Intelligent Solutions

# Linear Heat Series Under Test:

**Extensive fire tests prove Distributed Temperature Sensing (DTS) enables fast and reliable control of fire protection systems in road and rail tunnels**

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**Abstract**

Field trials in 1:1 scale under authentic environmental conditions have been performed in cooperation with Tyco Fire / Scum and SP Technical Research Institute of Sweden to reveal the capabilities of Distributed Temperature Sensing (DTS) to detect different types of fire fast, to localize fires precisely and to monitor fire size and spreading accurately over an extended period*. Nowadays these enhanced characteristics are beyond the scope of fire detection technology but vital to activate and supervise tomorrow's fire protection systems.

## Introduction

Underground transport facilities are sensitive links in the economic chain that carry thousands of people and tons of goods (including dangerous goods) every day and they are growing in importance. Therefore safety precautions are vitally important and the work involved is related to the high potential risk. By far the greatest risk is a fire out of control. There is a great danger to life from toxic gases, exceedingly high temperatures, total loss of visibility, limited means of escape and the panic reactions of drivers and passengers. At the same time it causes serious damage to the infrastructure of the transport facility.

For that reason greater and greater demands are being placed on fire prevention in tunnels. On the one hand the operators want real value protection and on the other public authorities demand the greatest possible protection of the general public from systems fraught with risk. Retention of function of important protection systems over a specific timescale (fire detection equipment, ventilation, extinguishing systems, escape route signalling etc.) is just one requirement which must be met by modern fire prevention systems. To fulfil these rising demands it needs new prevention concepts where the prevention level is not only defined as simple sum of single prevention measures but as the reasonable and efficient interaction between the protections systems including the fire brigade. Vital information is an indispensable precondition for these interactions like:

- Fast and reliable fire detection with precise indication of the fire location without being influenced by high speed air currents.
- Automatic activation of traffic control systems and the alerting of the emergency service i.e. fire brigade.
- Fire spread and size assessment at the scene of accident to activate and supervise ventilation and /or suppression systems adaptively and to give vital information's to the fire fighting forces.
- Control of success of countermeasures.

As an example of automatic supervision and a step in the right direction the emergency system of a newly refurbished tunnel in France uses the precise localisation of the fire by the fire detection system to adjust the longitudinal ventilation until the wind speed at the point of fire is close to zero. Consequently the smoke remains at the point of fire and the extraction is much more efficient.

**Test Goal**

Full fire monitoring for automatic supervision of fire prevention systems in tunnels which this paper deals with is still new and is under development. 1:1 field trials under authentic environmental conditions have been performed with the SP Technical Research Institute of Sweden in Boras, Sweden in co-operation with Tyco Fire /Scum. Among others, the aim of this research project was to test the capability of the DTS technology to:

- detect many different types of fire quickly and reliably
- provide high durability / survivability during the fire
- monitor the fire development in order to offer vital information
- control the installed extinguishing system (HotFoam - Tyco Fire /Scum, Sweden)


**Test setup**

The 1:1 fire tests have been conducted in a tunnel mock-up (L x W x H: 16m x 6m x 6m) equipped with non-combustible wallboards (Promatect®), 2 doors and observation windows. To simulate hidden fires and fires below a goods wagon a locomotive mock-up (L x W x H: 2.27m x 2.25m x 2.20m, located 1m above ground) has been used, a rail wagon mock-up (L x W x H: 4.8m x 2.4m x 3.0m) served to simulate open fires on a goods wagon. The tunnel mock-up has been equipped with a foam extinguishing system (HotFoam by Tyco Fire /Scum) generally utilized to suppress fire in tunnels without any passenger volume e.g. tunnels of freight railway lines. BRUsafety sensor cable has been installed under the ceiling of the tunnel mock-up using 1m clamp distance. The overall length of the BRUsafety cable was about 1250m. To imitate a tunnel length of 6.5 km an additional 5373 m optical fiber has been attached between control unit and sensor cable. The AP Sensing Linear Heat Series N4387A with 2 optical channels, each 8km in measurement range, served as the fire detection control unit.

The DTS system has been configured according to the EN 54-5 A1 standard approved by the German VdS. Although the system offers 5+2 alarm criteria, just 4 different alarm parameters have been utilized. The maximum threshold was set to 59°C and the three different rate-of-rise criteria has been adjusted to 13°C over 40s, 17°C over 120s and 28°C over 360s. The measurement time has been set to 10s – the alarm time included one confirmation cycle. The configured fire-zone was 800m in extension with a local discretization (spatial resolution) of 3m and a sampling interval of 1m.

## Test Program

Different fire scenarios have been applied to evaluate the performance of the fire protection system (detection system + deluge system). The fire scenario and the corresponding response time of the DTS linear heat system are listed in table 1. The response time is sub-divided showing the response characteristic of each single alarm-criterion. All test sequences have been run with a pattern starting the DTS system 1 minute before the ignition of the test fire. 30 to 90 seconds after triggering of the first alarm the “HotFoam” extinguishing system has been activated manually. The foam production went on until the heat release has reached a minimum – real time controlled by the DTS linear heat detection system.

| Test No. | Scenario | Fuel | HRR (aprox.) | First Alarm | T_abs Alarm 59°C | T_grad1 Alarm 13°C/40sec | T_grad2 Alarm 17°C/120sec | T_grad3 Alarm 28°C/360sec | T_ceiling_max TC7_max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Hidden fire inside locomotive | Diesel, 1.7m² pool | 2.4MW | 01:02 | 01:12 | 01:02 | 01:32 | 05:34 | 359°C |
| 3 | Hidden fire inside locomotive | Diesel, 4.5m² pool, spray | 7.4MW | 00:53 | 01:03 | 00:53 | 01:33 | 05:33 | 706°C |
| 4 | Wood pallets on wagon | Wood pallets, 2 piles | 8.4MW | 02:45 | 03:25 | 02:55 | 02:45 | 05:25 | 741°C |
| 5 | Wood pallets on wagon | Wood pallets, 4 piles | 16.8MW | 02:30 | 03:40 | 02:50 | 02:30 | 05:30 | 890°C |
| 6 | Pool fire on wagon | Heptane, 4.5m² | 9.0MW | 00:30 | 00:40 | 00:30 | 01:30 | - | 1107°C |
| 7 | Pool fire on wagon | E85, 4.5m² | 4.7MW | 00:31 | 00:41 | 00:31 | 01:31 | - | 875°C |
| 8 | Pool fire below wagon | Heptane, 4.5m² | 9.0MW | 00:35 | 00:44 | 00:35 | 01:24 | - | 752°C |
| 9 | Hidden fire inside locomotive and wood pallets on wagon | Acetone and wood pallets 1.75m² and 1 pile | 6.3MW | 02:15 | 02:35 | 02:15 | 02:15 | 05:25 | 800°C |

***Table 1: Different fire scenarios and corresponding response time***

## Test Results

All open pool fires have been detected within 30 to 40 seconds after ignition. Which is a detection in half the time required by the German RABT (RABT e.g. defines the tunnel fire detection requirements). Even hidden pool fires triggered an alarm within 60 seconds after ignition. Due to the slow fire development of wood pallets the response time was in the range of 2 to 3 minutes. In all cases the first alarm has been triggered by the rate-of-rise criterion while the temperature at the ceiling was still below 59°C at the time of the first alarm condition detection. Whereas the pool fires have been detected by the fast rate-of-rise criterion (13°C/40s) the wood pallet fires have been covered by the medium rate-of-rise criterion (17°C / 120s) consequently. All test results showing the capabilities of the DTS system to detect different fires in very short time suitable to fulfil special regulations being made in tunnel application (e.g. RABT, RVS, ASTRA etc.). The maximum temperature detectable under the ceiling is a function of the heat release and the time given the fire to develop. It has reached 360°C with the 2.4 MW hidden pool fire and more than 1100 °C with the 9 MW open pool fire. The sensor cable used survived all fire tests and thus the DTS system was capable to monitor the fire during the test and to provide vital information as shown in figure 1.

***Figure 1: Fire Monitoring of hidden diesel fire with a HRR of 7,4 MW using AP Sensing Linear Heat Series control unit N4387A***

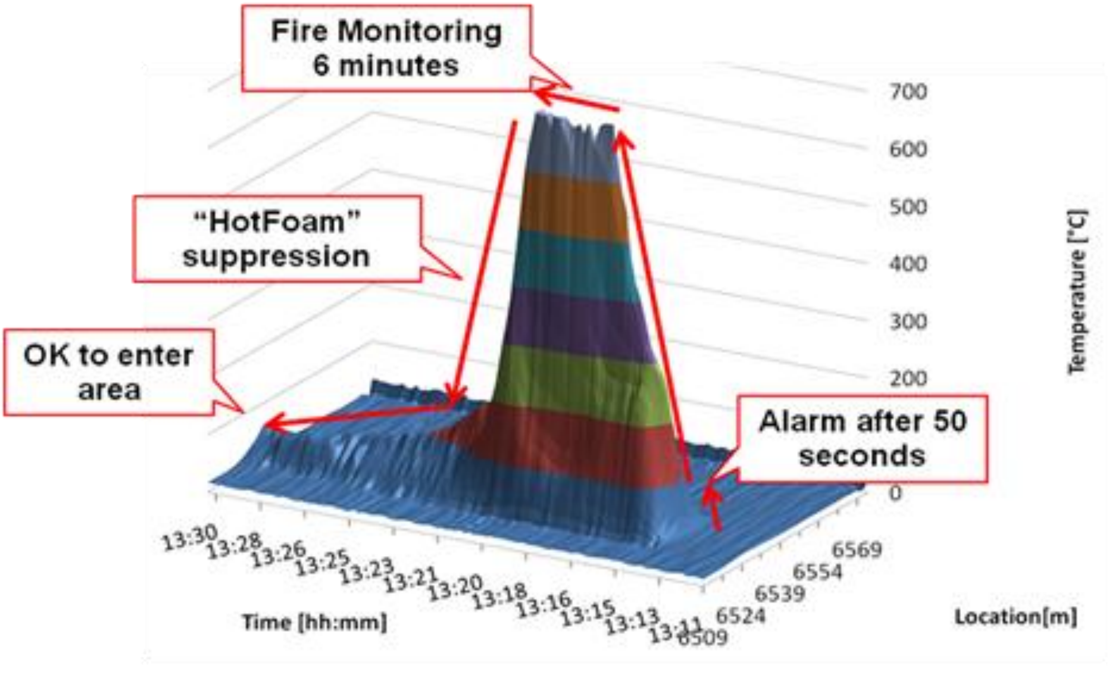

Figure 1 shows the result of the hidden fire inside the locomotive mock-up using Diesel fuel and a pool with a surface of 4.5 square meters. The HRR was calculated to 7.4 MW. About 40 seconds after ignition the first alarm condition has been recognized by the DTS system. After 10 seconds the alarm condition has been confirmed and the alarm was triggered by the fast rate-of-rise criterion reliably (Figure 2). The maximum rate of temperature growth was 50°C / 10s at the early stage and the growth rate slowed down slightly to 35°C / 10s until the maximum heat release rate of 7.4 MW has been reached after 200 seconds. The full growth fire has been monitored by the DTS system over a period of 6 minutes before the "HotFoam" deluge system has been activated. The maximum detectable temperature during the steady state stage was 706°C.

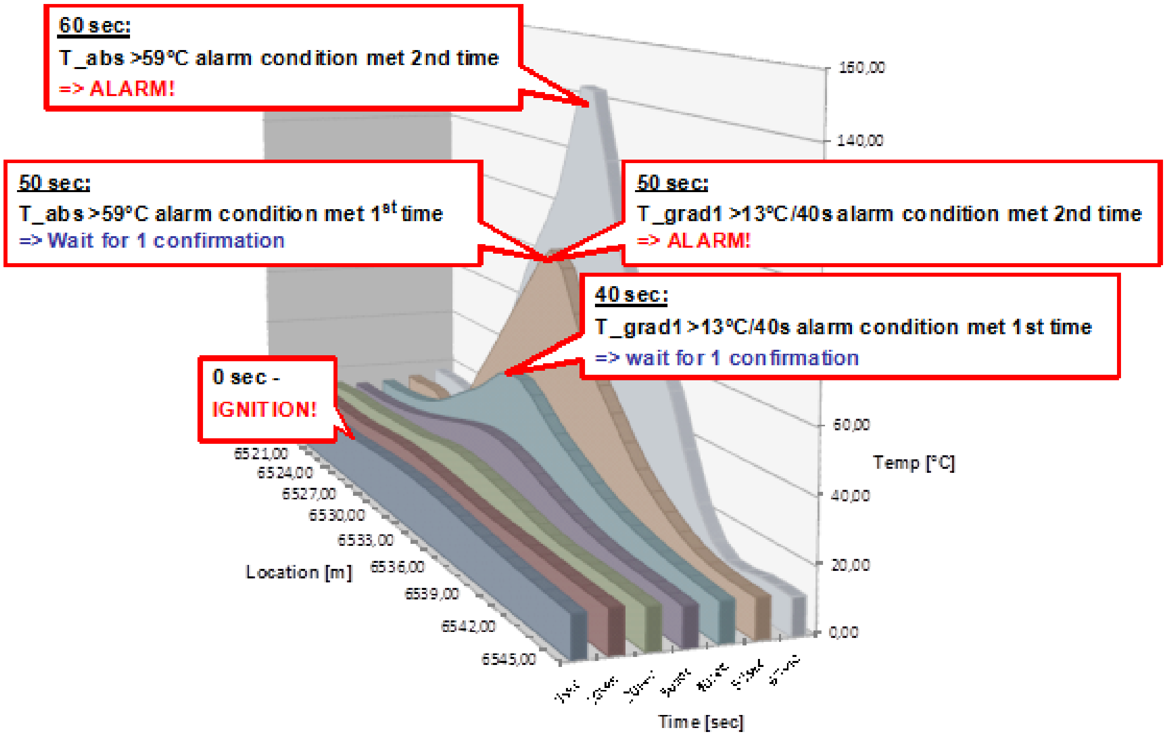


***Figure 2: Fire Development in the early stage of the hidden pool fire with diesel***

After activation of the "HotFoam" deluge system the DTS Linear Heat Detection System observed a rapid drop in temperature with a cool down rate of approx. 60°C / 10s. Within 80 seconds the temperature dropped from 700°C to less the 200°C but it needed additional 6 to 7 minutes to cool down the fire area then safe to be entered.

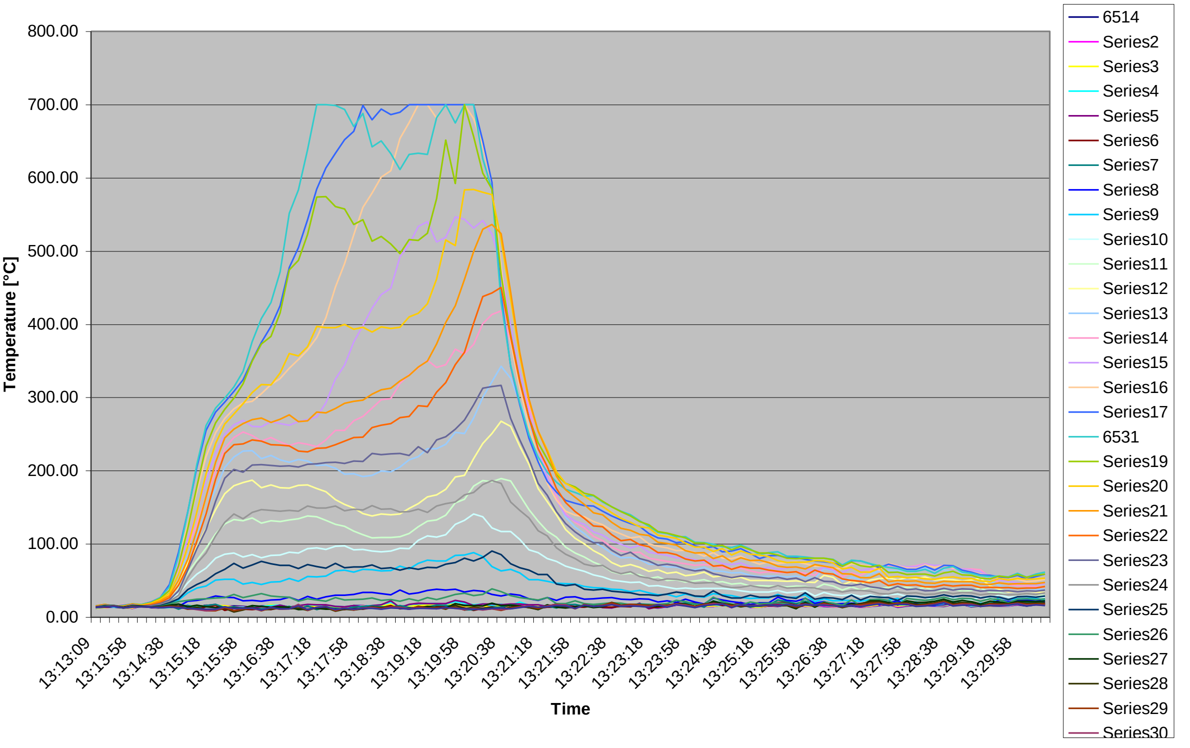


***Figure 3: Entire fire development at different point of locations inside the tunnel mock-up. Ignition time on the left side – overall 17 minutes of real time fire monitoring.***

## Conclusions

The 1:1 fire tests conducted in the SP Technical Research Institute of Sweden in Boras, Sweden in co-operation with Tyco Fire /Scum demonstrated the capability of a DTS Linear Heat Detection System to detect different fires fast, reliable and to monitor the fire development even with temperatures beyond 1000°C. The DTS Linear Heat Detection system is able to provide vital information about fire location, fire size, heat release and fire spreading during the entire process of the incident. Therefore the DTS technology becomes an ideal measurement instrument to supervise the activation and execution of prevention systems like fire suppression system, emergency ventilation system and the mission of fire brigades.

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*** further information available in: Proceedings from the Third International Symposium on Tunnel Safety and Security, Stockholm, Sweden, March 12-14, 2008 "Fire suppression and structure protection for cargo train tunnels: Macadam and HotFoam" Anders Lönnermark, Magnus Bobert, SP Technical Research Institute of Sweden, Boras, Sweden, Peter Kristensen, Mats Helltegen, Svenska Skum AB, Tyco Fire Suppression & Building Products, Kungälv, Sweden**