Test Duct for Multi Sensor Fire Detectors

Abstract
In the course of developing a testing concept for multisensor fire detectors and multi-sensor aspirating systems a new test bench has been built up at the department of Communication Systems at the University Duisburg-Essen. Main part of this test bench is a duct which provides the opportunity of performing a stability test of multisensor fire detectors while showing a high grade of repeatability. It needs to be stressed that the test bench has been developed to be used for carrying out a function-based stability test which allows the fire detector to be evaluated as one system including the influence of data processing. However, the new multi criteria duct can also be used for development purposes and/or to simulate potential conditions of deceptive alarm.

Introduction
The new test duct has a similar application area as the NIST’s Fire Emulator / Detector Evaluator FE/DE. However, the main task of the FE/DE is to simulate reality-like fire and non-fire scenarios and not to perform stability tests in order to quantify the response behaviour of fire detectors. In contrast to the open duct principle of the FE/DE the presented multicriteria duct is self-contained and provides for an improved repeatability and for linear rising concentrations of fire phenomena. It can be used for fire and non fire tests. The new test duct is applicable for detector design, development and test.

Within the multi criteria duct defined mixtures of a) smoke / particles b) gases and c) heat can be generated at flow streams between 0,1 m/s and 3,0 m/s. The single fire (and non-fire) phenomena can be generated the following ways:

a) smoke / particles:  - by leading in fire emissions or
                       - by leading in paraffin oil or
                       - by leading in (dust) particles as potential sources of false alarm
b) gases:
- by leading in fire emissions *and/or*
- by leading in single gases or gas mixtures from gas cylinders
  optionally water vapour can be injected (if necessary)
c) heat:
- by heating up the duct material by means of heating cables *and*
- by simultaneously leading in hot air to heat up the air in the duct

This paper shall show the setup of the new test bench as well as results of repeatability measurements regarding smoke density, gas concentrations and temperature.

**Technical Background of implemented features**

For testing multi sensor fire detectors with gas sensors it is important that the combustion gas mixture is not changed by the test equipment to a greater extend. So the new test duct uses a low temperature heating concept due to the reason that zones of high temperature might promote chemical reactions among the gases. Furthermore, the presence of silicone compounds has a potentially poisoning effect on some gases which might result in a non-reversible change of the sensing properties. Another unwanted effect has been excluded or minimised by the use of teflon-coated stainless steel. However, the use of chemical elements like zinc or copper might promote chemical reactions with the combustion gases. In addition further positive effects are reached due to the choice of the duct material: the metal is protected against oxidation, the whole duct can easily be grounded and the danger of water condensation at the heated metal surface is almost excluded.

The multi criteria duct is self-contained in order to reach a high grade of repeatability and almost linear rising concentrations of fire phenomena. A sheet metal of not more than 1 mm thickness is used to achieve a low heating time constant for the duct material. The maximum temperature rise of the duct (4 K/min) has been chosen with respect to the development of the moderate burning open test fire TF 1.

The testing of heat detectors according to EN 54–5 is not realised yet. For this purpose the heating concept would have to be upgraded to achieve a temperature rise of 30 K/min. However, this feature is not relevant for testing multi sensor fire detectors.
To achieve a homogeneous heating of the test duct the aerosol inside the duct and the duct material are heated up by different heaters. The whole surface of the duct is heated by 290 meters of heating cable, the inspection windows are heated by using heatable window panes. Currently the duct air is heated by means of a hot air blower. In the next time the blower will be replaced by a heater which will be mounted inside the duct. First experiments with the hot air blower have shown a bad influence on both linearity and repeatability of the rise of fire phenomena.

Figure 1 visualises a simulation of the heating concept. The left curve of Figure 1 shows the temperature rise of the air at the measuring zone being produced by the hot air blower working at a flow-rate of $\dot{V} = 200 \text{ l/min}$ and a temperature of $T = 60^\circ C$. The temperature rise of the duct material is shown in the right curve of Figure 1. It is produced by 290 meters of heating cable being operated at $P = 5500W$.

![Figure 1](image-url)

Figure 1: Simulated temperature of the duct air (left curve) and the duct material (right curve)
Figure 2: Setup of the test bench
The test bench setup
The setup of the test bench is printed in Figure 2. The technical data of the test bench is given below. Up to date photos of the test duct are pictured in Figure 3 and in Figure 4.

Technical data of the test duct:
Function: Testing of fire detectors with smoke-, heat- and / or gas-sensors
Temperature range: 20…60°C
Wind velocity: 0,1…3,0 m/s
Inserted substances: user-defined
Temperature rise: 0…4 K/min
Max. heat power: 8 kW
Measurement:
- smoke density: Transmitted light: MIREX
  Ionisation chamber: MIC
- gas concentrations: Infrared photometry: Uras 14
- temperature: PT 100
Volume: 1200 l (Mean airway 7,5 m; Cross section 0,4 m x 0,4 m)
Principle: self contained duct
Results of repeatability measurements

Particle density:
A Lorenz AGW paraffin oil generator was used to produce a defined rise of particle density within the duct. For first evaluation studies the following parameters have been chosen:

Frequency of the internal valve: 1.5 Hz
Total flow rate: 50 l/min and
Paraffin oil temperature: 100°C

With these parameters the following rise of smoke density can be measured in duct:

$$\frac{\Delta m}{\Delta t} \approx 0.07 \frac{dB}{m \cdot min}$$

The gradient fulfils the specifications for testing smoke detectors according to EN 54-7:

$$0.015 \frac{dB}{m \cdot min} \leq \frac{\Delta m}{\Delta t} \leq 0.1 \frac{dB}{m \cdot min}$$

The measured data is graphed in the Figure 5 to Figure 7. The studies have been carried out without using the heating system.
Figure 5: Smoke density measurement with the MIREX

Figure 5, Figure 6 and Figure 7 show a very high grade of repeatability. The rise of smoke density is almost linear. The repeatability factor for the MIC and the MIREX is $\frac{1.04}{0.96} = 1.08$. It describes the maximum factor of deviation regarding the highest and the lowest value being measured at the same point of time.

Figure 6: Smoke density measurement with the MIC
Temperature rise:

The temperature rise in the measurement zone shows the function of the heating system (Figure 8). Until the end of the test a temperature rise of $\Delta T \approx 27^\circ K$ was reached. The presented evaluation studies already show a high repeatability (repeatability factor: 1.04). However, currently no kind of heating control is implemented. A later implementation of a heating control is planned to obtain a high grade of flexibility for future investigations.
Rise of gas concentrations:

For generating combustion gases 3 cotton wicks have been burned down in the burning chamber which was provided with clean air at a constant flow rate of 42 l/min and a relative humidity of 50 %. The concentrations of carbon monoxide and carbon dioxide have been measured (see Figure 9 and Figure 10).

Figure 9: Measurement of carbon monoxide concentration

Figure 10: Measurement of the rise of carbon dioxide concentration
Former investigations at University Duisburg-Essen have already shown a high repeatability of gas concentrations being generated by cotton wicks being burned under defined conditions. According to the expectations also the current test results presented in the Figure 9 and Figure 10 show a low grade of deviation and a highly linear rate of rise. For both carbon monoxide and carbon dioxide a repeatability factor of 1.06 was reached. The studies have been carried out without using the heating system.

**Conclusion**
The first evaluation studies which have been performed with the new multi criteria test duct have shown absolutely promising results. Both the rate of rise and the repeatability of the generated fire phenomena already meet the initial objectives at a very early stage. These objectives have been set up in order to perform a defined and repeatable stability test for multi sensor fire detectors. The repeatability factors which have been achieved regarding the rise of temperature, particle density and gas concentrations are smaller than 1.1. This is far below the permitted max. change of response behaviour (factor 1.6) a detector may show according to EN 54. However, additional tests need to be performed for final conclusions concerning all repeatability issues.

In the future more automatic functions have to be integrated. Magnetic valves and the heating option shall be controlled by PC in order to allow fully automated testing. Furthermore, it is intended to implement a continuously adjustable temperature control (0…4 K/min) and a complex humidity measurement / control unit. Further work will also be done on the implementation of vapour and dust generators and tests concerning slowly developing fires. Beyond that the basic concept of the new duct shall serve as low-cost testing concept for multi sensor fire detectors by providing the opportunity to upgrade existing EN 54 - test benches with low financial efforts.
References


/3/ U. Müller et al., Design and functionality of a new test duct for multi sensor fire detectors, Proceedings of EUSAS-Workshop on “Multiple Sensor based (Fire-) Detectors; Design and Testing”, Lübeck/Germany, June 2004