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EXPERTS IN FLUID ENGINEERING

Smoke ventilation concepts of CEVA – an underground rail link with 4 stations

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ABSTRACT
The future rail link Cornavin-Eaux-Vives-Annemasse (CEVA) connects the Swiss to the French railway system in the urban area of Geneva. The total length of the project is approximately 16.5 km (14.7 km of which in Switzerland) and includes a single-tube, double-track 10 km long tunnel with 4 underground stations (Carouge-Bachet, Champel-Hôpital, Genève-Eaux-Vives, Chêne-Bourg) and two bridges. The CEVA project is an example of an urban-suburban, heavy-rail underground system.

For fire safety, the stations are equipped with ventilation systems. These are based on simple concepts in order to reduce the complexity and to increase the robustness of the systems. During the design phase, one- and three-dimensional numerical analyses of the ventilation concepts for each individual station were carried out in order to confirm the required performance during an emergency.

The paper focuses on both, the main fire safety objectives and the concept for smoke control in the stations. Fulfilment of design objectives is shown by results from CFD-simulations. The ventilation concepts of CEVA are compared to other contemporary projects with stations of similar size in Switzerland and Europe.

1 INTRODUCTION

Fire safety guidelines for road tunnels have reached a high level of detail and exhibit a substantial degree of international harmonisation. In contrast, the fire safety requirements for rail tunnels and under-ground systems are limited to more basic requirements (e.g. TSI (1)) which can be explained partly by the less frequent number of fire incidents. Comparing various similar underground rail projects in Europe, they are less uniform with respect to fire safety measures. The standards for smoke control of underground rail systems, for example, might vary even within a country from project to project.

Even though fires in rail and metro tunnels are rare, reasonable design objectives with respect to fire safety need to be defined, harmonised among the various parties, mutually accepted and implemented. As one approach to fire safety, the "state-of-the-art" can be taken as design basis and as reference for requirements specified by the safety authority. Therefore, it is of interest, which measures are taken to assure fire safety in contemporary underground rail systems.

Different classes of underground rail systems for passenger transportation can be distinguished (rail systems = rail and fixed guideway systems). In a simplified manner, they can be classified according to Table 1.

Table 1. Principal classes of underground rail systems

System	Typical features with relevance for ventilation
people mover systems	short stations (L < 50 m); short distance between stations (some 100 m); 1 – 2 tracks; new systems mostly equipped with full-height platform screen-doors
light rail / metro	short stations (L < 100 m); short distance between stations (some 100 m); 2 tracks; new systems often equipped with full-height platform screen-doors
heavy-duty rail / metro	medium-length stations (100 < L < 200 m); short distance between stations (several 100 m); 2 tracks; new systems often equipped with full-height platform screen-doors
urban-suburban railway / heav yrail	long stations (200 < L < 400 m); medium distance between stations (more than 1 km); 2 tracks or more; new systems occasionally equipped with full-height platform screen-doors
high-speed / heavy long distance railway with underground terminals	single station with length of more than 400 m; long adjacent tunnels (up to several km); often more than 2 tracks; new systems rarely equipped with full-height platform screen-doors

Various further features and several combinations of features could be taken to classify underground rail systems. However, with respect to ventilation and with respect to fire life safety, the above scheme leads to distinctive differences of the required handling of smoke in a station and in adjacent tunnels.

The future rail link Cornavin-Eaux-Vives-Annemasse (CEVA) shall serve as an example of the approach taken in Switzerland for an "urban-suburban railway" system. It is of interest, which ventilation measures are taken to assure fire safety. Examples of other Swiss or European projects are given to highlight differences and alternatives. The CEVA project connects Switzerland and France in the urban area of Geneva. The project includes several tunnels with a total length of about 10 km and 4 underground stations (Carouge-Bachet, Champel-Hôpital, Eaux-Vives, Chêne-Bourg). The CEVA project is characterized by long stations of limited width (empty station box at platform level 200 to 300 m long, 14 to 20 m wide, more than 6 m high). The adjacent double-track, single-tube tunnel sections are up to 2.5 km long. Commissioning is expected for 2017.

2 OBJECTIVES OF PAPER

The paper shall address the following objectives:

1. The methodology to establish the ventilation concept including criteria for ventilation design for the CEVA project shall be specified.
2. Numerical studies confirming achievement of design objectives shall be presented.
3. The ventilation concept shall be compared to similar Swiss and European projects.

3 METHODOLOGY FOR VENTILATION CONCEPT SPECIFICATION

3.1 Focus of measures on smoke control in stations

Passengers and staff in underground systems might be endangered by different incidents (e.g. derailment, collision with obstacle and/or other trains, train fire and stop in station or in tunnel, cable fires, and fire of elevators, in technical rooms or in station shops, collapse of infrastructure, overcrowding, explosions, and terror). Train fires are considered to be the main risk in rail tunnels compared to all other incidents mentioned above since they may lead to a significant release of heat and smoke. Consequently, in state-of-the-art underground systems, it is required to reduce the probability of fires occurring on trains and to limit the harmful consequences of them. These measures of prevention and mitigation of the consequences of incidents shall address infrastructure, rolling stock, operation and organisation.

Measures shall provide a sufficient level of safety based on a “reasonable worst case” scenario and appropriate design objectives. “Absolute safety” can not be achieved, particularly, considering the possibility of human error. It is required to focus on the most probable incidents. An analysis for the existing German underground network built according (2) came to the conclusion that scenarios of a burning train reaching the next station should be considered as standard fire scenario (4). The measures to cope with the scenario of a train on fire in a station, allow to address other risks associated with stations as well (e.g. cable fires, fire in technical rooms).

Another conclusion of (4) was that a burning train stopping in a tunnel section, i.e. in the tunnel section between portals and/or stations, is significantly less probable and, therefore, can be ignored with respect to requiring active measure to maintain tenable air conditions for escape. The latter is based on the assumptions that passive measures such as sidewalks, emergency exits and escape possibilities at a maximum walking distance of 300 m, etc. are provided according to German guideline BoStrab (2). The approach to neglect scenarios with trains on fire stranded in a tunnel section can be supported by the following points:

- The procedures dictate for rail and metro trains to continue out of the tunnel or to move into the nearest station should a fire or other incidents occur.
- Trains will not stop in the tunnel even if the emergency brake is activated.
- Stations are better suited for evacuation of large numbers of passengers and the application of a smoke control system is better suited for the finite station space.

The approach of ignoring a burning train stopping in a tunnel section with respect to maintaining tenable air conditions differs from the American norm NFPA 130 (3). In (3) it is stated, for example, that any tunnel section with a length of more than 305 m shall be provided with mechanical emergency ventilation system.

In summary, a train on fire stopped in a station needs to be considered with respect to maintaining tenable conditions during the phases of self-rescue and intervention by fire and rescue services. For this scenario, a realistic course of events needs to be defined including the following major time steps:

1. Start of fire on train
2. Detection of fire by sensors, staff or passenger
3. Confirmed alarm
4. Start of fire fighting systems on train – if any
5. Start of ventilation measures (active, passive; on-board and of infrastructure)
6. Arrival of train at station
7. Start of self-rescue phase, i.e. evacuation of passengers/staff from train and platform
8. End of self-rescue phase

9. Start of intervention phase by arrival of rescue and fire services on platform
10. End of intervention phase

3.2 Balance of time for self-rescue and for proper smoke control

A principal element of the approach taken in (4) and for the CEVA project is the balancing of the time for self-rescue and the time for sufficient control of smoke. This approach allows reaching a certain level of safety with different safety measures. The requirements regarding rescue time and time of acceptable smoke control are adjusted according to Figure 1.

Figure 1. Balance between time for self-rescue and time for proper control of smoke

The main objective of this approach is to assure a tenable environment in the station during the phase of self-rescue. Additionally, acceptable conditions for rescue and fire services are to be provided. Figure 1 illustrates that measures for improvement of self-evacuation (e.g. wider, more stairs) reduce the required efforts for smoke control (e.g. powerful ventilation, smoke barriers). Vice-versa, a better smoke control allows accepting a longer phase of evacuation. In order to improve fire safety, resources may be invested in improved measures for evacuation or in a better control of smoke. The approach allows an economical optimisation to achieve a certain level of safety.

3.3 Specification of quantitative objectives for self-rescue measures

The principal objective is to provide a tenable environment in the station for the phase of self-rescue. This requires calculating the time period for self-rescue, which is required to move all staff and passengers to a safe place. This task can be achieved by applying correlations of, for example, by NFPA 130 (3) or by utilizing appropriate simulation tools. This aspect is not in the focus of the paper at hand.

3.4 Specification of quantitative objectives for smoke control measures

The fire of a rail vehicle will release smoke according to the specifications of the design fire. From the fire location the smoke will rise and spread along the ceiling of the station box. If flow disturbances are limited and if openings, shafts, etc. are absent, the smoke will accumulate below the ceiling and concentrate in a layer of hot gases. This layer of smoke is characterized by high temperature, low visibility, high concentration of carbon-monoxide and carbon-dioxide, etc. Below this layer a zone of colder and non-life-threatening air might remain for an extended period of time ("smoke-free layer"). In a simplified manner, it may be assumed that for most of the fire incidents, these two gas layers will built-up above the platform during the initial phase of a train fire, i.e. a smoke layer at the top and a smoke-free layer at the bottom (Figure 2).

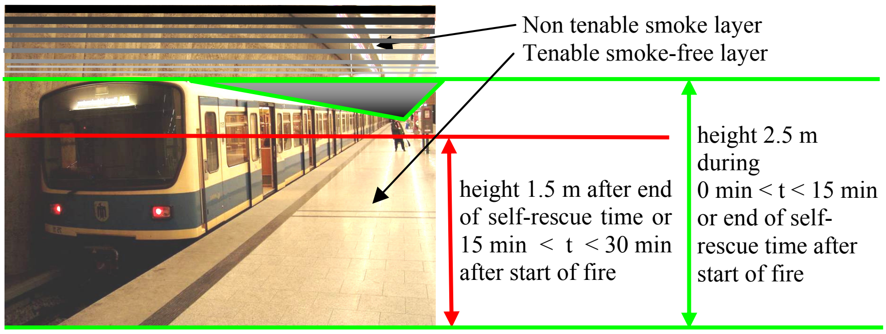

Figure 2. Objectives for maintaining a smoke-free layer above platform

In the layer with highly concentrated smoke at the ceiling, people can not survive. A tenable, smoke-free layer of minimum height and sufficient air quality is required. According to (4), this layer for the phase of self-rescue and the later phase of intervention by rescue and fire services is characterized by:

- the height of the smoke-free layer as illustrated in Figure 2
- the further features according to Table 2 (including some differences between (4) and design basis for CEVA project)

Ideally, all the passengers should be able to self-evacuate to a safe area during the self-rescue phase, if this is not possible (e.g.: passengers with reduced mobility, panic behaviour, etc.) they will be brought in safe by the rescue team during the intervention phase.

Table 2. Tenability criteria for a smoke-free layer along the station platform

Aspect	**Self-rescue phase**	**Intervention phase**
Duration	0 min < t < 15 min after start of fire or end of self-rescue	15 min < t < 30 min after start of fire or end of self-rescue
Height above platform	$H \geq 2.5$ m *(CEVA: $H \geq 3.0$ m)*	$H \geq 1.5$ m
Visibility	*(CEVA: $S \geq 20$ m)* $S \geq 10$ m[1]	*(CEVA: $S \geq 10$ m)*
Temperature	*(CEVA: $T \leq 40$ °C)* $T \leq 50$ °C	*(CEVA: $T \leq 60$ °C)*
Concentration	$C_{CO2} \leq 1$ Vol.-% / $C_{CO} \leq 500$ ppm / *Not used for CEVA*	

Typically, the visibility is the most critical parameter, i.e. the analysis of visibility leads to the largest extension of the hazardous smoke layer. Inversely, analysing visibility leads to the lowest smoke-free layer above the platform. Typically, if a sufficient visibility is maintained, the toxic or thermal conditions are acceptable as well. In addition to the above specifications regarding the platform, further requirements need to be fulfilled for other spaces (stairs, emergency exits, mezzanine level, etc.). However, these are out of focus of this paper.

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[1] $S \geq 10$ m = optical density of 0.13 m^{-1} in 40 lx illuminance

3.5 Specification of a design fire in general and for CEVA project

For the analysis of the escape and rescue conditions, it is essential that a fire model is defined. The temporal development of the release rate of heat, soot, gases, etc. is required in order to simulate the propagation of smoke and the resulting visibility, temperature, etc. on the platform and along the egress path. The characteristics of the design fire might vary, i.e. the relation between releases of soot, of heat, of harmful gases, etc. might be different from fire to fire.

The design fire for the CEVA project is defined by its heat release rate (HRR) and the rate of combustion as indicated in Figure 3. This design fire is the same as chosen by the Swiss Federal Railway for long tunnel projects crossing the alps (AlpTransit) and is based on the EUREKA F-11 test, see (8).

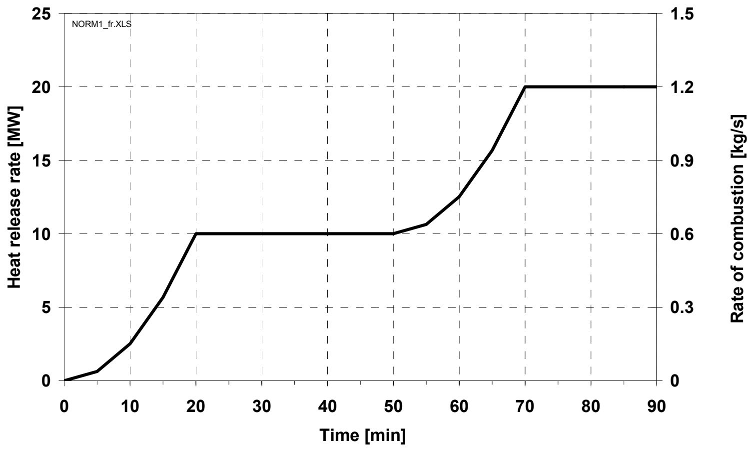


Figure 3. Design fire of CEVA project

3.6 Methods to balance measures of smoke control and times of evacuation

To limit the consequences of fire incidents in underground stations, the following measures need to be considered:

- Reliable and early detection of fire
- Early activation of fire suppression or deluge systems – if any
- Efficient smoke control along trackway and platform by passive (e.g. smoke barriers, shafts, platform screen doors) or active measures (e.g. ventilation)
- Passive or active ventilation of emergency exits and rescue path
- Rapid self-rescue and evacuation of people to a safe location by support through
  - egress ways
  - lighting
  - signage
  - communication and alarm system
- Traffic monitoring equipment
- Power supply
- Fire suppression and extinction of fire

During the design process of a station, the above objectives for smoke removal need to be verified by numerical analysis. Three-dimensional, CFD-analysis (computational fluid dynamics) is required to investigate the smoke stratification and propagation in a station and to confirm the objectives for a tenable, low-smoke layer along the platform of the station.

3.7 Summary of methodology

The approach taken for the CEVA project is summarized in Figure 4.

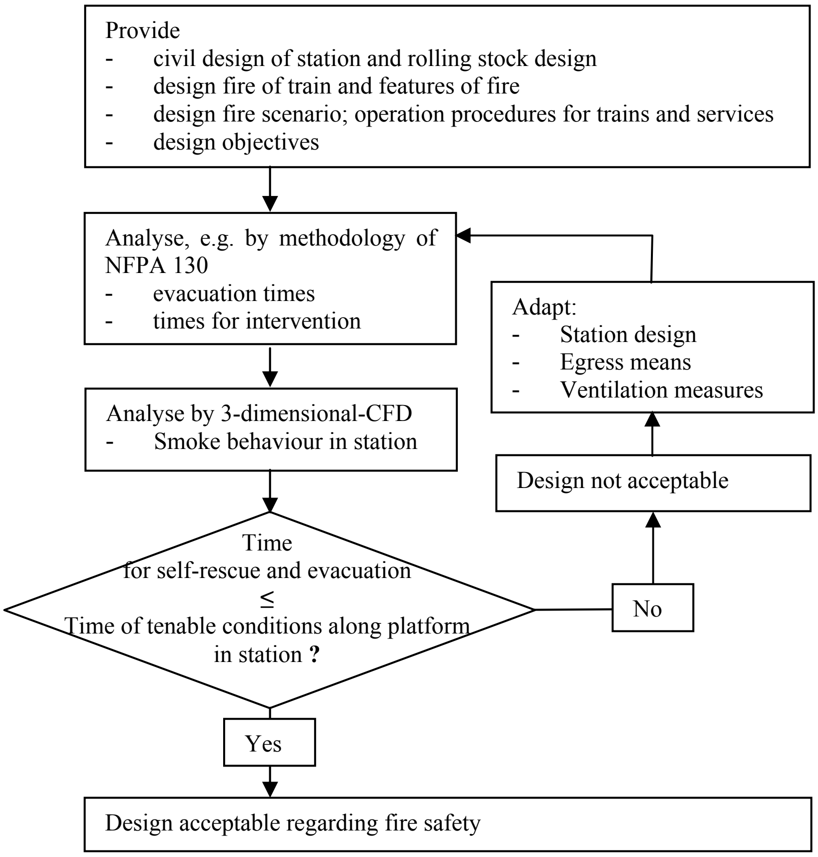


Figure 4. Methodology for analysis of scenarios and functional objectives as basis for the design of fire safety measures for underground systems

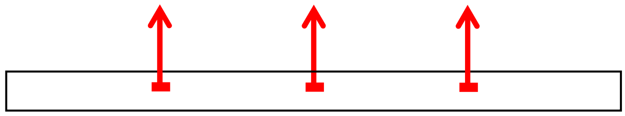
4 VENTILATION CONCEPTS FOR RAIL STATIONS

With respect to measures of “smoke control” of underground rail stations, the following principle passive or active measures can be employed:

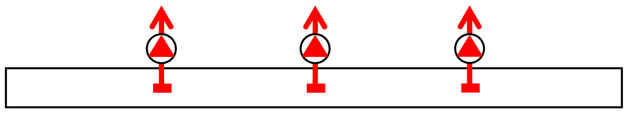
- Limitation of smoke propagation by smoke curtains, barriers, doors
- Limitation of smoke propagation by ventilation of corridors and platforms
- Increase of “storage volume” for smoke by high ceiling of stations
- Passive smoke removal by smoke extraction shafts / openings in ceiling
- Active smoke removal by mechanical ventilation

Examples of principal methods of smoke extraction from underground rail stations by passive or active mechanical ventilation are sketched in Figure 5. Possibilities to exhaust smoke from trackway at platform level are shown.

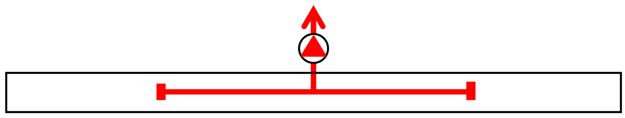
a) Single or more passive exhaust points by shafts and openings to ambient



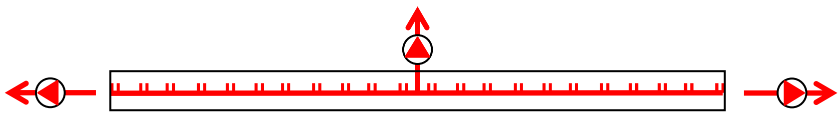
b) Single or more exhaust points of mechanical ventilation with independent fan stations and simultaneous operation of fans



c) Double or more exhaust points; mostly one for a certain station section; one open at a time; exhaust by mechanical ventilation



d) Multiple exhaust points and even exhaust rate along station; openings open all time; exhaust by mechanical ventilation in middle of station (or alternatively at station ends)



e) Selected local exhaust points; only openings near fire open; exhaust by mechanical ventilation in the middle of station (or alternatively at station ends)

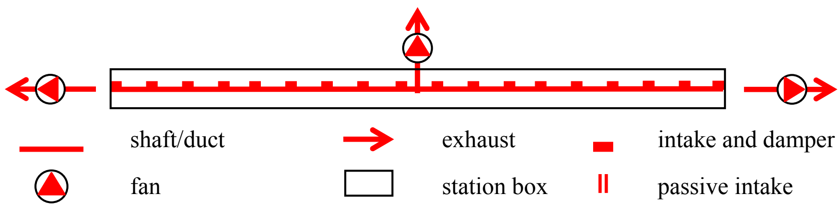


Figure 5. **Typical measures for smoke removal from underground station box; exhaust from trackway at platform level**

5 VENTILATION CONCEPT FOR CEVA

The CEVA project is an example of an “urban-suburban railway” link. Stations are up to 300 m long and the distance between stations is typically between 1 km and 2 km. The stations have 2 tracks and side or island platforms. Along the platforms, there are 2 or more stairwells at each platform. There are no platform screen doors along the platforms.

Adjacent tunnels have a large free cross-sectional area of about 62 to 74 m^2 which is due to the twin-track system with overtrack catenary system with sidewalks on both sides. Emergency exits are provided along the tunnel sections in order to limit the distance to the next exit, portal or station to less than 500 m. In one tunnel section, the maximum distance to the next exit, portal or station is about 640 m.

Rolling stock is characterized by a length of up to 300 m with partly double-deck trains. Various types of rolling stock lead to inhomogeneous features of trains.

Figure 6 shows the principle ventilation concepts for smoke extraction at CEVA. Smoke released from train fires is extracted simultaneously at few selected locations. There is no system to locate the exact fire position. No ductwork is required along the station platform. Both, natural, buoyancy driven (Chêne-Bourg) and mechanical ventilation (Carouge-Bachet, Champel-Hôpital, Genève-Eaux-Vives) are applied.

Compared to light rail / metro systems according to Table 1, the CEVA stations or the stations of urban-suburban railways are longer, higher and slightly wider at trackway level. For such stations, the concepts according Figure 6 appear to be most appropriate as will be shown later. Concepts a) and b) of Figure 5 were chosen.

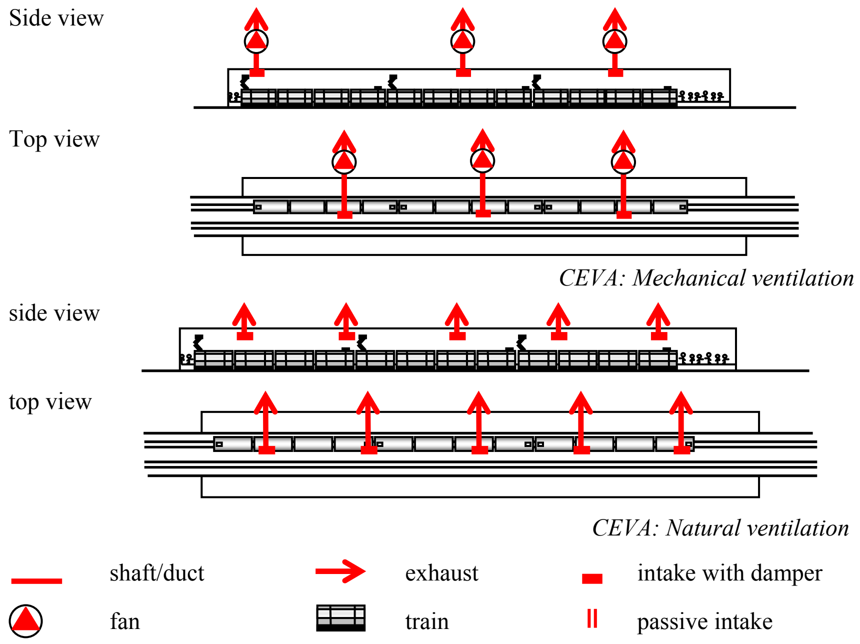


Figure 6. Principal concepts chosen for ventilation of stations of CEVA project corresponding to types a) and b) of Figure 5

An alternative concept would have been to provide ducts with distributed openings and dampers along the platforms and to extract smoke only in the vicinity of the fire. This approach has been chosen for another current Swiss underground project, i.e. the station of the City Link Zurich (Durchmesserlinie DML). Due to 4 tracks rather than 2, the DML station is more than twice as wide as the CEVA stations. The station is also longer than the station of the CEVA project. The ventilation concept of DML is sketched in Figure 7.

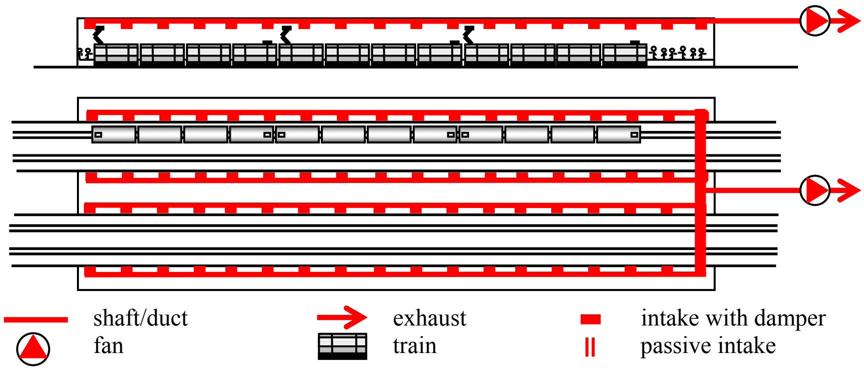


Figure 7. Possible alternative concept for ventilation of stations of CEVA as chosen and illustrated for underground station of Zurich City Link (Durchmesserlinie; two island platforms and 4 tracks)

Smoke/air is extracted only in the vicinity of the fire by opening of few selected dampers. A detection system is required to locate the exact fire position within the station. Ductwork is provided along the station platforms to carry away the smoke to a station end. Due to space limitations, there is no possibility to carry away the smoke on top of the station. The ventilation concepts of the CEVA and the Zurich City Link project (Durchmesserlinie, DML) exhibit the advantages and disadvantages as given in Table 3.

Table 3. Advantage and disadvantages of station ventilation concept of CEVA and alternative concept of Zurich City Link

CEVA	**Zurich City Link**
- 4 underground stations - 2 tracks and island / side platforms - Typical length of station about 200 m (1 of 300 m length) - 10 km of adjacent tunnels with ventilation of emergency exits only - Single or more exhaust points for passive/mechanical ventilation (a/b)	- 1 underground station - 4 station tracks with 2 island platforms - Length of station about 400 m - 5 km of tunnels with ventilation of parallel emergency gallery only - Selected local exhaust points open near fire; exhaust by mechanical ventilation at one station end (e)
Advantages - No ductwork and no dampers for local smoke/air extraction - More architectural freedom - Less fan power due to missing ducts - No system to localise smoke source - Ventilation control of low complexity, i.e. more reliable in principle ("On/Off only") - Handling of multiple fire locations - Less maintenance for equipment	***Advantages*** - Low flow rate / high efficiency due to exhaust at fire location only - Less number of fans and reduced space and maintenance work for fans - Air flow direction towards incident location only - No particular space requirements for shafts and fan stations above platform level
Disadvantages	***Disadvantages***

CEVA	Zurich City Link
- Large flow rates and fan capacity to be provided due to intake of false air - More power due to simultaneous operation of fans - Possibly zones of stagnant air/smoke - More maintenance for more fans - Space required above trackway level	- Long ductwork and dampers required - Substantial power requirements for fans due to long ducts and resulting pressure losses - Smoke detection system - More complex ventilation control and risk of malfunctioning - Handling of multiple fire locations

As shown in Table 3, distinct differences are noted for the different projects. For the CEVA project it appeared reasonable to have simple systems with powerful fans for smoke exhaust (no ducts and dampers, no detection system for detailed fire localisation). For the DML project with its longer and wider station, a ventilation system became necessary which allows smoke extraction in the vicinity of the fire. Compared to the CEVA project, the installed fan capacity is smaller for the DML project but more extensive ductwork and dampers became necessary. A fire detection system to precisely localise the fire became compulsory.

Table 4 gives further examples of similar European projects which have been recently opened or are under construction. The examples show that depending on the various boundary conditions of a project, different ventilation concepts result.

Table 4. Examples of similar European projects with underground stations of urban-suburban railway

Similar projects	Key data	Ventilation type (Figure 5)
CEVA, Geneva, Switzerland	4 underground stations 2 station tracks 1 platform Opening expected for 2017	a)/b) Single or more exhaust points for passive and mechanical ventilation; smoke exhaust rate of fans from 150 to 300 m^3/s per station; no dedicated tunnel ventilation (except French section)
City Link, Zurich, Switzerland (Durchmesserlinie)	1 underground station 4 station tracks 2 platforms Opening expected for 2015	e) Selected local exhaust points; openings open near fire; exhaust by mechanical ventilation in the middle of station (or alternatively at station ends); smoke exhaust rate up to 200 m^3/s; no ventilation of rail tunnel but of safety and rescue tunnel
Station Museumsstrasse, Zurich, Switzerland	1 underground station 4 station tracks 2 platforms In operation since 1991	b) Single exhaust point for mechanical ventilation; smoke exhaust rate up to 75 m^3/s; longitudinal ventilation of tunnel
Airport station Zurich, Switzerland	1 underground station 4 station tracks 2 platforms In operation since 1980	a) 2 exhaust points at station ends for passive ventilation; smoke exhaust rate depending on thermal draft; no tunnel ventilation

Similar projects	Key data	Ventilation type (Figure 5)
Underground station at Brussels airport Zaventem, Belgium	1 underground station 3 tracks 2 platforms In operation since 1994 and extension expected for 2012	e) Selected local exhaust points; openings open near fire; smoke exhaust rate up to 100 m^3/s; longitudinal ventilation of tunnel
Citybanan, Stockholm, Sweden	2 underground station 2 / 4 tracks 1 / 2 platforms Opening expected for 2017	e) Selected local exhaust points; openings open near fire; smoke exhaust rate up to 225 m^3/s; longitudinal ventilation of tunnel possible (jet fans); exhaust ventilation at particular tunnel junction
Citytunnel Leipzig, Germany	4 underground stations 2 tracks 1 platform Opening expected for 2013	a) Exhaust points for passive ventilation; smoke exhaust rate depending on thermal draft; no tunnel ventilation

Corresponding to the methodology as given in Chap. 3.1 and in accordance with (4), no particular ventilation measures were foreseen for the tunnel sections of the CEVA project. At a later phase of the project, it was investigated to which extend the already planned measures for smoke control at station could be useful for smoke control during train fires in the tunnel sections as well and it was decided not to use the station ventilation system in case of fire incidents in tunnel.

6 NUMERICAL CONFIRMATION OF PERFORMANCE

6.1 Mechanical ventilation concept

The ventilation concept as illustrated in Figure 6 has been implemented, for example in the station Champel-Hôpital. At this station, 3 exhaust points with flow rates of 75 to 150 m^3/s each are implemented. Figure 8 shows a side view of the platform level, the train position and the 3 exhaust points.

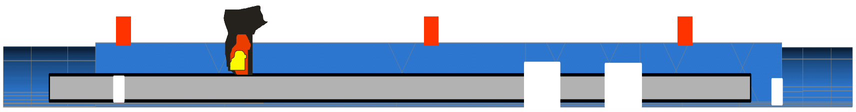
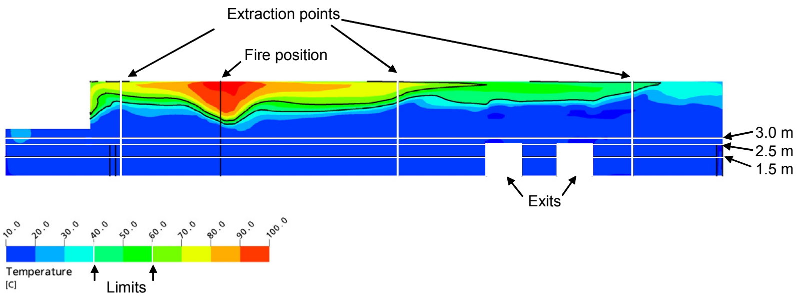


Figure 8. Side view of station Champel-Hôpital along centerline of trackway (grey: train; white: exits towards mezzanine level; red: smoke extraction points)

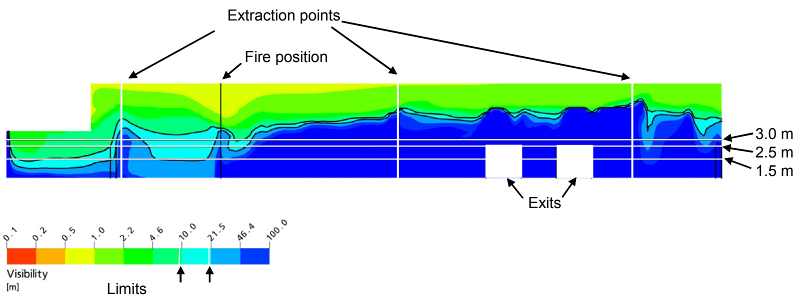
The required flow rate of smoke extraction was determined by 1D-simulations, considering different reasonable worst cases for the ventilation system. Later, 3D-simlations were used to verify the fulfilment of design objectives by the ventilation system regarding the smoke-free layer along the station platform as given in Table 2.
THERMOTUN was used for 1D-analysis (www.thermotun.com, see also (7)), CFX was employed for 3D-simlations (www.ansys.com).

Figure 9 shows a side view of temperature and of the visibility distribution at platform level close to the fire position after 45 min after start of fire, i.e. after the phase of intervention by rescue and fire services. The heat release rate of the fire has reached 10 MW (see Chapter 3.5).

An analysis of the temperature and of the visibility distribution shows that:
- the visibility is effectively the most critical parameter
- the tenable, low concentration smoke layer extends up to 3 m above the platform with the exception of the region close to the fire position



Temperature



Visibility

Figure 9. Temperature and visibility in a side view along the platform

6.2 Natural ventilation concept

The ventilation concept illustrated in Figure 6 has been implemented e.g. in the Chêne-Bourg station. The near-surface location of the station and the cut-and-cover construction method allowed for implementing a natural ventilation system with shafts. Figure 10 shows a side view of its platform level, the train position and the several chimney openings.
The fulfilment of the requirements for the smoke-free layer along the station platform as defined in Table 2 for reasonable worst cases was verified by means of 3D-simlations.
Figure 11 shows a side view of temperature and of the visibility distribution at the platform close to the fire position after 45 min, i.e. after the later phase of intervention by rescue and fire services. The heat release rate of the fire has reached 10 MW (see Chapter 3.5).

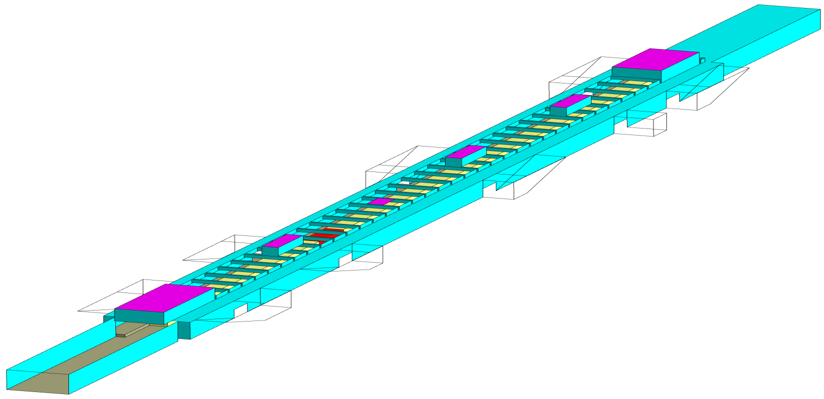
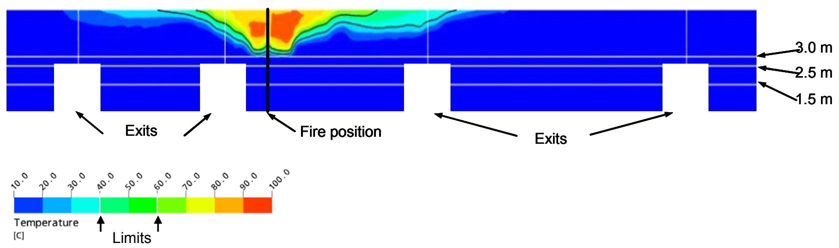
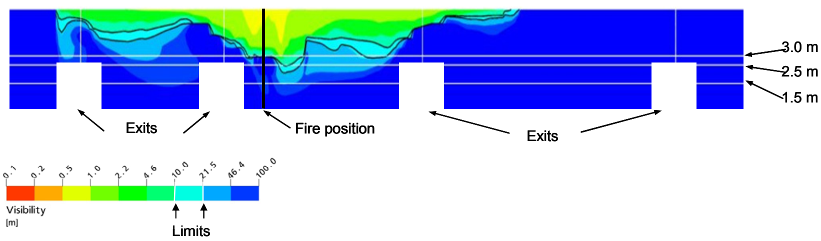


Figure 10. 3D view of Champel-Hôpital station (grey: train; white: exits towards mezzanine level; red: chimney openings)



Temperature



Visibility

Figure 11. Temperature and visibility in a side view along the platform

An analysis of the temperature and of the visibility distribution shows that:

- the visibility is the most critical parameter
- the tenable, smoke-free layer extends well above the 3 m above the platform line defined in Table 2.

7 CONCLUSIONS AND RECOMMENDATION

The various features of underground stations, tunnels, rolling stock and their operation determine the required ventilation system of an underground rail system. Together with further boundary conditions and design objectives they lead to a wide range of implemented ventilation concepts to assure fire safety.

Functional fire safety requirements are well suited to allow for the most economical design to achieve a specified safety level. For achievement of the required fire safety, the preventive and mitigating measures should be balanced appropriately. Based on functional requirements, measures to mitigate the consequences of a fire can be focussed on either improvement of means of self-rescue or improved smoke control and removal. Particularly for underground systems with short inter-station distances it might be reasonable to focus measures for mitigating the consequences of train fires on the station boxes only, i.e. no assurance of tenable conditions for trains on fire in a tunnel.

In general, large stations in terms of width and length (not in height) are to be equipped preferably with ventilation systems with smoke extraction focussing on the immediate vicinity of a fire location. Smoke extraction in the vicinity of the fire increases the efficiency of the ventilation (i.e. less excess air), however, requires more complex equipment (ductwork, dampers, sensing devices, control system, more powerful fans) and leads to higher pressure losses. For small stations in terms of width and length, simple single-point extraction without major ductwork tends to be more favourable.

8 ACKNOWLEDGEMENT

We like to thank Mr. Eric Canivet from Swiss Federal Railways for the support and permission to publish results from the ventilation analysis of the CEVA project.

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