Tunnel Incident Management in Frankfurt am Main - Operational Smoke Management -

Prof. Reinhard Ries
Fire Department of the city of Frankfurt am Main,
Germany

INTRODUCTION

The city of Frankfurt am Main

City data

The city of Frankfurt am Main is located in the heart of Europe. The urban area covers a surface of 248 km² (95 mi²). The city's original population ranges around 655.000 people. In addition to that, more than 360.000 commuters enter the city every day, so that in day times there are more than 1.000.000 people in town. This is the largest number of commuters a city has in Germany.

Specific risks

If you talk to people which places they know in Germany nearly everybody will answer you "Frankfurt" because they once entered Europe through FRA, the Frankfurt International Airport. FRA is one of Europe's most frequented airports at all. Actually about 51.000.000 people use FRA every year to get to or come from 307 destinations in 109 countries all over the world. Also about 1.750.000 tons of cargo are handled through FRA every year. The constant growth of air traffic will cause a considerably extension of FRA in the next years. This extension includes a new runway, a new terminal which will rise the passenger capacity of FRA to over 80.000.000 per year and several new buildings to meet the requirements for the future and everything it brings like the new Airbus A 380. FRA itself runs its own private fire department, so that initially the fire department of the city of Frankfurt is not responsible for the airport. But if there's any kind of incident exceeding a primarily defined level of dimension, also the city's fire department will respond to the airport.

Another facility the Frankfurt Fire Department has to care about is the city's main central station. In here, about 350.000 passengers enter or leave the station in about 1.800 trains every day. Interesting about the building is, that most of the total building area is located under the ground level. That includes an underground shopping centre and two different lines and types of the metro system, which will be mentioned a little bit more detailed later.

The most characteristic thing about Frankfurt am Main is its skyline and the high- rise buildings that are forming it. In the city you will find some of Europe's highest buildings and the biggest amount of skyscrapers on the continent. Actually a total of 383 high- rise buildings are completed (including 10 over 150m), 5 are under construction and another 20 are planned. Due to the relatively strict building codes in Germany the skyscrapers themselves are not posing so many problems to the city's fire department in daily operations, of course if you disregard any kind of possible acts of terrorism and the consequences from it. A more critical look has to be set to old or even historical building structures which were constructed in times when building codes weren't based on today's knowledge.

The city has also three big chemical plants which cover a surface of more than 1500 acres. All of them also run their own private fire departments, the cooperation between them and the city's fire department is comparable to the situation at the airport.

TUNNELS IN FRANKFURT AM MAIN

Overview

The following kinds of tunnels are under the jurisdiction of the Frankfurt am Main Fire Department:

- Two street tunnels
- Two railway tunnels
- Two metro systems, one operated by the city, the other one operated by the country

Street tunnels

The longer of the two street tunnels is the so called “Theater- Tunnel”(Gutleuttunnel), which is located downtown in an inner city area. The tunnel itself is about 500m (0.3 miles) long, and runs on two- way traffic with one lane for each direction. The tunnel has an own radial ventilation system and various emergency exits. From the fire department’s point of view, this tunnel is uncritical, operations caused by accidents or car fires have never caused any serious problems.

Railway tunnels

In 2002 the German federal railway company (DB AG) opened a high speed railroad track between Frankfurt and Cologne on which the trains run on a speed up to 350 km/h (about 220 mph). Therefore the time of travel between the two cities has been reduced to 1hr 15min. To enable that top speed it was necessary to build a total of 18 tunnels along the track. Two of these tunnels are under the jurisdiction of the Frankfurt am Main Fire Department. The tunnels are located around the airport. One of them was build to cross the biggest highway interchange of the city. The two tunnels are 990m (0.61 mi) and 1883m (1.17 mi) long.

Every tunnel is equipped with escape routes, emergency exits, automatic shut- offs with grounding for the catenary line and some ventilation devices.

Metro system

Frankfurt's metro system has an overall length of 113 km (70.2 mi). The system is operated by two railway companies, one owned by the city and the other by the state. Some of the stations are used by both companies. Technically, the two systems are different. The System owned by the city just covers the city and some suburban areas around. The federal system covers a large area around the city and is more like a supra- regional train system for the whole Rhein- Main area that is put underground in the inner city parts of Frankfurt. Technically, the systems are also different. The city's system operates with a voltage between 700 and 750V DC. The voltage of the federal system reaches from 13.000 to 17.000V AC. Both systems use a catenary overhead line system for the electrical power supply. Electrical shut- offs are carried out by the control centres of the two operating companies, grounding has to be done manually on scene. Only the city's system has ventilation devices in parts of some stations and the tunnel itself.

From all the possible incidents, the ones in the metro tunnel system are the most complicated. For this reason a closer look is given on this topic. The results and findings are transferable to the other types of tunnels.

METRO FIRES

Problems

A fire department is facing a wide variety of problems in case of a fire in a metro tunnel. First there's the smoke that extends quickly and nearly uncontrollable because of the weather conditions in the underground system. Other trains, still moving in different parts of the system, are also causing pressure differences that are interfering the air movement and possible attempts of ventilation. Connected with that, smoke and toxic gases have a bad influence on the possibility for the self- rescue of the affected passengers.
The transfer of fire and heat to other parts of the concerned carriage is supported by the narrow tunnel system, which works like an oven in that case. The heat exposure, which might reach up to 1300°C within minutes, also has a negative influence on the tunnel construction itself, it might cause the collapse of parts of the tunnel section.

Causes

The possible causes for metro fires are also different. First there are technical reasons on the coaches, like engine- fires caused for example by overheating or technical defects. One of the biggest problems in that case is the oil used for the insulation of the transformer system. The quantity of this oil varies between 700 and 1500 l (185 – 370 gal), depending on the type of the train. Also electrical short circuits, often followed by a cable fire, are possible. The braking system might also be a cause for the ignition of a fire, with brake

hot- boxes occurring from time to time. Inside the coaches electrical devices like for example under seat heaters might catch fire, especially when proper ventilation is impeded by baggage.
Other reasons for fires in coaches are the ones caused by intention like arson or possible terrorist attacks. Operations on that kind of incidents do not differ from the ones caused by technical defects in the beginning, because in the first phase the cause of an incident is not always determinable.

Objectives
As a conclusion from the recognized problems and causes it is possible to define the objectives to reach an appropriate level of safety. So the main objectives are:

- Minimize the danger of a fire breaking out,
- Guarantee a rapid activation of the fire alarm and fire fighting operations
- Enable endangered people to save themselves, and guarantee the others to be saved by the fire department
- Limit the fire to the smallest possible area
- Minimise consequential damage to the tunnel construction and possible disruptions of the vehicle service.

In the following, the overall concept of the city of Frankfurt am Main to achieve these objectives should be presented a little bit more detailed.

PREVENTION

Determination of the initial situation
To get an idea of what in case of a metro fire might happen, the boundary conditions have to be defined. In Frankfurt the first step to be initiated was to find out how a metro coach is behaving under fire conditions. The objective was to determine the heat and smoke exposure rate of a standard coach that is in daily use in the city's metro system. For that purpose, a research institute was charged to conduct a full scale burn test with an original coach.

Actions taken
The results of that test were taken as planning criteria for a comprehensive review of all existing metro stations. In addition to that, the fire protection in the coaches itself have been improved by the use of different materials for seats and interior lining to prevent ignition. With the determined rates for heat and smoke, artificial smoke tests have been realized in nearly every station, especially the large ones with different underground levels, different lines and metro systems.

In the stations different technical installations were made to improve the level of security and to achieve the following objectives:

- Limitation of the maximum distance to a safe area (metro station or emergency exit) to 300m (982 ft.),
- Prevent smoke to reach the area of the escape routes for at least 15 minutes after the start of a fire,
- The low- smoke layer must be more than 2.5m (8.2 ft.) high and the visibility must be more than 15m in the first 15 minutes (phase of self rescue),
- During the next 15 minutes (rescue phase by the fire department) there must be a low- smoke layer more than 1,5m above the escape routes

The following measures have been taken to achieve these objectives:

Measures in the building

Constructive measures

1. Smoke barriers and smoke doors have been installed to prevent the smoke from influencing the escape routes for the defined amount of time,
2. Ventilation systems were improved in some stations,
3. The indication of the escape routes has been completed and improved,
4. GSM- repeaters have been installed to enable passengers to use their cell phones also for emergency calls,
5. Lifts have been equipped with a so called “dynamic evacuation mode”, that prevents a lift from stopping in a smoke filled area,
6. Escalators have been set to support a possible evacuation,
7. The emergency lightning system has been improved,

Organisational measures

1. Emergency phones have been installed in a wide range. With these phones the caller is directly connected to the control centre of the metro operator.
2. Every station is monitored by a camera system. All pictures are transferred to the control centre of the metro operator. The control centre is also able to look at the emergency phones via the camera connection.
3. An operational and danger avoidance plan was created for every metro station. In that all information about the building and its important features like exits, the fire alarm panel and positions of hydrants are displayed,
4. For some stations a computer simulation of the evacuation combined with a simulation of a fire was made to verify the defined objectives.

Measures for the Fire Department

1. A central command post will be installed in the upgrading process of every single station.
2. A repeater system for the department's handheld radio system has been installed to cover the entire underground area,
3. If a station was equipped with different fire alarm systems these were brought together to one central panel point at the command post,
4. Bigger stations were equipped with a PA- system, existing systems were brought together at the command post to enable the use by the FD,
5. Additional grounding devices have been stocked in some of the stations for emergency use.
6. The fire department was equipped with plans and manuals from the stations and the used trains, these were custom- made for the FD's needs,
7. Regular trainings have been established in the metro system and the metro depot to handle the rolling stock.

SMOKE MANAGEMENT

Objectives

The objectives of smoke management by installed building service engineering have been defined earlier on, also the constructive measures to meet these objectives. This part deals with smoke management from the fire department's point of view. For an effective smoke management all operations have to be planned carefully. No state of the art mobile ventilator will be effective without the right tactical approach. To find out how to use any mobile ventilator effectively, artificial smoke tests were conducted with the objective to find out general rules for mobile ventilation in tunnel systems because conditions on the same station might be different on different days. Conclusions drawn out of these tests were, that there is no general rule, just basic principles that can be defined and every ventilation has to be planned on scene with the known basics. For these basics the performance limits of the used ventilators have to be known. Also an exact knowledge of the soon to be ventilated facility is essential to be aware of the decided actions and their consequences.

During the phase of self rescue the use of mobile ventilators is prohibited because the smoke layer is relatively stable and any interference by a ventilator would mix up the smoke layer with the low- smoke layer.

Mobile ventilation

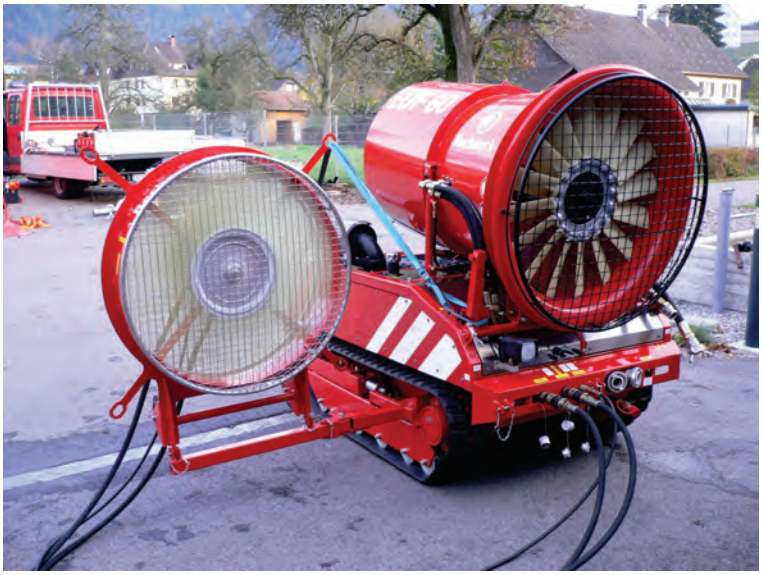
Actually, the following mobile ventilation systems are in use at the Frankfurt am Main Fire Department:

MGV

MGV is the abbreviation for the German word for "Large Mobile Ventilator". The maximum airflow is about 210.000 m³/ h. The ventilator's mode of operation is based on the principle of positive pressure. It's also possible to generate a water fog through the air flow. The MGV is endlessly rotatable in both directions and can be lifted up to 6m high.

LuF

LuF is the abbreviation for the German word for "Fire Suppression Support Vehicle". The maximum airflow is about 90.000 m³/ h for the main ventilator and 50.000 m³/ h for the support ventilator. The LuF is operated by a diesel- engine that powers a hydraulic pump. It is operated by a remote control. The ventilator's mode of operation is based on the principle of radial stream ventilation. It's also possible to generate a water fog through the air flow. Furthermore the support ventilator can be used for the ventilation of shafts and tubes. Both ventilators are powered by the hydraulic pump. The hydraulic pump can also power up to five sewage pumps with a theoretical capacity of 2000 l/min (528 gal/ min). With the help of the chain drive the LuF is able to climb and descend stairs.



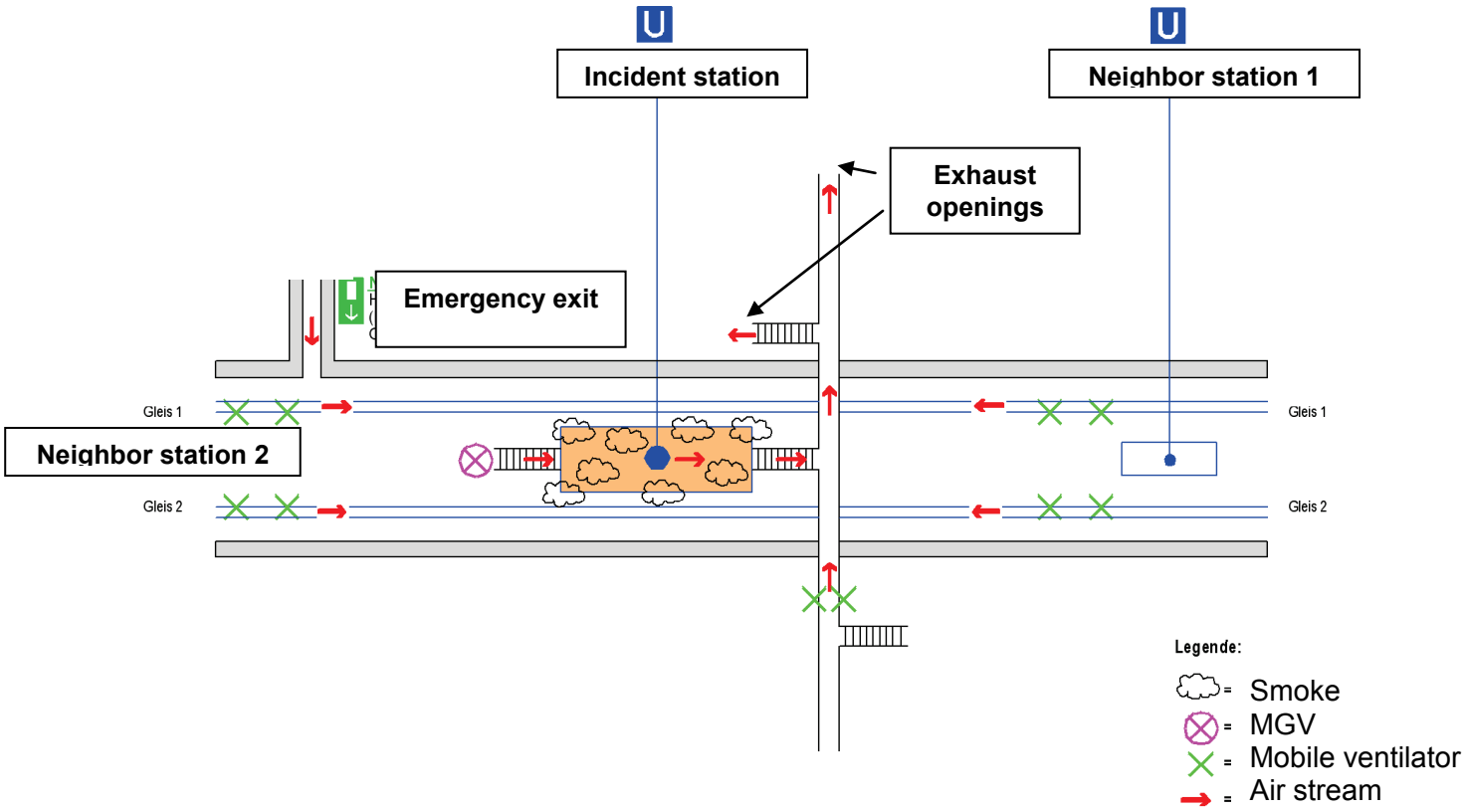
Mobile ventilators

Smaller mobile ventilators can be used to support the bigger ventilators. It's also possible to prevent smoke extension to adjacent metro stations. The big advantage of the smaller ventilators is their higher flexibility in use and transport. The mobile ventilators used in Frankfurt have a maximum airflow of 45.000 m³/ h.

Basic principles of mobile ventilation

- Definition of an air supply and an exhaust opening. If there is still smoke coming out of an opening, check out if this can be used as an adequate exhaust opening.

- The MGV is deployed at the air supply opening to support the intended air stream. Never use the MGV to blow air into the exhaust opening.
- The LuF is used inside the building to support the intended air stream. It is deployed through the air supply opening and uses the ventilation air stream of the MGV. Also a water fog can be created to cool down the temperature inside. Note: The LuF is Diesel- powered and needs clean air for proper operation.
- Small mobile ventilators are used to direct the air stream and prevent smoke from entering areas where it is not intended to be.
- A possible arrangement of mobile ventilation might be:
    1. MGV at the smoke free entrance
    2. LuF entering through that entrance
    3. Small mobile ventilators at the side entrances and the neighboured stations for directing and blocking the smoke



Note: In some of the experimental ventilations, the MGV was able to turn around the natural air stream caused by the weather in the metro system. This is also a possibility, but highly dependable on the intensity of the present conditions.

LIST OF REFERENCES AND FURTHER INFORMATION

A list of references is available at the author. If you have any further questions please do not hesitate to write me an e-mail at reinhard.ries.amt37@stadt-frankfurt.de

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