all. This table gives general simplified characteristics of tunnels for each transportation mode:

Item	Metro	Rail	Road
Length	5 to 600 meters mean between 2 stations	30 m to 50km No stations	200 m to 20 km No stations or accesses*
Location	city	city, country	city, country
Exits	stations	tunnel ends	tunnel ends, shelters with access to other tunnels
Intervention time of firemen at the end of tunnels	5 to 10 minutes	10 to 60 minutes	5 to 60 minutes
Transport	people	People, goods, TMD**	People, goods,TMD
People	100 to 250 per wagon	150 per wagon	1 to 100 (bus)
communication for alarm	Driver or interphone	driver of the train	each driver of each vehicle
Vehicles	Dedicated fire resistance standard	No dedicated fire resistance standard	No dedicated No fire resistance standard
Firemen intervention	Stations ,special firemen access	ends of tunnel	ends of tunnel, special accesses

* : only for urban or very long tunnels **: dangerous goods

Table 1 Simplified charateristics of road, rail and metro tunnels

1.2 Main differences with other modes of transportation

They consist mainly in the existence of stations and the rolling stock.

1.2.1The stations

The strategy of fire protection in metros is based on the couple station-tunnel because the most important issue is to evacuate people by the stations. In fact, each train of the metro network in the world is fitted with inhibit of emergency break. This safety device allows to bring the train in the station, except in few exceptional cases (stopping of the train in the tunnel caused by a mechanical incident or signalling). Moreover the time the train is running in the tunnel is generally short, nearly 30 seconds; the time the train is stopped in a station is nearly the same. Thus the probability to find a train stopped in a tunnel in fire is very small.

1.2.2 The rolling stock

The rolling stock is dedicated to a metro line in each town of each country. It is only passenger transportation and never, except maybe in case of war, the transportation of hazardous goods. For this reason, the fire risk is very small.
The main objective is therefore to reduce the risk at the source, using very efficient fire safety standards for the train design and materials used for his construction.
It appears that this quality is specific to the metro and allows to optimise the tunnel equipment So, for a same level of fire safety as for road or train tunnels, it should allow to reduce the constraining character and the number of safety equipment in tunnels.

2. GUIDELINES

To present the relevant fire safe guidelines, regulations, standards or current best practices from European member states design it seems more realistic to integrate the all system train-infrastructure in the analysis because of the interaction of the different equipment to reduce the fire risk in the metros.

2.1The stations

Generally the stations in a metro network are dealt as “Class public receiving establishments”. As such, they are generally compelled to the safety regulations and standards for buildings and, sometimes when existing, to specific regulations for stations. As they are also considered as evacuation egress, they have to be conform with the safety rules according to the evacuation time reference.
The number or width of different facilities are based on people estimation at peak or normal hours for:

- the exits: at least 2 except for old stations
- the platform accesses
- the corridors
- the staircases and travelators
- the escalators or lifts
- the three-rod turnstiles
- the open toll gates

2.2 The rolling stock

The most restrictive standards concern the trains. In each country are applied European or local standards related to the fire behaviour of materials, smoke opacity and toxicity in case of fire. Moreover for some metros, extinguishing means are used in each wagon.

2.3 The tunnels

For the tunnels, the level of safety measures depends on the safety level fixed for train. More over in case of fire on a train in a tunnel, it is highly recommended to bring the train into a station the structure of which is sized to ensure passenger evacuation in the best possible conditions. In most cases this requirement is complied with by inhibiting the emergency brake (UITP requirement). So few safety equipments are existing; they concern mainly facilities for fire brigade intervention:

- specific entrance
- standpipes
- communication means
- etc…

In some networks, the ventilation system is very developed allowing to satisfy both comfort, environment and safety goals for passengers.

3. LIST of GUIDELINES

The list of European guidelines for metros is very short. It concerns only at our knowledge:

- Austria
- France
- Germany
- Italy
- Spain

In many countries, in Europe but particularly in America and Asia, the EU standard NFPA is applied in many existing or project metro networks. Each standard takes in account, in separate or unique documents stations, tunnels and vehicles, including:

- the field of applications
- stations and tunnels
- structural conditions
- escape and guidance facilities
- fire ventilation
- communication alarm system
- fire fighting equipment
- traffic regulation
- others(lighting, emergency power supply,…)
- fire resistance and reaction
- communal requirements
- particular requirements
- sometimes construction works

The different standards are based on existing equipment in national networks. So, due to a small number of standards, the safety requirements analysis had to consider simultaneously actual usage in different networks in Europe and use a study about fire safety for the Metros carried out by the "Union Internationale des Transports Publics" (UITP) during last years.

4. DETAILED COMPARISON OF SAFETY MEASURES

4.1 Structural conditions

Due to the characteristics of the metro tunnel, the need for specific emergency passenger or staff exit is not important, except in some specific cases like blind sidings or long tunnels.

In fact the evacuation of passengers or firemen intervention are based on 4 main principles:

- the presence of stations with many corridors and accesses
- the short distance between stations
- the emergency braking inhibit of the trains
- the use of walkway or track side or both

To create specific firemen access, the requirement based on the maximum distance between accesses may be very different for each network:

Metro	Distance maximum between stations or firemen accesses (in meters)
Praha	2140
Paris	800
Rennes	600
Helsinki	500
Hambourg	1000
Berlin	1700
Munchen	1717
Lisboa	1300
Barcelona	500
Madrid	500
Wien	600
USA	381

Table 2 Distance between accesses

4.2 Safety equipment

This chapter takes in account the same equipment that for road or rail tunnels.
The general document deals with:

- smoke control ventilation
- emergency exit and rescue access ventilation
- lighting
- signage
- communication and alarm system
- traffic regulation-monitoring equipment
- power supply
- fire suppression
- others

4.2.1 Smoke control ventilation

As we are obliged to consider underground stations and tunnels like a continuous underground environment, the role of the ventilation is fundamental. Ventilation is a need to obtain in an underground space comfort, air changes and fire safety. So to satisfy all these goals many systems are available:

- specific fire and/or comfort fans
- air conditioning + fire safety ventilation
- only fire safety ventilation
- only natural shafts

dedicated to the:

- stations/tunnels
- only stations
- only tunnels.

The use of the ventilation system differs with the strategy fixed by each metro network for fire safety. During an incident there are 2 important phases, before and after the decision taking. Before the smoke spreading can be due to:

- the piston effect caused by the stopping of the incidented train or the passing train in the other way
- the effect of the comfort ventilation
- or the both effect.

Generally in metro tunnels piston effect is the most important.
In the most of the European metro networks ventilation is used but the number, the distance and the flow rate of each fan is very changing. Moreover there is no ventilation control by sensors.
The fire resistance for many countries is defined in the following table:

Country, network	Resistant to fire (°C) (in station)	Duration (hour)
F- Paris	200 (400)	2 (1)
F- Rennes	200	2
FL- Helsinki	350	----,
D- Hambourg	300(100)	1,5
D- Munchen	----;	-----; (1,5)
P- Lisboa	300(300)	1(1,5)
SP- Barcelona	400(400)	1(1)
SP- Madrid	----;(100)	-----;
OS- Wien	250(60)	1,5
RU- Moskva	---;(0)	---; (0,5)
UK- London	350(360)	1(1)
USA	250	1

Table 3 Temperature and time resistance for fire safety fans

4.2.2 Lighting

The emergency exits, located generally in the stations are equipped with normal and emergency lighting in case of fire or power supply failure. For all the tunnels emergency tunnel lighting is available. In the next table, the main characteristics of tunnel lighting are indicated:

LIGHTING	Normal lighting		Emergency lighting	
Country, network	24h/24	During operation	Height (cm)	Mean Illumination (lux)
B-Brussels	yes	yes	120	2
F-Paris	yes	Yes	225	2
F- Rennes	yes	Yes	---;	60
FL-Helsinki	yes	yes	100 to300	5
TCH-Praha	no	----;	----;	2
I- Milano	yes	yes	4 to 6	100
S-Stockholm	no	No	----;	3
D-Hambourg	no	No	----;	>3
D-Berlin	----;	---;	100	1
D- Munchen	----;	no	---;	----;
N-Rotterdam	yes	no	----;	10
P- Lisboa	yes	Yes	320	10
SP- Barcelona	yes	Yes	----;	>1
SP- Madrid	no	No	----;	----;
OS- Wien	no	no	----;	20
RU- Moskva	no	no	-----;	
UK- London	no	No	150	
S-Stockholm	------	------		
USA	-------	-------	NFPA70	2,69

Table 4 Lighting

4.2.3 Signals

In metro tunnels, signals are simple. They consist of escape direction signs, lighted or located near the emergency lighting, indicating the name of the station and the distance.

4.2.4 Communication and alarm system

This is an important point. In many exercises or events, the communication system is insufficient and brings lack of time and efficiency.
During the intervention phase, the chief operator, the firemen, the station operator, the staff, the police, have to communicate or to intercommunicate. So the communication system has to be coherent, multiple, complete to satisfy all these needs.
Part of these systems, such as normal telephone, emergency telephone, leased line, mobile line, direct line, satellite teleline, underground communication system can be used separately or together.

To give alarm in case of fire in station or in tunnel, there are many people.
During the alert phase, it concerns the driver of the train (automatic cameras if not), the station operator(s) or passengers.
On the other hand a conventional automatic detection is generally installed in premises or areas considered as hazardous, namely:

- in stations for commercial shops or specific technical rooms (transformer room, escalator machine room, technical galleries)
- in tunnels for train stalling areas.

4.2.5 Passengers information

This information is given in stations near the location of the incident by radio or station operator and on the trains by the driver.

4.2.6 Traffic regulation –monitoring equipment and power supply

These equipments are required in normal conditions to ensure the efficiency of the metro system. So, in emergency situations, the same system is used allowing to be the more pertinent and efficient possible.

4.2.7 Fire fighting equipment

In tunnels, some equipments are installed essentially for firemen. Networks or parts of network are equipped with pipes, dry or wet. For example, the following table gives the diameter of the pipes:

Country, network	Diameter (cm)
B-Brussels	100
DK-Kopenhagen	….
F-Paris	100
F- Rennes	100
FL-Helsinki	100
TCH-Praha	75
I- Milano	50-180
D-Hambourg	80-100
D-Berlin	80
D- Munchen	80
N-Rotterdam	55-110
P- Lisboa	50
SP- Barcelona	50
SP- Madrid	45
OS- Wien	80
RU- Moskva	80-100
UK- London	-----
S-Stockholm	25

Table 5 Diameter of pipes

4.3 Structure and equipment, response to fire

The scope of application of many building standards are also the metros, essentially for the stations, less for tunnels (walls, partitions, etc…) .
The only main difference is the risk for the numerous cables laying in tunnels on large distances according to the different functions: power, communication, control and command.
So the structure of the cables is very important to analyse risk assessment.
The next table gives the cable structure (310 : PVC ; 311 :Self – extinguishing ; 312 :Halogen free ; 313 : no smoke development ; 314 : no toxicity ; 315 : mineralisation) installed or not in each country / network and the duration time:

Country, network	Structure						Fire resistance time (hour)
	310	311	312	313	314	315	
B-Brussels	no	no	yes	yes	yes	no	Yes (0,5 to1,5)
F-Paris	no	yes	yes	yes	yes	yes	Yes (1)
F- Rennes	no	no	yes	yes	no	no	Yes (1)
FL-Helsinki	yes	yes	yes	yes	yes	no	no
TCH-Praha	no	yes	yes	yes	yes	No	Yes (1)
I- Milano	no	yes	yes	yes	yes	no	no
D-Hambourg	yes	yes	yes	yes	yes	No	Yes (0,5)
D-Berlin	No	yes	yes	yes	yes	Yes	Yes (0,5)
D- Munchen	yes	yes	yes	no	yes	Yes	Yes (0,5?)
N-Rotterdam	no	yes	No	yes	yes	No	
P- Lisboa	No	Yes	yes	yes	Yes	No	Yes (0,25)
SP- Barcelona	No	yes	yes	yes	yes	Yes	Yes (1)
SP- Madrid	No	yes	yes	yes	yes	no	
OS- Wien	Yes	yes	yes	yes	yes	yes	Yes
UK- London	no	yes	yes	yes	yes	no	Yes (1)
S-Stockholm	yes	yes	yes	yes	no	no	

Table 6 Cable structure

5. CONCLUSION

All the items developed in this paper show many differences between different networks in a same country or in different countries. These facts come essentially from the age of the network and the upgrading safety solutions. But it appears many accordance between the different countries about the strategic choice, such as ventilation and communication systems. Therefore the metro safety system has to include all the components consisting in improving safety in stations, rolling stock and tunnels.