# Tunnel on Fire:

## Fast, precise and dependable heat detection


### Abstract

On October 17th and 18th, 2013, major fire detection tests were carried out in the Einhorn Tunnel in Schwaebisch Gmuend, Germany. Participants included the fire department and officials from the road construction and tunnel operator teams.

A total of **11 controlled fire tests** were designed to stringently test the tunnel itself, AP Sensing's Linear Heat Detection system, and the smoke extraction system. The fiber-optic based *Linear Heat Series* from AP Sensing played a decisive role in all of the tests. The tests (most of which were carried out following **RABT – the German Guidelines for Road Tunnel Equipment and Operation**) simulated burning autos, to ensure the fires were detected quickly by the sensor cable installed along the tunnel ceiling. This ensures rapid responses from the firefighting personnel and smoke removal systems, with the overall goal of ensuring the overall personal safety of any passengers in the tunnel.

In every test the detection time was lower than the Guideline requirements. In the case of the RABT tests, fires were detected in **less than half the time** specified. Even very small fires with only **0.5 MW (1/10 the energy of the RABT Standard for Fires)** were reliably detected and their position localized in a very short time.


## Introduction

Security systems for underground infrastructures need to meet or exceed a high level of security standards.

The **important points to consider**:

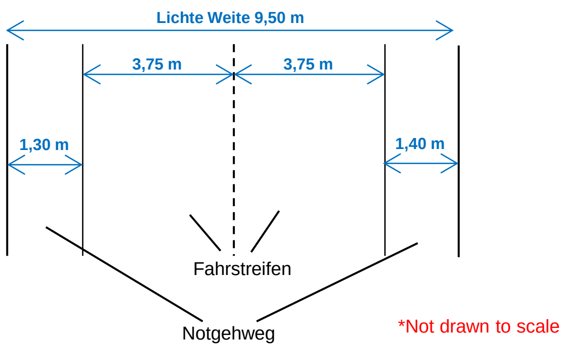
- Fast and dependable heat detection with precise localization
- Automatic activation of security controls and alarms for emergency services, especially for the fire department
- Safe evacuation for persons in the tunnel

*Picture 1: Tunnel entrance*

A good example of such an automatic setup is the Einhorn bypass tunnel in Schwaebisch Gmuend, in southwest Germany. Should a fire break out inside the tunnel, the fire detection system releases an alarm, and also the zone and precise location of the fire. This information enable the security system to set the appropriate smoke removal steps into action.

The tunnel, which is 2230 m long (W x H: 9,50 m x 4,70 m – see Drawing 1, "Internal tunnel dimensions"*) is monitored by a fiber optic sensor cable with a length of 3182 m. This is installed along the middle of the tunnel ceiling. The sensor cable measurements are evaluated via two AP Sensing Linear Heat Series devices. They detect the fire independently of each other and issue the alarm to the control system through Relays and Modbus.

*Picture 2: Tunnel interior*




*Drawing 1: Internal tunnel dimensions*

## Test preparation and execution

**Eleven fire tests in 5 different locations** in the tunnel were developed to test the fire detection (the time between the outbreak of a fire and its recognition), the spread of smoke, and the functionality of the smoke extraction system.

In order to simulate different real-life scenarios, the tests were carried out with different fire loads (gasoline/petrol and gas), as well as with varying wind velocities.

A fire as defined by RABT was made with a large tub of petrol -- 20 l in a 4 m² space. The starting value for the wind speed was 6 m/s.

To simulate a fire in an engine block a rebuilt auto was used, with gas pipes installed in the interior. Gas was supplied from a central source, but that source was some distance away from the test location. Because a gas fire produces no smoke, two bottles of pressurized smoke were used just next to the test location, in order to simulate real smoke from a fire.

In terms of fire detection, the sensor cable has the highest priority. The complete system (DTS device, sensor cable and the differently-defined temperature zones along the cable) are configured in accordance with the EN 54-5 Class A1 standard. In addition to the pre-defined alarm parameters, one additional parameter was defined for the test cases (the *Linear Heat Series* is VdS-certified). The following 5 alarm criteria were therefore defined per zone:

- Maximum high temperature: 60° C
- Thermal-Differential Quotient 1: 13° C auf 40 s
- Thermal-Differential Quotient 2: 17° C auf 120 s
- Thermal-Differential Quotient 3: 28° C auf 360 s
- Difference to zonal differences:
  - a) Entrance and exit areas: 25 °C
  - b) Tunnel interior: 20 °C

The DTS measurement interval was set to 10 seconds.

*Picture 3: Gas fire test*

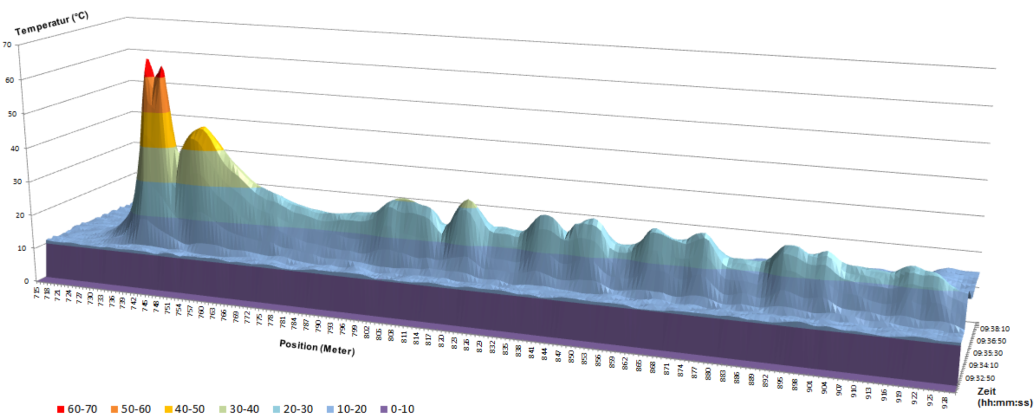
## Results

The 11 fire tests that were performed on October 17th and 18th, 2013, all delivered very clear results. In addition to a RABT test (5 MW), which was carried out in accordance to all standards, even smaller fires, for example 0.5 MW (1/10 of a RABT fire), were simulated and were successfully detected.

| Test number | Zone number | Type of fire | Energy of fire | Wind speed | Max (60 °C) | Gradient 1 (13°C / 40 s) | Gradient 2 (17°C / 120 s) | Gradient 3 (28°C / 360 s) | Max Delta | Max Temp °C |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | Petrol | 5 MW | Start with 6 m/s Peak 3,3 m/s | 00:54 (DTS East) | 00:29 (DTS West) | 00:34 (DTS East) | 00:39 (DTS West) | 00:34 (DTS East) | 79,62 |
| 2 | 7 | Petrol | 5 MW | Start with 6 m/s Peak 4 m/s | 00:63 (DTS East) | 00:33 (DTS East) | 00:38 (DTS West) | 00:43 (DTS East) | 00:33 (DTS East) | 72,84 |
| 3 | 7 | Petrol | 2 MW | 2 m/s Air Flow (Start & Peak) | -- | 00:53 (DTS West) | 00:63 (DTS West) | -- | 00:63 (DTS West) | 39,19 |
| 4 | 2 | Gas | 1,5 MW | 1,2 m/s Air Flow | 00:58 (DTS East) | 00:33 (DTS West) | 00:33 (DTS West) | 00:43 (DTS West) | 00:33 (DTS West) | 101,73 |
| 5 | 2 | Gas | 0,5 MW | | 02:07 (DTS West) | 01:17 (DTS West) | 01:27 (DTS West) | 01:47 (DTS West) | 01:42 (DTS East) | 89,37 |
| 6 | 22 | Gas | 0,5 MW | - 1 m/s Air Flow | 02:18 (DTS West) | 00:48 (DTS West) | 00:53 (DTS East) | 01:53 (DTS East) | 00:43 (DTS East) | 104,2 |
| 7 | 22 | Gas | 7 MW | - 5,3 m/s Air Flow | 01:44 (DTS East) | 00:44 (DTS East) | 00:49 (DTS West) | 01:14 (DTS East) | 00:44 (DTS East) | 115,14 |
| 8 | 35 | Gas | | | 02:31 (DTS West) | 00:31 (DTS East) | 00:41 (DTS East) | 00:51 (DTS East) | 00:41 (DTS East) | 94,5 |
| 9 | 35 | Gas | 0,75 MW | | 01:16 (DTS East) | 00:36 (DTS East) | 00:36 (DTS East) | 00:56 (DTS East) | 00:36 (DTS East) | 103,04 |
| 10 | 35 | Gas | 0,5 MW | | 07:10 (DTS East) | 01:00 (DTS East) | 01:10 (DTS East) | 05:10 (DTS East) | 01:10 (DTS East) | 74,23 |
| 11 | 32 | Gas | 1 MW | | 01:08 (DTS East) | 00:28 (DTS East) | 00:33 (DTS West) | 00:43 (DTS West) | 00:38 (DTS East) | 109,99 |

*Table 1: Detection times*

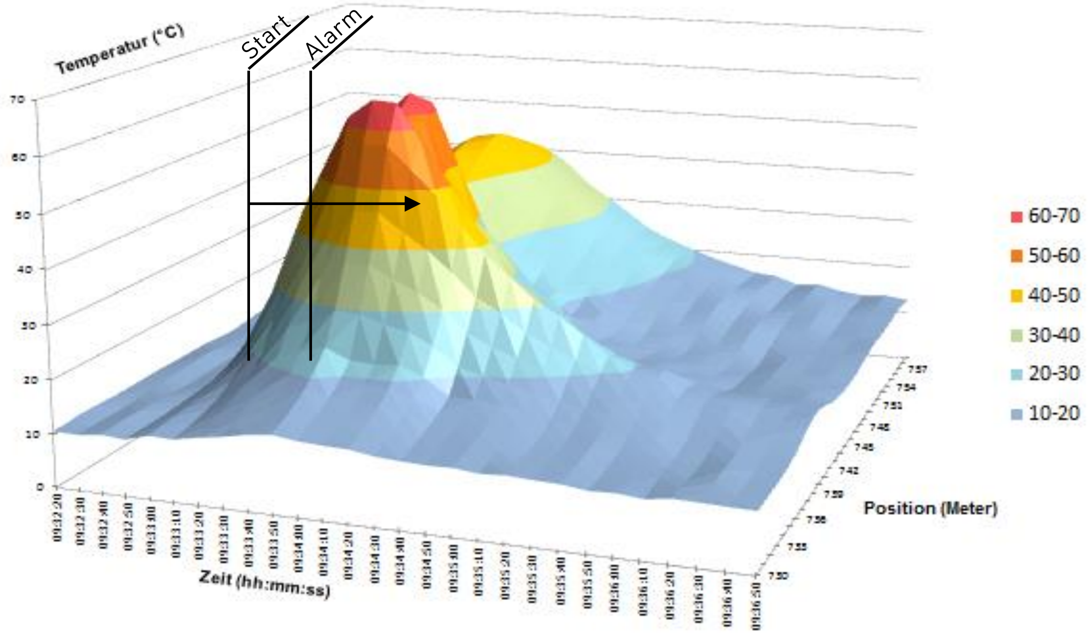
As shown, all fires were detected within the required time limits. For the test carried out under RABT conditions an alarm was triggered after 29 seconds – much faster than the required time of 60 seconds. The alarm was triggered because of the thermal differential quotient of 1. Shortly thereafter the alarm threshold of 60 °C was reached. Graphic 1 *„Second test – Temperature over distance“* shows both the rapid temperature rise as well as the heat dissipation in the tunnel.




*Graphic 1: Second test – temperature over distance*

One can see how rapidly the temperature rises in the test area. Just beyond the test area the temperature has sunk to below 30 °C. This phenomena is due to the ventilation outlets in the tunnel ceiling. As soon as a fire is detected all of the pre-defined automatic activities to fight the fire are started, including the ventilation. The smoke is quickly transported up and away from street level, a major safety factor; at the same time a clear view of the fire and its surroundings is maintained for further fire-fighting activities.

In Graphic 2 *„Second test – Temperature over time“* the fast and precise temperature measurement of the sensor cable is demonstrated. As shown, the temperature rises above 60 °C (the alarm has already been triggered by then). After the fire test is over, the temperature cools rapidly to below 20 °C.



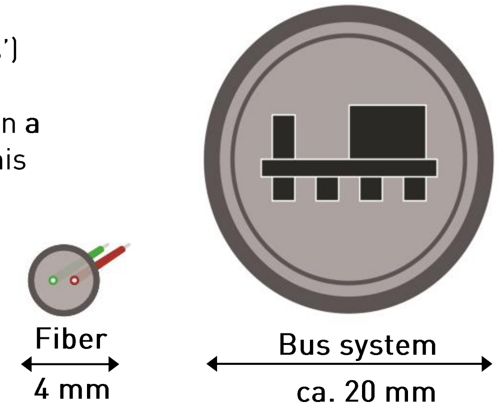

*Grafik 2: Second test - Temperature over time*

The fiber optic based system detects the fire and its precise location as well as the size of the fire and the direction it is spreading, due to the wind factors in the tunnel. And all of this data is updated continuously, providing valuable information for additional fire-fighting measures, like the evacuation of people in, and how the fire department should coordinate their activities.

**The AP Sensing *Linear Heat Series* is therefore the ideal fire detection system for traffic tunnels and offers the highest possible measure of protection and security.**

**Why is the fiber optic system so much faster and more precise?**

Electrical bus systems (also called 'point systems') use a sensor cable with a diameter that is ca. 5x greater than the fiber optic solution. This results in **a total mass that is 30x greater than the fiber.** This results in a much slower response time.




Fiber optic sensor cable:

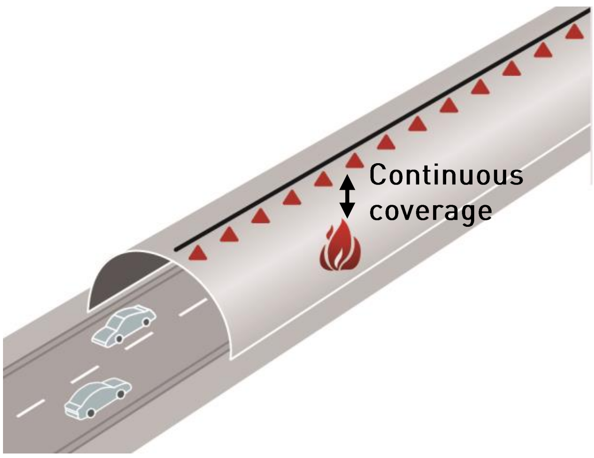
- **15 kg/km**
- no active components in the cable (**100% passive**)
- very **fast reaction times**

Typical electrical sensor cable

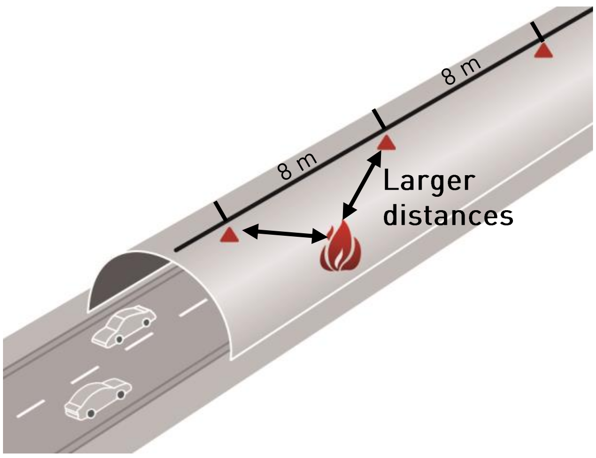
- **450 kg/km**
- active sensors every 4 – 8 m
- 30x more mass – **slower reaction times**

Point systems typically have their active sensor points spaced 4 to 8 m apart. A fiber optic cable operates like one very long sensor along the entire length of the cable.

In case of a fire, a point system needs a longer amount of time (because of the distance from the fire to the sensor, which can be up to 4m) before the heat has reached the sensor. Considering that the heat is also dissipating within the tunnel space and through wind effects, this amount of distance can make a significant difference.




- alarms triggered fast and reliably, even with smaller fires




- larger fires and/or more time needed to trigger an alarm

## Conclusion

The thorough set of fire tests that were carried out in the Schwaebisch Gmuend "Einhorn Tunnel" demonstrate **the fast and precise fire detection** capabilities of the AP Sensing *Linear Heat Series*.

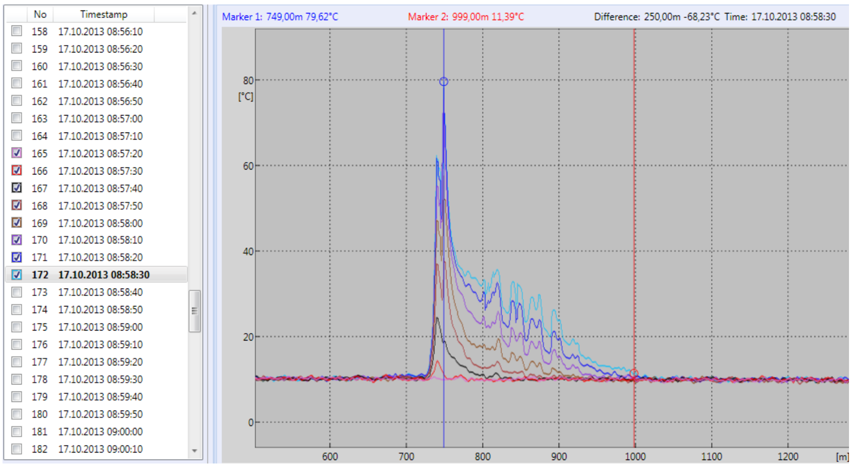
Every fire was detected and localized in less than the prescribed time. For the RABT test the AP Sensing *Linear Heat Series* detected the fire in 33 seconds. This is **45% faster than prescribed by the RABT standard** (fire energy 5MW; fire detected within 60 seconds).

In addition, even smaller fires were detected successfully: a **fire with only 0,5 MW (10 % of the fire energy required by the RABT test) was detected within 60 seconds.**

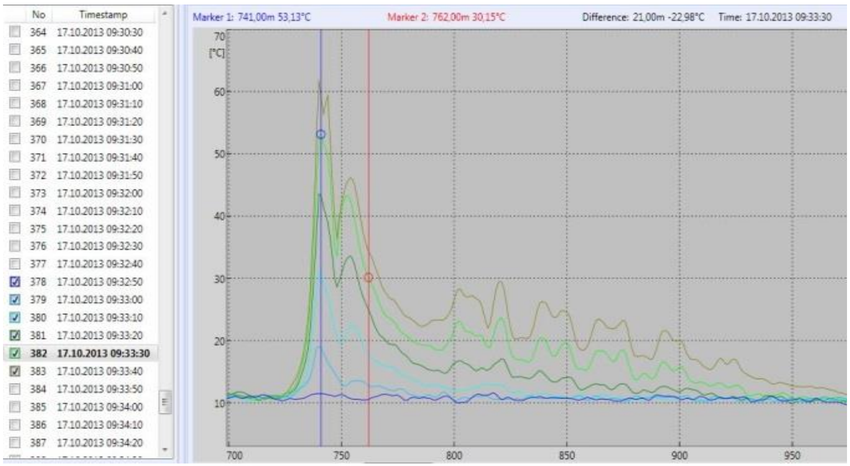
**For tunnel operators the speed and reliability of the AP Sensing system is a major advantage**, when even smaller fires can be detected and countermeasures (closing the tunnel, activating smoke exhaust systems, rapid deployment of the fire department) can be quickly initiated.

# Appendix

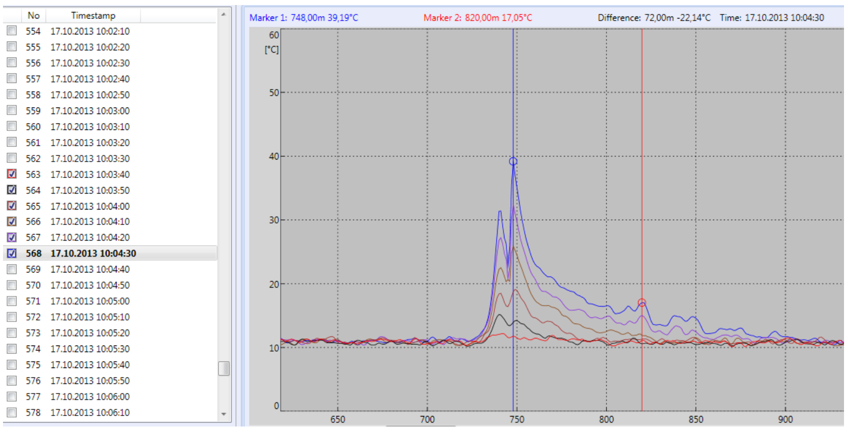
## Temperature graphs of the fire tests 1 through 3




*Test 1 (Petrol fire): 5 MW ; Detection time: 29 s*

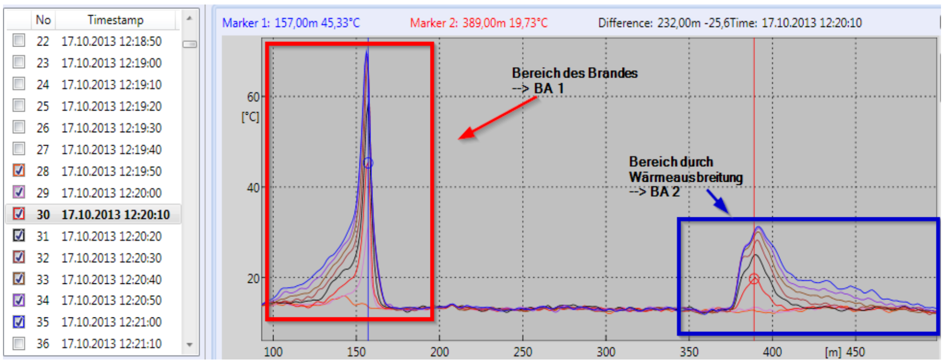



*Test 2 (Petrol fire): 5 MW ; Detection time: 33 s*

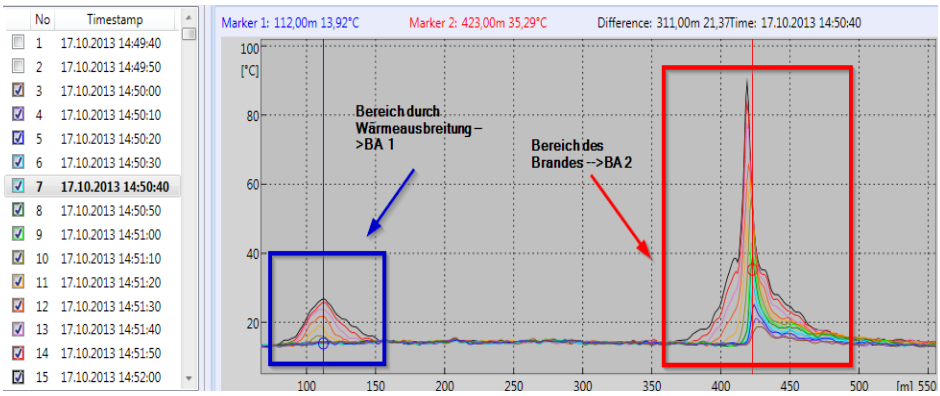



***Test 3 (Petrol fire): 2 MW ; Detection time: 53 s***

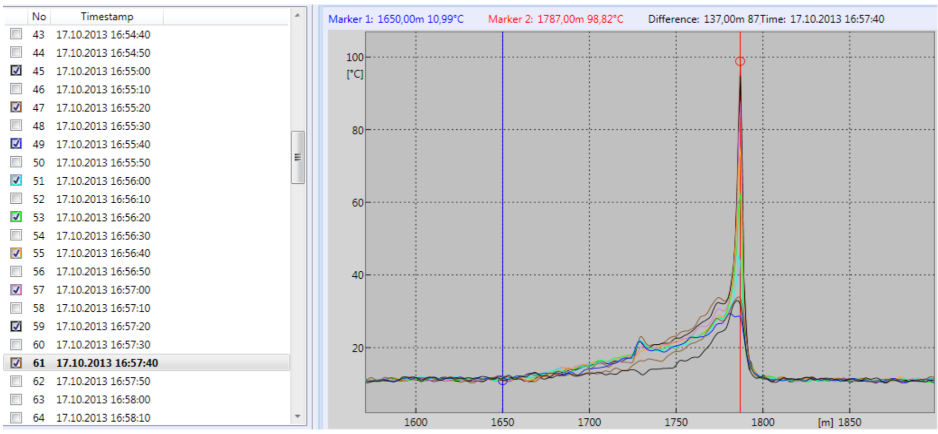
## Temperature graphs of the fire tests 4 through 6




*Fire test 4 (Gas fire): 1,5 MW ; Detection time: 33 s*

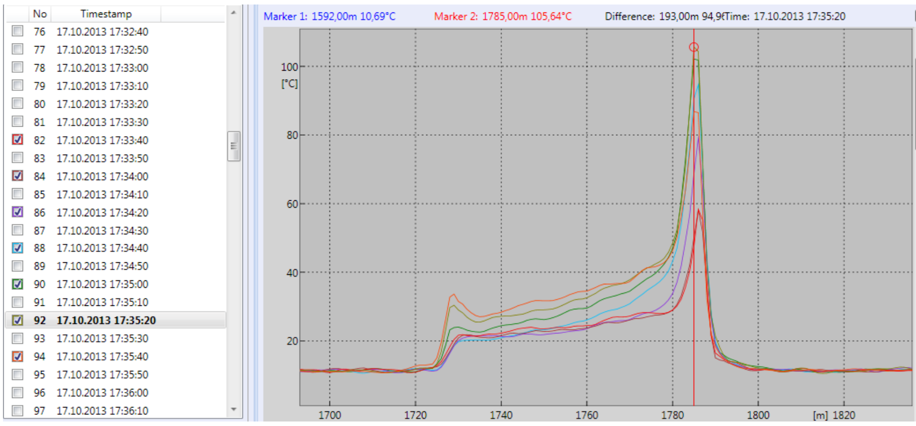



*Fire test 5 (Gas fire): 0,5 MW ; Detection time: 77 s*

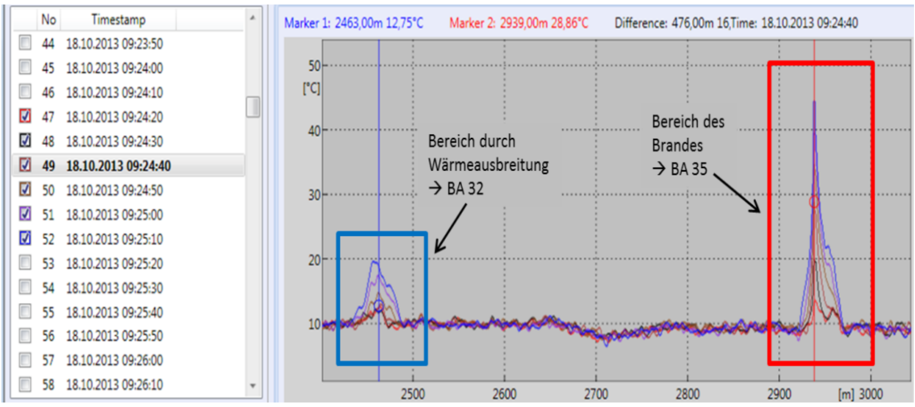



*Fire test 6 (Gas fire): 0,5 MW ; Detection time: 48 s*

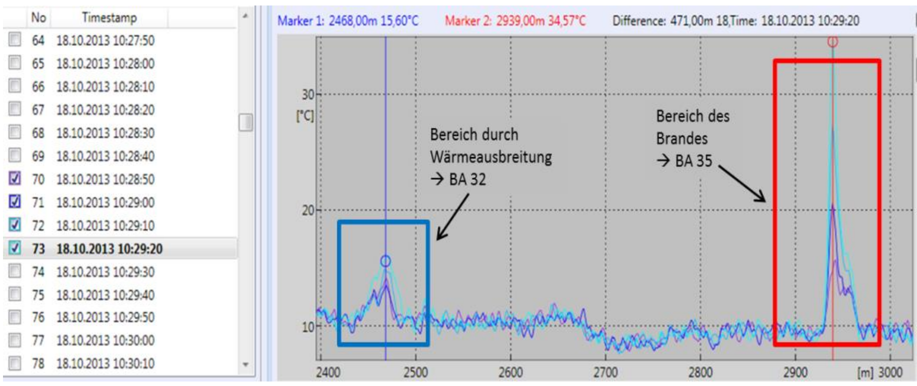
Temperature graphs of the fire tests 7 through 9




*Fire test 7 (Gas fire): 7 MW ; Detection time: 44s*

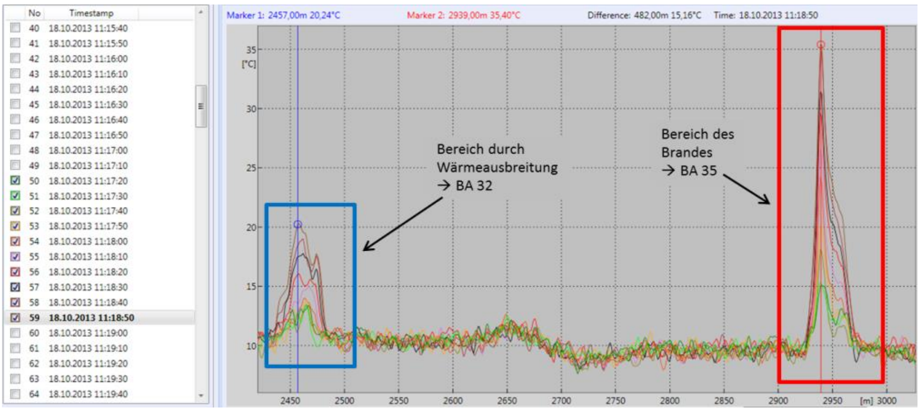



*Fire test 8 (Gas fire); Detection time: 31 s*

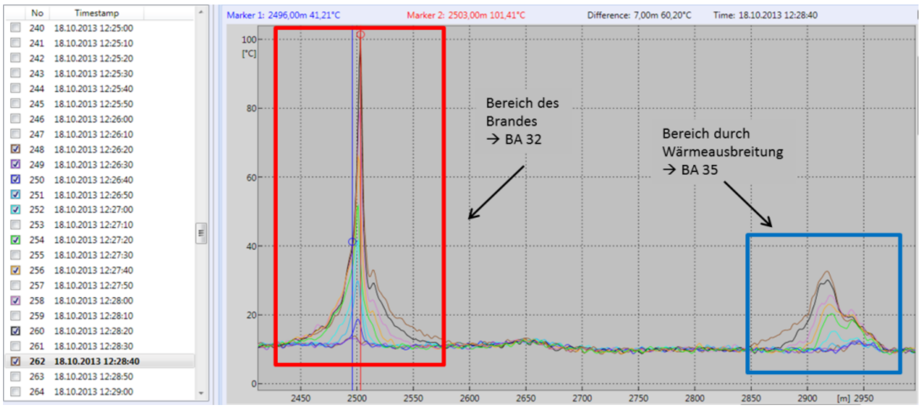



***Fire test 9 (Gas fire): 0,75 MW ; Detection time: 36 s***

Temperatur graphs  of the fire tests 10 and 11

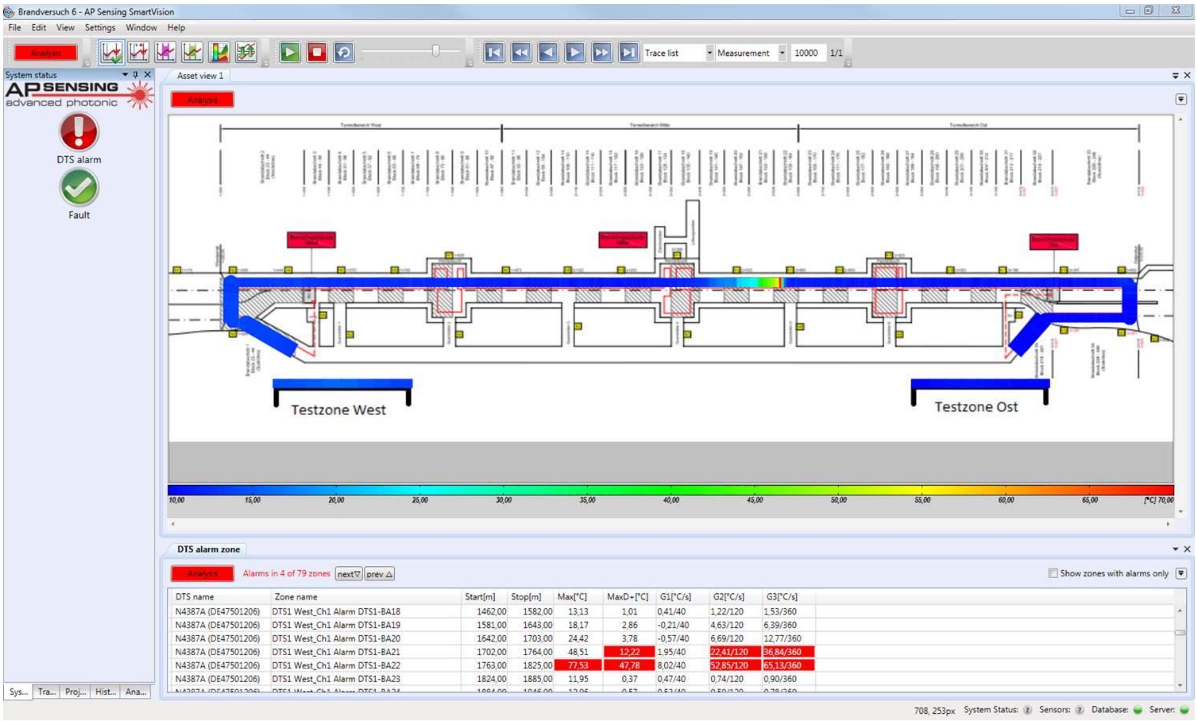



*Fire test 10 (Gas fire): 0,5 MW ; Detection time: 60 s*




*Fire test 11 (Gas fire): 1 MW ; Detection time: 28 s*

## AP Sensing´s SmartVision Asset Visualization Software: Fire test 6




*SmartVision - Fire test 6 (Gas fire): 0,5 MW ; Detection time: 48 s*