# MINING for Answers

AP/Wide World Photos

A number of tunnel fires in recent years raised questions about suppression standards and equipment effectiveness in fighting fires in confined and underground spaces. Maybe the highly controlled mining industry can provide some solutions.

*By Holger de Vries, Ph.D.*
*Fire Protection Engineer*
*University of Wuppertal, Germany*

With more tunnels being built to save time and cost for transportation, traffic is becoming more dense and the likelihood of railway and automotive accidents and tunnel fires is increasing.

However, with decreasing public funding for maintaining the bare transportation and structural safety — not to mention fire safety — of roads, there's higher financial pressure on railroad companies to become privatized, so there's very little financial effort to properly equip tunnels with appropriate means of fire detection, escape routes and fire suppression equipment.

We currently are seeing an increasing number of tunnel and transportation emergencies. While working at the University of Wuppertal, Germany, in 1998 reviewing the safety of tunnels and fire departments' response tactics, a fairly large number of tunnel fires with fatalities occurred. (See "Notable tunnel emergencies, 1949–2001," page 46.)

Located just south of the German coal and iron belt, Wuppertal has a strong liaison with the German mine rescue services, which lended itself to comparison with the fire rescue services. Facts and findings originate from three different sources:

- General tactics of municipal fire departments,
- Tactics of the German mine rescue services, and
- Training programs and research at Wuppertal University.

## Review of tactics

Firefighting usually faces one of two different scenarios:

**1) Smaller routine calls to structures such as apartments, houses and workshops,** with a fast-advancing attack team and an estimated time of less than one hour to control or even extinguish the fire.

**2) Major incidents at facilities such as factories and warehouses,** where the extent of the fire will outnumber the fire department's available resources during the initial stages of the response. Tactics usually are aimed at controlling the fire, protecting adjacent property and extinguishing the fire after a longer period of time, when its intensity has decreased.

In these surround-and-drown operations, fire departments usually are confronted with untrained and unskilled civilians who often are unable to control the situation and ensure their own rescue.

As during all fire emergencies, life safety and maintaining structural and functional integrity are key issues. Because there's a lack of fast and efficient directed ventilation, smoke spreads at least two meters per second, causing a major threat to civilians, as well as an obstacle for the firecrews' advance into the structure. (See Table 1, at right.)

Also, a means of escape (door, window, balcony) is usually a few steps away, so fire departments can work with small entry teams. However, two- or even three-person teams are too weak to deal with a firefighter's emergency at a major incident.

Additionally, fire crews are used to having their vehicles and equipment nearby, as fire department equipment is designed to be used directly off the truck or at a maximum 100 to 200 meters away from the vehicle staging area.

Fighting fires in underground facilities virtually turns the tables on standard operating procedures of municipal fire departments. When the emergency site can be accessed only through shafts, fire teams first have to overcome layers of hot smoke and gases before getting near the seat of the fire.

## Equipment of the mind and body

Firefighters are very focused on short-term tactics, often leading to tunnel vision and performance on the fireground that is driven by adrenaline. During standard firefighting operations, such as fighting a room fire, firefighters in today's fire gear, be it NFPA- or EN 469–approved, will easily increase their core body temperature by approximately 1° Kelvin or more, leading to fibrous-like body reactions.

With sweat trapped inside the firefighters' gear, the body can't get rid of excess metabolic heat. This rise in body heat not only places a burden on the circulatory system, causing heart attack deaths in a high number of firefighters over 50, it impairs firefighters' perception processes and decision-making.

Under ergonomic theory, temperatures of 35°C (95°F) already are considered environments with elevated temperatures, but firefighters can and have to sustain much higher temperatures. They also lose up to one liter of body liquid within 30 minutes. Unlike steel workers and miners, firefighters don't work constantly in a warm environment, so their bodies don't adapt to higher temperatures.

According to recent studies, firefighters performing routine operational tasks like carrying equipment, climbing stairs, and conducting search and rescues require between 52 and 95 liters of breathing air per minute. Thus, this workload matches "heavy work" in ergonomic theory.

A standard SCBA tank holds approximately 1,800 liters of air, while a double-bottle set holds between 3,600 to 4,000 liters. Tables 2 and 3, page 44, show how long breathing apparatus is expected to last under these constraints and how much is required. However, the times given here must be reduced by 50%, because the firefighters will need the other half of their air supply to leave the premises. It's obvious that no major tasks can be accomplished if a firefighter's air supply lasts a mere 17 minutes.

With their breathing equipment designed for 30 minutes of use, firefighters basically escape severe physical damage because their equipment forces them to retreat. However, after only 30 minutes of intense firefighting, personnel must resupply body liquid and decrease body temperature by cooling wrists and/or feet. This means that simply equipping firefighters with breathing apparatus which last longer than 30 minutes without providing adequate

*Table 1*

### Smoke spread velocities

| Fireload | Smoke spread velocity [m/s] |
|---|---|
| Car fire | 1 – 2 |
| Truck fire | 2 – 4 |
| Tank truck fire | 4 – 8 |

**Opposite:** On Jan. 30, 2001, a recovery crew walks up to the Kaprun cable car tunnel that caught fire in November 2000, killing 155 people.

*Table 2*

## Breathing air, oxygen demand versus workload

| Workload | BA demand [lpm] | Oxygen demand [lpm] |
|---|---|---|
| Rest | 8 – 10 | 0.3 – 0.4 |
| Walking with BA | 15 – 20 | 0.6 – 0.9 |
| Medium work | 25 – 40 | 1.1 – 1.8 |
| Heavy work | 40 – 50 | 1.8 – 2.3 |
| Short term max. work | 60 – 90 | 2.7 – 4.0 |

*Table 3*

## Theoretical duration of BA (minutes)

| BA capacity | Average demand [60lpm] | Maximum demand [90lpm] |
|---|---|---|
| 1,600 liter | 26 | 17 |
| 4,000 liter | 66 | 44 |

training will knowingly put firefighters' safety, health and lives at risk.

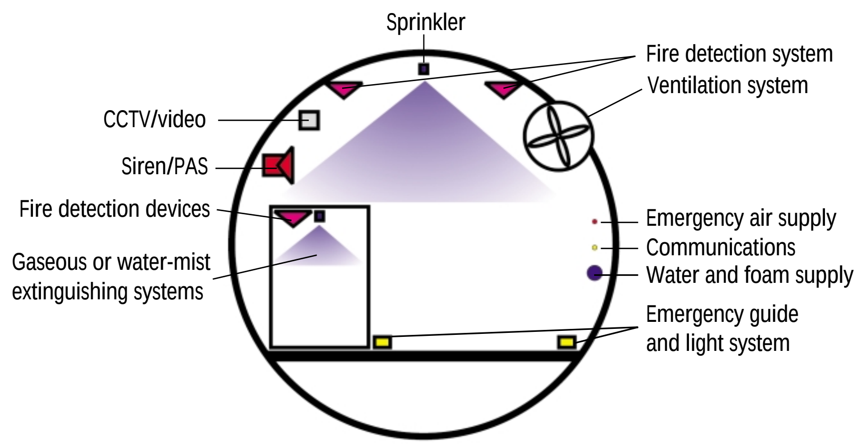
There are, however, fire departments that have purchased circulatory breathing apparatus known as four-hour sets. These breathing apparatus usually use a chemical reaction inside a KOH/NAOH cartridge to remove carbon dioxide from the air that the firefighter exhales. The disadvantage of these breathing apparatus is the high cost of the cartridge, which needs to be replaced after every use. Because of the cost involved, fire departments usually undergo minimal training with these sets, which leads to a very small safety margin.

The values for advance times and speeds of attack teams given in Table 4, page 46, were determined during exercises and training sessions. During an exercise inside an underground train station, with a fire on the second-basement level and zero visibility, it took fast-working attack teams about one hour to lay one 2-inch attack line. This shows how personnel must be assigned and used in rotation to perform a successful rescue and firefighting operation in these premises.

If we take a closer look at the 20- to 40kg that a firefighter might still be able to carry, it can be broken down to two lengths of hose, a nozzle, a rope and a flashlight. This, in turn, means that everything but the hand tools must be provided within the structure. This includes firefighting equipment, lifting and transportation devices, a water supply, foam supply, an emergency air line and means of communications.

*Figure 1*

## Safety installations for tunnels




Firefighters' personal equipment is optimized for the achievement of short-term tactics. PPE is too heavy, breathing apparatus don't last long enough, and communications equipment usually doesn't work inside tunnels or other large structures. Firefighters are neither trained in nor accustomed to tunnel operations.

### Mine rescue operations

Contrary to municipal fire and emergency services, mine rescue organizations are set up with long-term strategies. The mining environment is a highly controlled one and features mining teams who train to maintain their own survivability.

For example, German mine rescue teams consist of one team leader and four miners trained in and equipped for mine rescue operations. The minimum size of a mine rescue brigade is 70 members, which allows for 10 deployment teams and 20 command and support staffers. Response time of a mine rescue team plus one backup is one hour, calculated from the initial call to the teams' reporting ready at an entry point. Thus, it's expected that a miner in distress will be taken care of by first aiders or is lost.

In the case of an emergency, the work force and their supervisors will leave the affected area and report the emergency to the mine control room. From there, ventilation is controlled to provide adequate airflow in the right directions.

The rescue team will move toward the site of the emergency with fresh air in their packs, reporting their position and findings from certain points to the mine control room via wired phone. This standardized phone system is installed throughout every mine and can be accessed with special pliers at any location. The team constantly monitors oxygen, carbon monoxide, methane, air temperature and humidity.

Their PPE consists of Aramid-type, two-layered flash protective clothing without a liner or moisture barrier; helmet; Aramid hood; explosion-proof helmet flashlight; and four-hour circulatory breathing apparatus. The team carries one emergency breathing apparatus and at least one of two different wired phone systems. The maximum allowable time for mine rescuers to work with this gear is 90 minutes. The breathing apparatus would allow for longer use, but the chemical reaction inside the KOH/NaOH cartridge is exothermic and constantly increases the temperature and humidity of the air circuit.

The breathing apparatus is donned only when the atmosphere requires it. The team leader then calculates the allowable time under breathing apparatus from air temperature and air humidity. Table 5, page 47 shows the allowable time under a closed-circuit breathing apparatus in relation to dry air temperature and relative air humidity.

It can be seen that 90 minutes are not exceeded in any environment that matches with a firefighting environment. While I'm not suggesting that fire departments should adopt the measuring of temperature and humidity during incidents, I believe that officers as well as firefighters should be well aware of the limitations of the human body.

In mine pits, minor fires are dealt with immediately by using the hydrant system and fire equipment provided throughout the mine. Once life safety is achieved, the emergency operation basically turns into an engineering task. Mine fires have to be left to burn freely, or the area may be walled off, sealed and flooded with nitrogen.

### Fixed installations

After a number of disastrous tunnel fires, the hunt for adequate fixed fire and emergency installations is on in Europe. In an ideal world, a "safe underground facility" would be equipped with installations as shown in Figure 1, opposite page. This tunnel would include:

**Ventilation system.** The ventilation system needs to be capable of handling 1,000°C (1,800°F) hot smoke for at least 90 minutes. It requires an independent power supply.

**Sprinkler systems.** Though generally associated with high installation costs, corrosion and water damage, sprinkler systems can be installed using plastic pipe to reduce installation time and cost and to avoid corrosion. Also, water damage caused by frost and leaks usually goes along with improper maintenance. Sprinkler statistics show that, on average, four sprinkler heads respond in case of a fire. Thus, fire and water damage are far more confined to a small area than if the fire would have been permitted to grow.

AP/Wide World Photos

Smoke pours from a tunnel in Baltimore after a freight train derailed on June 18, 2001. The 60-car train was carrying hazardous materials, including hydrochloric acid.

Another cost factor is insurance certification of sprinkler systems. Here a mental change has to be prompted on the insurers' side. With the vastly increasing fire losses in industrial fires, insurers have to give in to leaner certification processes. The growth of fire losses shows that the current policies need improvement.

**Water-mist and gaseous extinguishing systems.** After halone-gaseous extinguishing systems had to be replaced with non-ozone depleting agents, the fire industry came up with a completely redesigned array of "clean extinguishing systems." Among those are new gaseous systems as well as water systems, which are designed as low- or high-pressure water-mist systems.

Water-mist systems can be very successful. However, they need to be designed with more care and proficiency than conventional, low-pressure sprinkler systems. A water-mist system will be successful only in enclosures specifically designed according to the constraints of fuel type, fuel geometry, fuel distribution, fuel heat release, water mist nozzle type and spray pattern, flow rate, relative position of water mist head and fuel, and ventilation. Furthermore, water-mist systems will be successful only if a fire detection system ensures that suppression sets in during a very early stage of fire growth. Once a fire is freely burning and ventilating, water-mist systems aren't very successful.

**Water and foam supply.** In most fire service training manuals, water still is considered to be the most effective and cheapest extinguishing agent. This is only partly true. Water does cost money, but fire departments aren't paying for it. Furthermore, it costs money and effort to set up water supplies over long distances. This also requires vehicles and personnel, and the collection and cleaning of contaminated runoff water.

From reports of tunnel fires, it's known that plain water usually lacks the knockdown and full-suppression capabilities required during tunnel firefighting operations. Fire departments are usually equipped with at least some kind of foam agent. Polysynthetic foam agents usually consist of sulfuric carbon

*Table 4*

## Advance times and speeds of attack teams

| | Full visibility | Zero visibility |
|---|---|---|
| Plain advance | 5 minutes at 20 m/min | 20 minutes at 5 m/min |
| Advance with hoseline | 10 minutes at 20 m/min | 60 minutes at1 m/min |
| Rescue and transportation | 15 minutes at 6 m/min | N/A |

in aqueous solution. They can be used to produce light-, medium- or high-expansion foams. The majority of municipal German fire departments use these foam agents.

Aqueous film-forming foams are widely used by North American fire departments, and their use by municipal fire departments in Germany is increasing. AFFF have better knockdown capabilities and better burnback resistance than plain polysynthetic foam agents because of the oil-repellent properties of their fluorocarbon-tensides.

The next step in foam development is alcohol-resistant AFFF, marked as ATC for alcohol-type concentrate or AR for alcohol resistant. These are crucial to knock down spill fires of unleaded gasoline, because the alcoholic compounds of such fuel breaks down plain AFFF foam too easily. However, any type of AFFF is substantially more expensive than polysynthetic foam, and the majority of fuels encountered during a tunnel fire will still be of Class A type.

Class A foam, a blend of polysynthetic foam, offers the advantages of relatively low cost, a less than 1% induction rate, and a large array of reliable proportioning systems for fixed and mobile installations such as bladder tanks and water motor proportioners. For underground facilities, a flow of at least 200gpm water or water/foam solution at 100psi should be provided. Connection points should be every 100 to 200 meters with flat hose and combination nozzles.

### Discussion and consequences

While looking at mine rescue operations shows some interesting details, fire departments won't be able to adopt these, because during our emergency operations too many members of the public are affected, requiring time-critical rescue. Since the majority of tunnels and underground facilities have been in use for 20 years or more, the high cost to retrofit them with safety systems makes it highly unlikely that any effort will be taken to upgrade these German tunnels.

It remains with the fire departments to prepare and provide for adequate emergency response. Fire departments should consider using larger than two-person entry teams. Guidelines and buddy lines should be used. Guidelines of 300 meters in length and six millimeters in diameter help firefighters to track their way in and out of premises. Buddy lines between two and five meters long help team members to stay in contact with each other and to use advantageous search tactics.

## Notable tunnel emergencies, 1949–2001

Holland Tunnel, 1949
New York
Truck crash, sulfuric compound
66 people with symptoms

Bosnia, 1971
Defective diesel locomotive
34 fatalities, 120 injured

Hokuriku Tunnel, 1972
Japan
Restaurant rail car crash
30 fatalities, 700 injured

Velsen Tunnel, 1978
Netherlands
Collision, 2 trucks and 4 cars
5 fatalities, 5 injured

Nihonzaka Tunnel, 1979
Japan
Collision of rail car and ether tanker
7 fatalities, 2 injured

Salang Tunnel, 1982
North of Kabul, Afghanistan
Trucks collided with gasoline tanker
Between 700–2,000 fatalities, est.

Caldecot Tunnel, 1982
Oakland, Calif.
Collision, burning tank truck
7 fatalities, 2 injured

Todmorden Tunnel, 1984
United Kingdom
Derailment of 13 tank cars carrying 1.3 million liters gasoline/petrol. 12 hours after ignition, 30-meter high flames coming out of exhaust ducts. Firefighting took four days, requiring 3.5 million liters of waters and 24,000 liters of foam concentrate

San-Benedetto Tunnel, 1984
Railway tunnel north of Florence, Italy
Terrorist bomb attack
17 fatalities, 200 injured

Gumefens Tunnel, 1987
Switzerland
Mass collision after road icing, fire caused by gasoline spill
2 fatalities, 5 injured

King's Cross Station, 1987
London, metro rail tunnel
Wooden escalators on fire
31 fatalities

Brenner Tunnel, 1998
Between Austria and Italy
Fire during reconstruction, while emergency lights and ventilation system were off
2 fatalities, 5 injured

Pfaendertunnel, 1995
Near Bregenz, Austria
Car crash
3 fatalities

Metro rail tunnel, 1995
Baku, Azerbaijan
289 fatalities

Channel Tunnel, 1996
Between United Kingdom and France
Arson suspected
2 injured

Leinebusch Tunnel, 1999
Germany, high-speed train tunnel
Fire after ball bearing ran hot
1 firefighter injured

Mont-Blanc Tunnel, 1999
France
Truck crash
45 fatalities

Tauern Tunnel ,1999
Austria
Truck collision
12 fatalities, 50 injured

Tunnel construction site ,1999
50 km south of Oslo, Norway
Dynamite explosion and fire
2 firefighter fatalities, several injured

Subway tunnel , 2000
Berlin
Subway train car fire
28 injured, mostly smoke inhalation; 350 evacuated

Kitzsteinhorn Tunnel ,2000
Austria, cable train tunnel
Possibly overheated gearbox
155 fatalities

Road tunnel, 2000
Near Florence, Italy
Car and truck collision
20 with smoke inhalations

Road tunnel, 2001
Gleinalmtunnel, Austria
Road traffic accident
2 fires in 2001, one with 5 fatalities

Subway tunnel, 2001
Dusseldorf, Germany
Burning train car roof
2 injured

Road tunnel, 2001
St. Gotthard, Switzerland
Truck fire
35 fatalities,severe structural damage, approximately 3 months of repair

*Table 5*

## BA times given ambient temperature and humidity (minutes)

**Relative humidity [%]** / **Dry air temperature [C]**

| Dry air temperature [C] | 100 | 100 | 95 | 95 | 90 | 90 | 85 | 85 | 80 | 80 | 75 | 75 | 70 | 70 | 65 | 65 | 60 | 60 | 55 | 55 | 50 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **22** | 80 | 90 | 85 | 90 | | | | | | | | | | | | | | | | | | |
| **23** | 75 | 90 | 80 | 90 | 80 | 90 | 85 | 90 | | | | | | | | | | | | | | |
| **24** | 70 | 90 | 70 | 90 | 75 | 90 | 80 | 90 | 85 | 90 | | | | | | | 90 minutes for all | | | | | |
| **25** | 65 | 90 | 65 | 90 | 70 | 90 | 70 | 90 | 75 | 90 | 80 | 90 | 85 | 90 | | | | | | | | |
| **26** | 60 | 90 | 60 | 90 | 65 | 90 | 65 | 90 | 70 | 90 | 75 | 90 | 80 | 90 | 85 | 90 | | | | | | |
| **27** | 55 | 90 | 55 | 90 | 60 | 90 | 60 | 90 | 65 | 90 | 70 | 90 | 70 | 90 | 75 | 90 | 80 | 90 | 85 | 90 | | |
| **28** | 50 | 80 | 50 | 85 | 55 | 90 | 55 | 90 | 60 | 90 | 65 | 90 | 65 | 90 | 70 | 90 | 75 | 90 | 80 | 90 | 85 | 90 |
| **29** | 45 | 75 | 50 | 75 | 50 | 80 | 55 | 85 | 55 | 90 | 60 | 90 | 60 | 90 | 65 | 90 | 70 | 90 | 75 | 90 | 80 | 90 |
| **30** | 45 | 65 | 45 | 70 | 45 | 75 | 50 | 80 | 50 | 85 | 55 | 90 | 55 | 90 | 60 | 90 | 65 | 90 | 70 | 90 | 75 | 90 |
| **31** | 40 | 60 | 40 | 65 | 45 | 70 | 45 | 70 | 50 | 75 | 50 | 80 | 55 | 85 | 55 | 90 | 60 | 90 | 65 | 90 | 70 | 90 |
| **32** | 35 | 55 | 35 | 40 | 40 | 60 | 40 | 65 | 45 | 70 | 45 | 75 | 50 | 80 | 50 | 85 | 55 | 90 | 60 | 90 | 65 | 90 |
| **33** | 35 | 50 | 35 | 55 | 40 | 55 | 40 | 60 | 40 | 65 | 45 | 70 | 45 | 75 | 50 | 80 | 50 | 85 | 55 | 90 | 60 | 90 |
| **34** | 35 | 45 | 35 | 50 | 35 | 50 | 35 | 55 | 40 | 60 | 40 | 65 | 45 | 65 | 45 | 70 | 50 | 75 | 50 | 85 | 55 | 90 |
| **35** | 30 | 45 | 30 | 45 | 35 | 50 | 35 | 50 | 35 | 55 | 40 | 60 | 40 | 60 | 45 | 65 | 45 | 70 | 50 | 75 | 50 | 85 |
| **36** | 30 | 40 | 30 | 40 | 30 | 45 | 35 | 45 | 35 | 50 | 35 | 55 | 40 | 55 | 40 | 60 | 40 | 65 | 45 | 70 | 50 | 75 |
| **37** | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 | 30 | 45 | 35 | 50 | 35 | 55 | 40 | 55 | 40 | 60 | 40 | 65 | 45 | 70 |
| **38** | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 | 30 | 45 | 35 | 50 | 35 | 50 | 35 | 55 | 40 | 60 | 40 | 65 |
| **39** | 25 | 30 | 25 | 35 | 25 | 35 | 25 | 40 | 30 | 40 | 30 | 40 | 30 | 45 | 35 | 50 | 35 | 50 | 35 | 55 | 40 | 60 |
| **40** | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 | 35 | 50 | 35 | 50 | 40 | 55 |
| **41** | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 | 35 | 50 | 35 | 50 |
| **42** | 20 | 25 | 20 | 30 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 | 35 | 50 |
| **43** | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 40 | 30 | 45 |
| **44** | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 30 | 40 | 30 | 45 |
| **45** | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 | 30 | 40 |
| **46** | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 | 25 | 35 |
| **47** | 15 | 20 | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 30 | 25 | 35 |
| **48** | | | | | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 | 25 | 35 |
| **49** | | | | | | | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 | 25 | 30 |
| **50** | | | | | | | | | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 | 20 | 30 |
| **51** | | | | | | | | | | | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 | 20 | 25 |
| **52** | | | | | | | | | | | | | 15 | 20 | 15 | 20 | 20 | 20 | 20 | 25 | 20 | 25 |
| **53** | Any use only by direct order of incident command | | | | | | | | | | | | | | 15 | 20 | 15 | 20 | 20 | 25 | 20 | 25 |
| **54** | | | | | | | | | | | | | | | | | 15 | 20 | 15 | 20 | 20 | 25 |
| **55** | | | | | | | | | | | | | | | | | | | 15 | 20 | 20 | 20 |

Standard operating procedures (white) — Extended duration/exposure, if approved by incident command (shaded)

For emergencies in the River Elbe Tunnel, which consists of three tubes, each with two lanes, the Hamburg Fire & Rescue Department mobilizes three paid platoons, each with two pumpers and one ladder, to each entrance. They also deploy three volunteer platoons, each with two pumpers.

Departments also should plan for massive breathing air and foam agent supply. Once you receive a call, get the cargo rolling. Don't wait for supply calls from scene — the incident and sector commanders will be busy enough. Check for local sources, mutual aid, staging and supply areas beforehand, and include all this in your SOPs.

The Dortmund (Germany) Fire & Rescue Department responds to subway train emergencies with 46 firefighters and officers to the affected or nearest subway train station and 24 firefighters and officers to the adjacent stations. Given the demand for human resources, backup teams or even rapid intervention teams for our own protection, these first-due assignments are well justified.

Establish proper breathing apparatus control and entry procedures. To increase the reach of firefighting teams, long-term breathing apparatus have to be used. These can either be Twin Pak compressed-air breathing apparatus or circulatory breathing apparatus. The purchase of this equipment must go along with firefighter endurance training.

Also, plan for communications, alternate communications and backup communications, and define interfaces with the tunnel owner/operator. For underground emergencies this means cooperating with the tunnel owner/operator; streamlining terminology, strategy and equipment; and training together whenever and however possible.

Finally, conduct thorough mission preplanning and review of SOPs. If you have a tunnel in your area and you have no SOP for that kind of emergency, then you have a problem. FC

A member of the German fire service for 20 years, Holger de Vries has been a fire protection engineer and assistant lecturer at the University of Wuppertal in Germany, holding a master's and a Ph.D. in safety engineering and fire and explosion protection. His main research fields are the use of foam on solid fuel fires by fire services and in fixed installations, personal protective equipment, strategic management in public administration, deployment analysis, and training of fire and emergency services. He's a volunteer captain and platoon commander with the Hamburg Fire and Rescue Department and a live fire instructor. De Vries now works as a fire safety consultant, for DESY Hamburg, and CSS Sensor GmbH in Hamburg, and owns Sensor Business Consult America Inc. in Hickory Hills, Ill.