TUNNEL EXPERTISE

CONTEXT AND ISSUES

TABLE OF CONTENTS

ISO 9001 14001 Certified

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F2A Manufacturer Air handling components

CONTEXT AND ISSUES

Traffic can reach up to 200 000 vehicles a day in a road tunnel and the safety of users is a major issue. A fire taking place in a tunnel can have awful consequences on both human and strctural scales :

"From an aeraulic point of view, a tunnel differs from a classic building, because of longitudinal airstreams and because the air change rate is very high."CETU

The risks of a fire in a confined space are numerous and smokes whose velocity can reach up to 4 m/s can lead to:

- Asphyxiation: the fire consumes Oxygen molecules in the air, leading to the asphyxiation or Carbon Monoxide poisoning of the user, due to the smokes.
- Loss of visibility (most dangerous factor): the user is lost in the smokes and cannot evacuate, thus exposing himself to toxic fumes.

While fire can lead to :

- Explosion: when a fire is deprived of air in a confined space, it can lead to the appearance of gas pockets. The consequences of an explosion in a tunnel are devastating and the shockwave can be fatal all along the tunnel
- Collapse: Ventilation and lighting elements can fall on the road under the effect of extreme heat.

Visibility	Heat radiation	Temperature
10m	2 kW/m²	Between 50 and 80°C depending on the air humidity

Fire is apparently not frequent, but if we consider the large quantity of vehicles travelling every day and the risk of fire in a tunnel (rates below), "prevention measures" must be taken.

Type of vehicule	ligth vehicles	Truck (light fire)	Truck (heavy fire)
Fire rate (this rate is calculated for 10^8 vehicles per km)	2	7	1

Case study:

We take a 2000m long urban tunnel with a daily traffic of 48 000 vehicles, which makes about 2 000 vehicles per hour. If a light vehicle catches fire, there is around 2 000 to 4 000 people to be evacuated under 12 minutes, which is the time the smokes would take to invade 80% of the tunnel.

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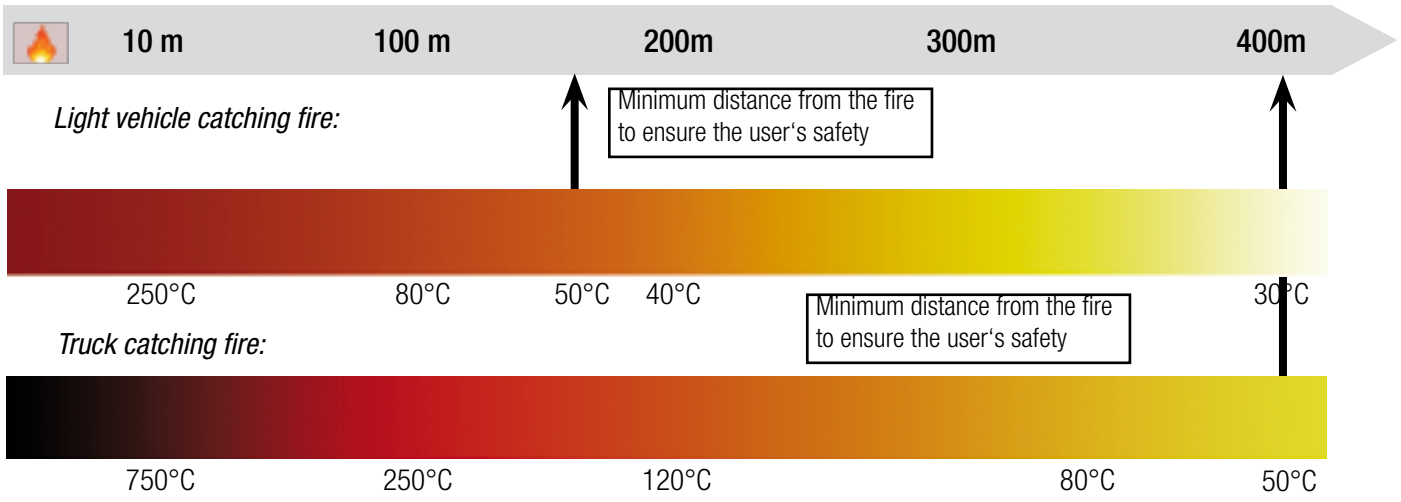
RISE IN TEMPERATURE

In 2003, the CETU carried out a study which showed that in case of a vehicle catching fire, the heat radiation varies between 2 MW for a light vehicle and up to 200 MW for a gas tank. A fire is considered as “heavy” when it exceeds 10-20MW.

To ensure the user’s safety, the latter must be at a minimum distance of the fire:

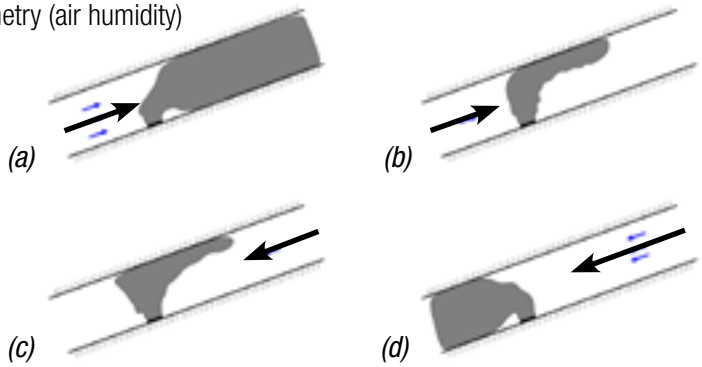


VISIBILITY

Losing visibility because of smoke propagation is one of the most dangerous factors for the users. If someone loses his landmarks, he becomes disoriented and his chances to survive diminish greatly.

The smoke propagation is directly connected to the typological aspects of a tunnel:

- The slope which induces a chimney effect (if over 10%)
- The tunnel’s building materials, depending on their resistance to heat
- The pressure difference between the two entry points of the tunnel
- The tunnel length
- The tunnel’s vault (depending on whether the tunnel is vaulted or flat)
- The hygrometry (air humidity)



Smoke behavior in a tunnel with slope: (a) strong ascending air draft; (b) average ascending airstream; (c) average descending airstream; (d) strong descending airstream.

Source CETU

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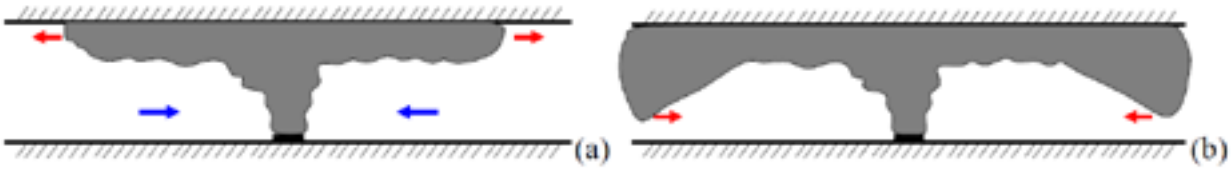


Source CETU

If we consider a tunnel with no slope and a light vehicle catching fire, on average, smoke will spread over the tunnel in less than one minute on 100 meters on each side of the fire.

When there is no ventilation to help the smoke evacuation, it follows the same pattern invariably:

	Ligth vehicle	Truck (heavy fire)
Smoke propagation velocity	1 to 2 m/s	Up to 4 m/s

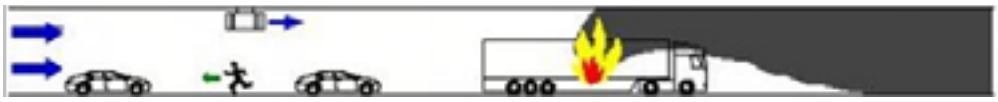
When the smoke moves from the fire, it loses its heat, gets heavier and infiltrates the lower stratum of the tunnel, making the air opaque and harder to breath.

SMOKE EXHAUST PROCESSES

Smoke exhaust processes enable to face this danger. Many criteria define how they will be carried out: length of the tunnel, traffic density, geographic location of the tunnel and whether it is unidirectional or bidirectional.

1. Longitudinal ventilation

When in normal functioning, jet fans are placed at regular intervals in the tunnel and push the air toward the exit.



Source CETU

In case of fire, the smokes are pushed toward one of the tunnel's entrance. The airstream velocity must be high enough for the smoke to de-stratify.

Source: CETU

It can be associated with massive extraction dampers. The smoke will then be extracted as close to the fire as possible. This strategy will be used depending on the following criteria:

- Tunnel length
- Unidirectional or bidirectional
- Urban or non urban
- Traffic density

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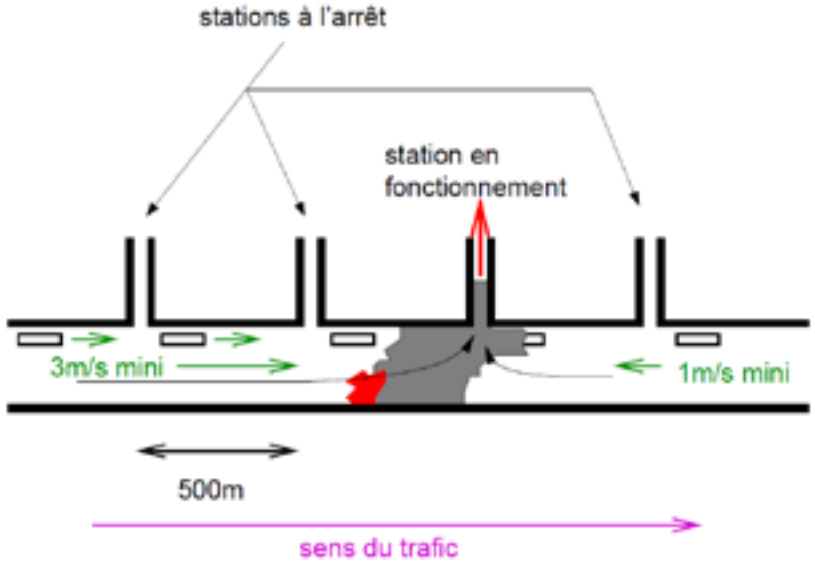


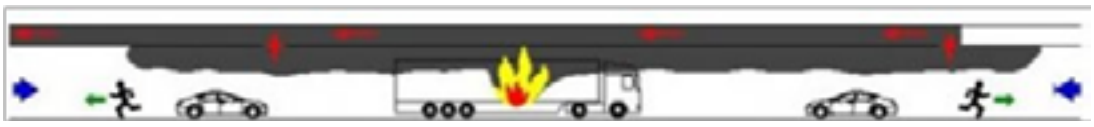
Source CETU

The air flows must be calculated based on the smokes velocity, in order to keep them stratified.

2. Transversal ventilation

When in normal functioning, it works as an air renewal system, thanks to air ducts that supply the air from an air dwell and diffuse it through dampers located on the lower part of the tunnel. The used air is extracted through horizontal dampers located on the ceiling of the tunnel.

In case of fire, the extraction fan combined with the opening of the smoke exhaust dampers as close as possible to the fire enables to extract the smoke. The purpose is to maintain the smoke in the upper part of the tunnel, so as to keep a stratum of fresh air in the lower part, thus helping the evacuation of users.



Source CETU

Smoke extraction velocity in case of transversal smoke exhaust:

Type of véhicule	Extraction velocity	Air supply velocity
Truck	1,5 to 2m/s	2 to 3m/s

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3. Equipments requirements

Smoke exhaust dampers and shutoff dampers are subjected to heavy constraints and must withstand high pressure applications (up to 10 000Pa) and high temperatures.

These products are subject to different regulations depending on the country and the clients' habits (see synthesis table below).

Specific regulations for smoke dampers depending on ventilation strategy:

Type of ventilation	Strategy	Regulation requirements for smoke dampers		
		Françaises		International and European
		Smoke exhaust damper	*Fan shutoff damper*	*Smoke exhaust and fan shutoff dampers*
Longitudinal ventilation with massive extraction dampers	Push the smokes and extract them	2000-63 Directive	400°C/2h	British Standards 476/20 et UL555S Directive 2000/54/CE
Trasnversal ventilation	Extract the smoke and supply fresh air	2000-63 Directive	400°C/2h	British Standards 476/20 and UL555S Directive 2000/54/CE

Smoke exhaust damper MRS-T

400°C / 2h

2000-63 Directive

Shutoff damper TRS

Atmosphere constraint:

Depending on the atmosphere conditions, the equipment's materials differ. The salty fog and the exhaust gas, whether it be particles, gases or aerosol, corrode the equipments thus creating a risk of them falling on the circulating way or of malfunction. It is the task of the project manager to study the traffic and atmosphere conditions of the tunnel and to choose the proper materials that will guaranty their resistance to corrosion.

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ACOUSTIC CONSTRAINTS

1. Context and problematic

Road tunnels and railway tunnels are by their design, reverberating structures. The ventilation system and the noise created by the passing cars and trains generate an emerging sound level that is a nuisance for the users.

The requirements on acoustic performances depend on the location of the tunnel.

	Urban		Non Urban	
Location of the tunnel	Outside requirements	Inside requirements	Outside requirements	Inside requirements
Sound level requirements	Emergences according to neighborhood noise regulation 2006-1099 from August 2006	Decided by the engineering Office	Decided by the engineering Office & Emergence according to the Neighborhood noise regulation	Decided by the engineering Office

The acoustic problematic in a tunnel is:

- To guaranty the safety of users, in particular by controlling the noise levels enabling them to hear an alarm in case of danger.
- To guaranty the comfort of users and the people working inside the tunnel.
- To guaranty the comfort of local residents, by controlling the outside emergences in case of an urban tunnel.

Acoustic splitter SONIE BD
400°C / 2h

2. Road an Railway tunnels

In most road and railway tunnels, no acoustic treatment is expected. Users are inside their cars which are acoustically insulated and are therefore not directly exposed to the noise produced by the ventilation system.

If the Engineering Office notices that the emerging sound levels are not within acceptable values for tunnels near inhabited areas, acoustic corrections can be applied such as acoustic walls or attenuators.

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3. Metro tunnels

Fans are mostly placed near a station in a metro tunnel, in order to ensure its ventilation. This closeness can create a nuisance for users and the people working inside the tunnel. An acoustic treatment can be applied if emerging sound levels are above the acceptable values decided by the Engineering Office.

Outside a metro tunnel, emerging sound levels induced by the equipments are regulated by the Neighborhood noise regulation, especially in urban areas.

4. Material characteristics

Depending on the acoustic requirements decided by the Engineering Office, and/or on regulation, an acoustic study will enable to determine the optimal solution to reach the objective. The most common solution is to install circular silencers or rectangular baffle's silencers.

In addition to the equipments' acoustic performances, their resistance to heat and high air velocity must also be studied.

Indeed, in case of smoke exhaust, the air velocity inside the silencer's airway can sometimes exceed 14m/s. In that case, splitters will have to be strengthened by the use of a spread metal sheet protection on both sides.

Flexible sleeves will be added to absorb part of the vibrations, therefore reducing the overall emerging sound level.

When equipments are installed on a fan withstanding a temperature of 400°C for 2 hours, splitters, silencers and flexible sleeves will also have to withstand 400°C for 2 hours.

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STANDARDS AND REGULATION

Safety in road tunnels:

2000-63 Directive

It describes the measures to be taken for sanitary ventilation and smoke exhaust in a tunnel. It recommends a heat resistance test for the smoke dampers, following an accurate protocol:

Durée	Position	T° dans le tunnel	T° dans la gaine
15 min	Ouverture	400°C	20°C
60 min	Ouverture	200°C	200°C
60 min	Ouverture	400°C	200°C

The splitters and silencers are not specifically called in the directive, but since they are located close to the fans in transversal and semi transversal ventilation, it can be considered that they have to be 200°C for 2hours resistant, or 400°C for 2hours resistant if they are located close to the smoke exhaust dampers.

http://www.vie-publique.fr/documents-vp/circulaire_25-08-2000-1.pdf

The CETU (Center of Tunnel Studies)

In 2003 they edited a ventilation file explaining the different strategies of transversal or longitudinal smoke exhaust processes. It also gives many specifications regarding the sizing of dampers or the calculation of the optimal air flow depending on the situation (sanitary or smoke exhaust ventilation)

Safety in train tunnels

Technical ministerial instruction n°98-300

It describes the measures to be taken for safety in road rails tunnels. A smoke exhaust strategy is mandatory in tunnels located in an urban area and dedicated to public transport as well as in tunnels over 5 000 m long where the transport of hazardous materials is allowed.

http://www.developpement-durable.gouv.fr/spip.php?page=article&id_article=3249

European and international regulations:

http://www.cetu.developpement-durable.gouv.fr/IMG/pdf/DP_ventilation_cle557d66-3.pdf

European Directive 2004/54/CE

It describes the measures to be taken regarding the cooperation between the different security centers of a trans-European tunnel. It also explains the necessity of installing massive extraction dampers in bidirectional trans-European tunnels

over 3 000 m long.

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:167:0039:0091:FR:PDF

World Road association

The WRA is an organization that publishes and gathers different elements regarding fire safety in tunnel throughout the world, be it on heat regulation, pressure regulation or leakage rates. Its activity is close to the CETU's and their files also contain data on sizing and calculation.

http://tunnels.piarc.org/fr/equipements-et-systemes/ventilation.htm

BS476-20

The 20th article of the British Standard applies to fire and smoke dampers. The protocol is composed of:

- An integrity test with a closed damper following the ISO 834 curve (curve T°/time)
- An fire tightness test : No flames shall go through the damper during the test
- A rod of more than 6 mm in translation of more than 250 mm through the damper shall not go through it
- A 21 mm rod shall not go through the center of the damper

UL555S

The UL555S (Underwritters Laboratories) specifically describes the necessary test on a smoke damper so that it can be used in the USA or in any other country that uses this regulation. Its requirements cover smoke dampers used in Heating, Ventilation and Air-Conditioning (HVAC). The tests are always operated on 3 dampers (max height/max width, min height/max width, max height/min width).

The tests on the smoke dampers bears on different criteria:

- Operability: 100 000 operating cycles from opened to closed via all the intermediate positions of the blades.
- Heat resistance : beginning at a temperature of 121C° with a rise of 56°C every 30minutes in closed position
- The leakage rate is measured by applying heavy water pressure (from 1.1kPa to 3.1Pa) on the damper. It is then evaluated from class 1 to 3 depending on the results.

Acoustic regulation:

Neighboring noise, 2006-1099 directive, August, 31 2006

It describes the regulations that tunnel's equipments are subject to when they are near an inhabited area. The maximum values for emerging sounds are 5dBA by day and 3dBA by night.

http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000459023&dateTexte=&categorieLien=id

F2A SOLUTIONS

Volume control damper PO

IInstalled on fresh air intake networks, its adjustable opening allows for the settings of the escape issue's overpressure.

- Operating temperature : -20°C to 80°C
- Acceptable pressure : 2 100 Pa for a length of 1 m

Smoke exhaust damper MRS-T

2000-63 directive certified

Conforme aux standards Français, extrêmement performant pour les processus de désenfumage

- Withstands high pressure, up to 6 000Pa
- Class 3 leakage rate according to EN 1751)
- MRS-T damper can be used as smoke exhaust damper in any tunnel belonging to the state

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Smoke exhaust and shutoff damper **400°C/2h**

- Withstands up to 3 000Pa
- Class 3 leakage rate according to EN 1751
- 400°/2h et 600°C/1h certified

Fire and shutoff damper **BS476 certified**
400°C/2h

Designed to withstand high thermal and pressure applications

- Withstands up to 10 000Pa
- Class 3 Leaking rate according to EN 1751
- Sized up to 2500x2500 mm in one piece
- Joints are easily replaced

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Flexible sleeve ELYFORM

400°C / 2h

Used to connect the ducts and the fan..

- Withstands up to 10 000 Pa
- Rectangular, circular or conical shape

Baffles SONIE BD

400°C/2h

Designed to reduce noise levels

- Rounded corner, reducing pressure loss by 30%
- Specific mechanical protection
- Acousticly tested in an independent laboratory

SONIE BD +

- Specific mineral wool, two times lighter than standard wool

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F2A installe les servomoteurs sur les registres en usine et travail en collaboration avec les entreprises les plus performantes du marché.

En option, les servomoteurs peuvent être livrés avec un capotage thermique

400°C/2h

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