

Safety and Reliability of Fire Detection Systems in Road Tunnels

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ABSTRACT

Although automatic fire detection is used in road tunnels since the late sixties, the subject has been of growing importance since the big tunnel fires in 1999 / 2001. Besides introduction of new detection technologies, safety and reliability of these systems is an important issue. On one side early detection versus fault alarm rate has to be considered. On the other hand automatic detection versus control room decision is a subject. And another question is how much redundancy can be put into the budget? This paper gives an overview on actual tunnel fire detection systems including their safety and reliability features.

TUNNEL FIRE DETECTION SYSTEMS

Whereas line type heat detectors have been used as the most important technology for a long time, today new technologies as smoke detection, video and others have been coming up or are under investigation [1]. In addition, many countries started to implement these new technologies for early fire warning in the directives for tunnel safety equipment [2,3]. Actual systems are:

- Semiconductor temperature sensor cable (multipoint heat detector)
- Fiber optic sensor cable
- Pneumatic line type heat detector (copper tube system)
- Non resettable line type heat detectors
- Visibility monitors
- Video analysis
- Flame detectors

Table 1: overview of tunnel fire detection systems

System	Reacts on	Rate-of-rise detection	Detection speed	Typical sensor distance	Maximum system length	Local resolution	Fault alarm rate
Temperature sensor cable	temperature	yes	middle to high	7 m 10 m	2500 m	7 m 10 m	low
Fiberoptic sensor cable	temperature	yes	middle	cont.	8000 m	1-2 m	low
Pneumatic system	temperature	yes	middle to high	cont.	100 m	100 m	low
Non-resettable cable	temperature	no	low	cont.	250 m	250 m	low
Visibility monitors	smoke	yes	high	100 – 300 m	point type	100 – 300 m	middle
Video analysis	smoke, flames	N.A.	high	50 – 100 m	point type	50 – 100 m	high
Flame detectors	flames	N.A.	middle	25 – 50 m	point type	25 – 50 m	low

A more detailed description of these systems is given in [1]. Table 1 gives an overview on their most important properties and specifications.

SAFETY

Safety is used in the sense, that all these systems should detect a tunnel fire. A 5 MW fire (typical car fire) usually should be detected within 60 seconds. The general trend is, to detect the fire in a very early stage and prevent a real breakout or fire jumping to more vehicles. This brings up the question for a threshold to be used. Today various types of test fires are used to qualify fire detection systems. While the German RABT [2] uses a 5 MW test fire, Austrian RVS 9.282 [4] starts already with a 1.5 MW fire. Having in mind high wind velocities of up to 10 m/s in tunnels, this might be crucial for temperature detection based systems. Table 2 gives the result of the comparison of different line type heat detectors using different test fires at a wind velocity of 3 m/s [5]. It can be recognized that the semiconductor sensor cable is the fastest one, although all type of systems can detect the fires.

Table 2: comparison of different line type heat detectors using different test fires [5]

#	Fuel	Area of fire	LHD 1 copper tube	LHD 2 fibre optic	LHD 4 sensor cable
1	Petrol	2 m ²	28 s	42 s	13 s
2	Petrol	4 m ²	19 s	30 s	11 s
3	Diesel	2 m ²	83 s	60 s	31 s
4	Diesel	4 m ²	30 s	48 s	17 s
5	n-Heptan	1 m ²	165 s	98 s	46 s
6	n-Heptan	2 m ²	37 s	68 s	18 s
7	n-Heptan	4 m ²	25 s	61 s	13 s

Figures 1 and 2 show in addition a test with a 5 MW fire done at 10 m/s wind velocity and a real tunnel fire in a city tunnel. In both cases the detection has been triggered by the rate-of-rise. Significant absolute temperatures are not reached in the first case and only reached after several minutes in the second case. This means, that rate-of-rise detection is mandatory and systems working only by absolute temperature detection as non-resettable cables should not be used in the road tunnels.

Figure 1: Test of semiconductor sensor cable with 5 MW fire at 10 m/s

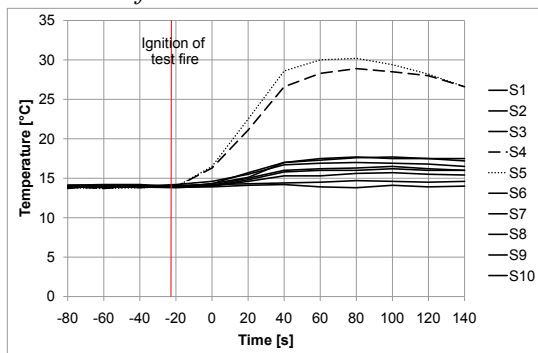
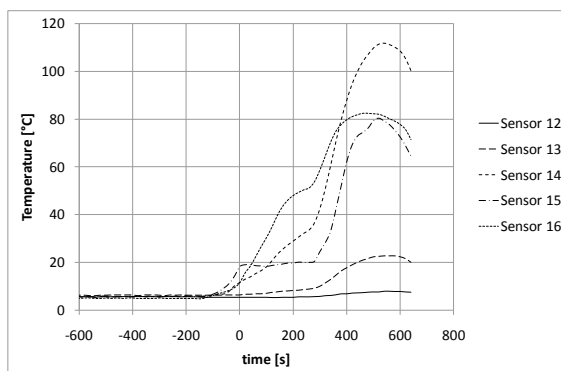


Figure 2: City tunnel fire detected by semiconductor sensor cable



Another safety issue is the human interface. Here we can see very different philosophies between a strictly automatic system going directly from detection (possibly by several independent systems) to alarm and control room dominated systems, where all alarms have to be confirmed before going to the different alarm reaction mechanisms. But in most tunnel applications a mixture can be found. Whereas temperature detection is usually triggering the fire scenario directly and has to be interrupted by manual

interference in case of a false alarm, pre-alarms of smoke detection or video analysis run via the control room for confirmation to avoid a large number of false alarms.

FALSE ALARMS

In a certain contradiction to a maximum safety to detect a fire is the false alarm rate. Of course the thresholds have to be high enough to suppress regular false alarms. But what is an acceptable false alarm rate? The Swiss standard [3] defines 1 false alarm per year and 2 km as acceptable. Generally this is no problem for line type heat detectors. For smoke detectors it depends on the used threshold values. Investigations as [6] show, that high safety and low fault alarm rate is possible. Video based fire and smoke detection systems up to now have always a certain false alarm rate. Even with an optimized setting for a specific application 1 fault alarm per camera and month is already a good value. So the increased safety by early fire detection using CCTV based smoke alarm has to be paid with an increased false alarm rate. If this can be accepted, video fire detection can be a good method for early fire warning.

RELIABILITY

Reliability here is used in the sense of availability or resistance against perturbations or damage. Generally only systems with approval e.g. by VdS according to fire detection standards as EN54-5 or the new EN54-22 should be used. This assures already a certain quality of the detection and the components itself. In addition, the systems and the networking should be prepared to compensate for a partial damage. The RABT[2] defines e.g., that a line type heat detector has to be split up in several segments and that an error of one segment should not influence the others. Generally, a good reliability can be reached with a redundant installation. Unfortunately, different ideas of redundancy with different reliability levels can be found in the field. Using the example of a line type heat detector, such system should at least comprise:

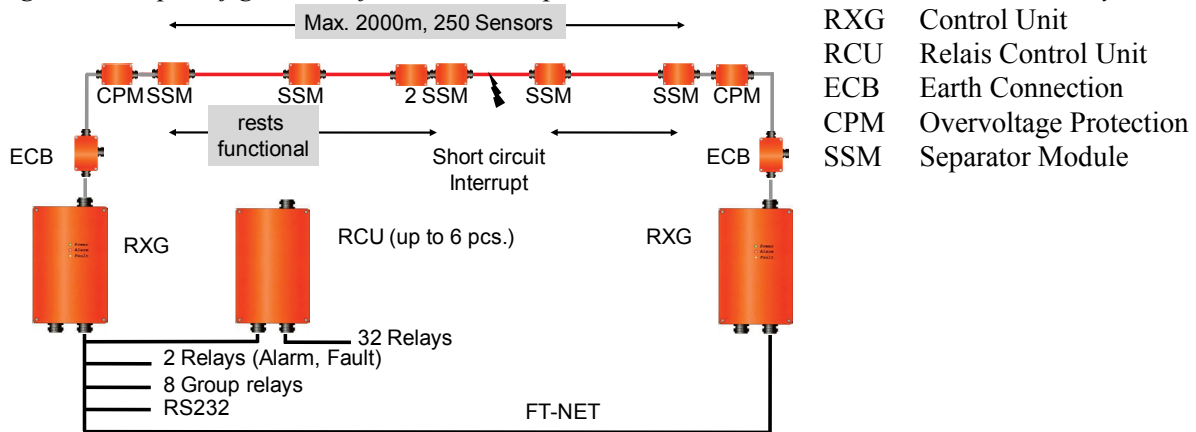
- Two separate detection cables in the tunnel or at least one cable with readout from both sides (loop system)
- Splitting up the cable in segments to remain functional in case of damage. It is important that the system can handle not only interrupts but also short-circuits.
- Two independent control units allowing full system operation in case of failure of one control unit. Ideally these two control units are located in different control rooms.
- Loop configuration of communication between both control units and control units and fire control panel
- Redundant fire control panel

SECURITON MHD 535 TEMPERATURE SENSOR CABLE

An example for a line type heat detector system fulfilling the actual requirements as given above is the Securiton MHD 535. It is a semiconductor sensor temperature cable giving most fast temperature and rate-of-rise detection due to a unique IR sensitivity and its high-speed bus readout principle. The temperature sensors are located in the cable with 7 or 10m distance, depending on the local requirements. The cable is separated in segments by separation modules allowing even an isolation of a defect segment in case of a short-circuit. The temperature values are read out by two independent control units at each end of the cable. In a fault condition, the two control units communicate via a fault tolerant network and rearrange the configuration of the separation modules to be used as connecting or terminating elements. In this way, only the part between two modules is not available. Figure 3 shows a typical arrangement.

The loop setup shown in Figure 3 is the simplest case of a network between two control units. The new developed FT-NET (fault tolerant network) allows the integration of several processor units with attached temperature sensor cables on a failsafe network. All information essential for fire detection like alarm, alarm localization, pre-alarm, system failure, or system status are transferred via this network. On one side, this allows central access on the data using digital interface modules on the network or central relay control units. On the other side, information from different temperature sensor cables can be combined to generate more complex alarm mechanisms and diagnostics.

Figure 3: Loop configuration of MHD 535 temperature sensor cable with increased availability



CONCLUSION

For the automatic detection of tunnel fires and the subsequent initiation of cost intense fire ventilation and fire brigade alarm, linear heat detectors today are the only 100% reliable detector with a minimum of fault alarms. However systems with the possibility of reaction by temperature gradient have to be used, as the maximum temperature for a car fire might not reach more than 50 °C. They fulfil all requirements including the required detection speed of 60 seconds for a 5 MW fire even at high air speed of 10 m/sec. For an optimized solution, the use of redundant systems restricting errors to single instruments or segments is recommended. For tunnel showing a high risk for fires, several different, independent detection technologies are recommended. At least one system should give an automatic reaction to the fire scenario.

Smoke detectors or visibility monitors should be used in addition for early fire detection as already mandatory in Germany and Switzerland. Today their signals have to be confirmed by the control room. In some applications, they start automatically the fire ventilation. With more experience in their application and on possible thresholds and interference, they might be used for automatic triggering of the complete fire alarm scenario, too. Video detection is due to its non negligible fault alarm rate a sensitive subject. However in tunnels with a high risk potential they might contribute to increase the safety.

It is recommended that the most reliable system –usually the temperature based detection – triggers automatically the alarm scenario. This helps to prevent any loss of alarms due to human failure.

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