EARLY FIRE DETECTION IN SWISS ROAD TUNNELS WITH MORE THAN 1’500 FIREGUARD SENSORS

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ABSTRACT

Major fire incidents in road tunnels with a larger number of casualties led to a discussion and measures to increase the safety in road tunnels. Technical evaluation of the various incidents showed, that the monitors typically installed for visibility monitoring and ventilation control gave early and reliable signals, indicating the start of a fire. In most cases, fire start due to technical reasons on the vehicles, such as defective engines, turbocharger, brakes, tires, etc. Such defects typically lead first to the development of cold smoke before an actual fire starts (in many cases, there’s even no fire, just smoke). Such incidents remain invisible to CCTV and linear fire cables.

In 2004, the Swiss Federal Roads Office (FEDRO) introduced the first draft of a standard for a suitable and reliable early fire warning detection system. Based on these recommendations, SIGRIST-PHOTOMETER was the first company developing and manufacturing a new smoke/fire detector fulfilling the requirements set by this draft, which eventually became the official standard in Switzerland in 2007.

The Gotthard road tunnel was the first tunnel which was equipped with more than 200 Fire-Guard sensors. In the meantime, several tunnels in Switzerland, Germany, Spain, Norway, Sweden and Czech Republic have been equipped with this monitor.

The presentation gives an overview about the major projects concluded in Switzerland and the practical experiences of early fire detection in road tunnels. At the end an impressive video demonstrates the reliable reaction of the smoke sensor in a real tunnel during the final inspection.

1. YES, IT HAPPENS!

Fire in a road tunnel - a nightmare for every driver! Fortunately, big accidents followed by an explosion or a big fire (like in the Montblanc or Gotthard tunnel) are rare. Smaller incidents however happen more often than generally recognized.

Below some incidents are listed which were important enough to be mentioned in the newspapers. In all these cases no casualties resulted, although in some cases people were just lucky. In any case, such incidents disrupt the heavy traffic flow and they can easily lead to costly structural damages.

June 19, 2011:
A coach with 59 passengers caught fire in a tunnel of the city ring west, Zurich. Damage on the infrastructure: € 400’000

January 27, 2012:
Due to a technical defect, a small truck caught fire in the «Saas» tunnel

April 4, 2012:
A coach with 74 passengers caught fire just in front of the entrance of the «Gotthard» tunnel
2. **FEDRO LEGISLATION FOR FIRE / SMOKE DETECTION**

Investigations of the various fire incidents in road tunnels and their technical evaluation clearly showed, that the instruments installed for visibility monitoring, always gave the very first clear signal when smoke was involved. Based on these findings, the Swiss Federal Roads Office (FEDRO) came to the conclusion that smoke sensors, based on scattered light technology, are ideal tools to effectively detect and localize incidents of cold smoke/smouldering fires.

FEDRO is the first and still only country which has set clear standards and requirements 1) for the installation of fire/smoke detectors in road tunnels. The most important requirements are formulated as follows:

1. The automatic system must be able to localize a fire within a maximum distance of 100 meters in less than 60 seconds
2. The automatic fire detection system shouldn’t trigger more than one faulty alarm for every 2 kilometer per year
3. Fog must not be detected as smoke

Based on these requirements, SIGRIST was the first company which developed and introduced a suitable sensor, the “FireGuard”, in the market in 2007.

3. **SIGRIST “FIREGUARD”**

The “FireGuard” sensor uses the principle of light scattering. The unique design has no moving parts; the function is based on the natural air flow existing in the tunnel. The response time is less than 5 seconds. An integrated temperature sensor helps to localize the place of the incident in case of a fire. Fog is effectively eliminated by optional heating elements. Typically they are only needed at the tunnel entrance and exit. Communication is made either via simple programmable relays or by Profibus DP. Installation can be done on the wall or ceiling using a multi-purpose holder. As an alternative, a special model is available for installation in the intermediate ceiling of the fresh air channel or even directly into the frame of the dampers.
4. PROJECTS

4.1. “Gotthard” tunnel - 2007

In June 2006, SIGRIST presented the first prototype, followed by the first test installation in September in the “Gotthard” road tunnel. During this test period, data were collected during normal traffic conditions, as well as from incidents which happened during this time. All data were logged, and the results analysed. Parallel measurements with the already existing SIGRIST visibility monitor “VisGuard” confirmed the correct measurement of the sensors.

Test installation: VisGuard (left) & FireGuard (right)

Collected data during the test received from various installations

After a successful trial period of 9 months SIGRIST received the order to supply 210 FireGuard sensors to be installed in September 2007.

Installation was made in the fresh air channel of the intermediate ceiling; the distance between the sensors was 96 meters.

FireGuard installation: view from top of the intermediate ceiling (left) and under the intermediate ceiling (right). Also visible is the linear heat detector

The alarming concept is as follows:

Detection of the smoke, differentiation between a moving and a stationary object based on time differences of the alarm sequences. Compared to linear heat detection systems, smoke detectors show a very rapid response time. The FireGuard sensors are used to automatically execute the first alarm and initiate the necessary actions, based on a complex algorithm defined in the software 2).
4.2. City ring West, Zurich – 2009

After decades of discussion and a lot of opposition, the bypass for the city of Zurich was finally built and opened in May 2009. This bypass connects the highways from Basel-Bern to Chur and also connects Zurich and Lucerne. The total length is 26.3 Km, 13.3 Km are tunnels. The total construction cost was approx. 3.2 Bn. Euros. The safety investment for the FireGuard sensors, including installation was only about 1‰ of the total cost. A total of 301 FireGuard sensors were installed every 100 meters in the newly constructed tunnels. Additional 66 FireGuard sensors were installed in the already existing “Gubrist” tunnel, which is part of the bypass system as well. The FireGuard is used for early smoke detection, linear heat detectors are installed for fire detection. For the visibility monitoring, a total of 77 VisGuard sensors were installed.

4.3. Projects concluded or planned

The following chart gives an overview about the major projects concluded (circle) in the past seven years and the projects currently executed (dotted circle). The number in brackets indicates the number of sensors installed in the tunnel.

Until now, a total of more than 1’500 FireGuard sensors have been installed in 60 tunnels in Switzerland.

5. PRACTICAL EXPERIENCES

The following chapter informs about the practical experiences so far collected from the numerous installations.

5.1. Parameter settings

One of the critical questions is: where do we set the alarm level? This question is most important as this decision will have a direct impact on the rate of false alarm. The goal must be to set the limits low enough to detect an incident as early as possible, but to avoid false alarms because the limit has been set too low. The analysis of various incidents, as well as fire tests with calculated heat release, demonstrates that the visibility level quickly exceeds the limits typically used by the operators to close a tunnel (in Switzerland this would be at 12mE/m).
The diagram below on the left shows typical visibility values during the night and the beginning of a day until midday in the Gotthard tunnel. One can clearly see the very low values during the night with visibility values not exceeding 1mE/m. From approx. 6 am, traffic starts to increase, resulting in visibility peaks reaching up to 5mE/m.

The graph below on the right shows typical values measured for early fire/smoke detection. The thick line marks the maximum of the typical measuring range used for visibility monitoring, which is 15mE/m. As shown, visibility values quickly increase above the 15mE/m level. Reasonable limits therefore should be set at 10mE/m as a pre-alarm and 30mE/m for the main alarm.

5.2. Example of the system reaction during a real incident

The following part describes the practical experience of the system reaction in the Gotthard tunnel from an incident which happened on July 11, 2008.

A truck with a defective turbocharger, developing strong smoke was moving south; about 2.1 Km into the tunnel before the driver realized that he had a problem with his truck and stopped. The air velocity in direction north was 2.2 m/sec. An area of 2.5 Km was covered with smoke.

The automatic reaction of the ventilation system was based on the alarm sequence triggered by the values of the FireGuard sensors. The algorithm determined that the truck was moving in the beginning and even allowed to calculate the average speed of the truck. As long as the truck was moving, an increased distributed suction was initiated by opening the corresponding dampers in the intermediate ceiling. Once the truck stopped (this again was determined by the algorithm applied), the ventilation system was changed to a concentrated suction, combined with a change of the flow direction towards the place where the truck stopped (S = 1.8 m/sec, N = 3.2 m/sec). The total time required to remove the smoke was 30 minutes.
Graphical display of the visibility values during the incident:
20:32:31 – Beginning of an increased distribution suction of the ventilation
20:35:51 – Change to a concentrated suction at the place where the truck stopped

6. PARAMETERISATION

Principle we learnt from the numerous installations: the optimum parameter settings must be established individually for each tunnel installation!

Parameterisation is complex and depends on:
- Kind of tunnel (profile, single or two-way traffic)
- Applied concept for the ventilation and fire
- Traffic volume and vehicle mix (passenger cars/trucks)
- Climatic conditions (e.g. salt spray in winter)
- Sensitivity (must be balanced between system reactions vs. risk for false alarms!)
- Way of data handling and philosophy of alerting. Basically, there are two possibilities:
  1. Transmission of the raw data to the control centre, evaluation and reaction based on safety concept (Example: Gotthard – fully automatic release, incl. definition whether the object is moving or stationary, all based on complex algorithms)
  2. Local evaluation and alerting by using the integrated parameter programmability in the control unit SIPORT

7. MAINTENANCE

Time for routine maintenance in road tunnels is limited. Typically, maintenance is done during scheduled closure times during the night. FEDRO regulations requests that sensors should be designed in such a way that a yearly scheduled maintenance must be sufficient to guarantee a proper and reliable function for the next 12 month, without any extra unplanned action. Therefore, the basic requirements for a sensor can be summarized as follows:
- One scheduled maintenance per year must be sufficient to guarantee a trouble-free function
- Maintenance must be simple and fast
- No parts subject to wear should be used
After 7 years of experience with the FireGuard we received the following feedback from operators:

- The only maintenance needed is to clean the measuring chamber. Sensors with heaters (tunnel entrance and exit) need to be cleaned once per year.
- Sensors without heaters: cleaning is only necessary every 2-3 years! The integrated soiling monitoring allows to immediately checking if cleaning is necessary or not.
- After the cleaning, an automated calibration is performed using a checking rod
- Time required per sensor for cleaning and recalibration: max. 15 minutes.

8. VIDEO CLIP: SMOKE TEST OF A SWISS ROAD TUNNEL 3)

Before a tunnel is opened for public it is thoroughly tested by the FEDRO authorities. Such a test includes the correct function of the complete electro-mechanical installation, including the ventilation control under normal traffic conditions and in case of an incident.

The video shows the simulation of an incident by creating artificial smoke generated on a small truck driving through the tunnel “Saas” and then stopping at a certain place. The graphic display shows the fast reaction of the FireGuard sensors installed and the corresponding ventilation control. It also demonstrates nicely that the linear heat detectors only reacted once the vehicle stopped and a slight temperature increase could be detected.

9. REFERENCES


2) Grässlin U., Lombardi Engineers, Switzerland: “Experiences from the Gotthard tunnel by using visibility, smoke and fire detection”, tunnel symposium SIGRIST, Brunnen/Switzerland, October 29, 2008

3) Smoke test tunnel “Saas”, September 9, 2011. Video by FEDRO and made available to SIGRIST by the courtesy of Mr Marcel Berner, specialist for operating and safety equipment