SMOKE AND HEAT EXHAUST SYSTEM FOR METRO SYSTEMS
NOVENCO GENERAL GUIDELINES AND RECOMMENDATIONS

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1. INTRODUCTION

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.

One of the most important safety installations in a subway system is the smoke and heat exhaust system in case of a fire. The goal of the smoke and heat exhaust systems for subways is to extract heat and smoke from the fire compartment in case of a fire and to improve the evacuation conditions for the subway passengers. In this paper the ventilation methodology in case of a subway fire in an underground station is discussed.

2. DESIGN REQUIREMENTS

1) The stations and tunnelparts must have a smoke and heat exhaust system with a capacity which is sufficient to ensure that the public space can be used for safe escape during the calculated evacuation time (minimal 15 min).

2) Furthermore the smoke and heat exhaust system should be designed with a capacity which is sufficient to ensure that the stations and tunnelparts can be used for resque- and firefighting purposes after the evacuation.

3) The smoke and heat exhaust system must comply with the requirements as set out in the EN 12101 - Smoke and heat control systems:
   a. EN 12101 part 1 : Specification for smoke barriers
   b. EN 12101 part 3 : Specification for powered smoke and heat control ventilators
   c. EN 12101 part 7 : Smoke ducts
   d. EN 12101 part 8 : Specification for smoke control dampers
   e. EN 12101 part 9 : Control panels

4) The smoke screens must be at least 0,5 m underneath the maximum smoke buffer height underneath the ceiling.

5) The design fire for the ventilation calculations for smoke and heat exhaust is 20 MW, based on the fire in one metro unit.

6) The design of the smoke and heat exhaust systems must be verified by CFD simulations (Computational Fluid Dynamics). Criteria are heat flux, temperature and sight length.

7) The smoke exhaust fans must be able to withstand at least 300°C during 1 hour. This equals class F300 in accordance with the EN 12101 part 3.

8) The smoke screens must be able to withstand 300°C during 1 hour.

9) Smoke ducts and dampers must have at least the same temperature resistance as the exhaust fans. However, higher temperatures at smoke inlets have to be taken into account.

10) The power supply for the mechanical smoke and heat exhaust system must be guaranteed during a fire situation for at least 1 hour.

11) The mechanical smoke and heat exhaust system must be activated by an automatic fire detection system.

12) The mechanical smoke and heat exhaust system must be fully operational within 60 seconds after detection.

3. SAFE HAVEN SAFETY CONCEPT

The "safe haven" concept is part of an integrated safety approach for underground metrolines. The functional fire safety design for the stations should be an essential topic. The depth of the (multi level) platforms and spatial constraints demand a solution whereby safe evacuation is supported by escalators and emergency ventilation systems.

The leading principle for this integrated safety approach, is the "safe haven" concept. There should be strict safety requirements formulated for exploitation, such as that trains should not depart before the tunneltrack to the next station is free. This principle is already established in (concept) Dutch-regulations.

The "safe haven" principle can be integrated by:

a. Operation: maximum effort to ensure (incident) trains will reach the station. The ATO (automatic train operating) system will ensure a fixed minimum interval in between the trains to ensure that the train will only depart as the track ahead is free and the next station can be reached with no delay.
b. Rolling stock: the latest technologies in rolling stock provide open gangway trains with multiple doors (1,3 m width) on each side per trainsection. With this configuration the dwelling and evacuation time at the stations will be reduced, as an even distribution inside can be reached by people walking along the train. The applicable European fire safety standards (DIN 5510 brandschutsstufe 3, NFF16-101 + 16-102 catégorie A1 and prEN45545 class 2) should be prescribed and fire barriers and detection in undercar sections and Passenger Emergency communication should be part of the requirements.
c. The train station: a safe haven. As the incident trains will always be directed to the stations the stations must be designed as Safe Havens. At these locations a rapid, safe and reliable evacuation shall be supported to streetlevel.

In the principle of (self) rescue the Safe Haven principle takes a central role. This corresponds to an intrinsic property of the metro system: stations are designed for the rapid transfer of large numbers of people.

The safe haven principle means that a calamity is handled in a safe place. This can vary from system to system. With metro tunnels a distinction is made between two situations:
- At underground parts without stations the safe haven is outside of the tunnel.
- Underground all platforms and stations are safe havens

The idea of self rescue is that the passengers will be much faster in the safe haven in case of an evacuation in the station compared to an evacuation inside the tunnel tube.

The critical (worst) case is the case of a stationairy train burning inside the tunnel tube. This means that a train stopped in the tunnel and it also caught fire.

Therefore there are two groups of possible measures to prevent this case from happening:

1. Preventing the occurrence of a fire and spread of fire inside the train
2. Prevent the train from stopping between two stations

The implementation of the Safe Haven principle is based primarily on the establishment of the safe havens, the railway stations. These must be organized and equipped so that in case of an emergency, a train can be efficiently evacuated and emergency services can effectively fight the calamity.

Secondly, the demands on the rolling stock; the train. That would include the choice of fire resistant and low-toxic materials and measures for fire spread between the trains compartments to slow down.

Besides the safe haven principle, there should also be a fire safety concept in case the safe haven principle fails. The essential question then is to what provisions should be made in between the safe havens in case the evacuation has to be performed from a burning train inside the tunnel.

Therefore it is also advised that in case of distances between the underground stations of more than 1km some sort of mechanical (reversible) smoke and heat ventilation should be available in the tunnel tube.

4. GENERAL SAFE HAVEN VENTILATION PRINCIPLE

The smoke and heat exhaust system for the safe haven principle utilizes smoke screens to prevent the spread of smoke and heat. With the smoke screens, the station is divided in multiple compartments. By using the smoke screens, the spread of smoke and heat along the ceiling is delayed. Each compartment is equipped with mechanical smoke exhaust units, to delay the filling of the compartment buffer with smoke and to delay the spread of smoke underneath the smoke screens to the next compartment. This provides the passengers inside the station with more time to evacuate. The locations of the smoke screens and capacity of the mechanical smoke exhaust units have been selected on the basis that the available evacuation time sufficient.

Depending on the length of the platform, the platform is divided into a number of sections by lowering smoke screens. A starting point is that in all sections the exhaust ventilation immediately is started at 100%. This to make sure that the smoke is always exhausted on the shortest route and the smoke does not have to travel over bigger distances over the platform. When the smoke has to travel over a bigger distance, the danger exists that due to mixing with cold air and heat exchange with colder element the smoke is cooled down too much. Cooled down smoke will descend and can block the evacuation ways for the passengers. This is especially the case for smaller capacity fires, of which the risk of happening is the highest.

The stairs and interlevel platforms have to be kept free from smoke and therefore the supply air is drawn through these spaces and openings. To create sufficient underpressure inside the tunnel / ends of the platforms further dampers for the pressure relieve openings inside the tunnels and smoke exhaust systems in other stations may have to be controlled simultaneously.

The activation of the smoke and heat exhaust system will be triggered through an automatic fire detection system on the platforms. Furthermore it can also be triggered from a general calamity switch on the fire brigade panel.

5. MECHANICAL SMOKE AND HEAT CONTROL SYSTEM

From the smoke extract points at the ceiling of the station, the smoke and heat must be transported through a fire resistant duct to a smoke extract fan with sufficient capacity and high temperature rating to ensure the functionality of the smoke control system during the evacuation period and beyond.

To create sufficient underpressure inside the tunnel tubes and at the station, the pressure relieve openings inside the tunnel tubes should be closed with fire resistant dampers. This to make sure that the air intake is over the tunnel tubes and from the floor level through the intermediate levels and staircases / escalators to the fire compartment.

The main components for the heat and smoke exhaust system are:

- mechanical smoke exhaust fans in the ceilings of the underground metro stations;
- smoke exhaust ducts which are connected to the smoke exhaust fans;
- smoke screens, to keep the smoke in pre-defined smoke compartments;
- smoke dampers, to prevent a shortcut of air intake;
- smoke and fire detection system;
- local control panels to control the fans, dampers and smoke screens.

The functionality of the applied products should be guaranteed and ensured by:

- pressure drop calculations for the smoke ventilation system
- strength and fatique calculations of materials used
- FAT (Factory Acceptance Tests) of the local control panels, smoke exhaust fans, smoke dampers, smoke screens and ductwork.
- SAT (Site Acceptance Tests) of all components of the smoke and heat exhaust system.
- IAT (Integration Acceptance Tests) functional acceptance of the smoke and heat exhaust system as a whole.
- Certification of all used products and systems according to the relevant standards.