Characterization of Dust and Water Steam Aerosols in False Alarm Scenarios - Design of a Test Method for Fire Detectors in Dusty and in Highly Foggy Environments

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Optical smoke detectors are designed to detect small concentrations of smoke to ensure a fast and reliable detection of arising fires. Unfortunately the complex task of avoiding false alarms is not completely addressed. In contrast to the well standardized methods for the evaluation of the detection capability of a smoke detector, there is a lack of reproducible and representative test methods concerning the false alarm susceptibility with regard to nuisance aerosols. Even though the standard of optical smoke detectors is very high, false alarms caused by dust and water steam consistently happen. A recent German study says that about 10 % of false alarms are caused by dust and another 10 % are caused by water steam.

For this reason several dust and water fog and steam sources have been analyzed during a big field campaign. The focus was on the dust properties caused by construction works as well as on water steam properties in the surrounding of an installed smoke detector. In a comprehensive test campaign typical size distributions of water droplets in common false alarm scenarios, as showering have been analyzed. Finally a new approach for the test of optical smoke detectors regarding their susceptibility to false alarms due to the nuisance aerosol dust is presented.

Several dust sources have been analyzed (e.g. grinding concrete and red bricks as well as sanding wood). All measurements were performed in a construction tent with a footprint of about 20 ft by 10 ft respectively and 6.5 ft to 9 ft height. The working distance to the measuring devices was varied in order to analyze the aging process and the resulting dwell time of dust particles. The particle size distribution (measured by the HELOS analysis system, Helium-Neon Laser Optical System) as well as the time-dependent dust density variation was measured. The dust density was measured with the EN54 reference measuring device MIREX (Measuring InfraRed EXtinction) mounted close to the HELOS system at the level of 6.5 ft. The working distance to the measuring devices was about 5.5 ft and 13 ft respectively.

Depending on the tool for work, particles were blown into the air with high speed during all performed tests, leading to many particles being bigger than 100 µm. The measured particle sizes and their median were smaller than 360 µm. Based on the mass 90 % of the particles are smaller than 200 µm. For the evaluation of false alarms of optical smoke detectors caused by dust those distributions measured in a bigger distance from the source of dust are relevant, as they are closer to real life situations.

Designing a test procedure for the evaluation of the behavior of smoke detectors in non-fire situations the focus should be on dust particles smaller than 100 µm because it is well known that particles > 100 µm settle down very fast. The analysis of dust properties caused by construction works in comparison with standardized test dusts showed that e.g. the quartz-free vacuum cleaner test dust DMT Dolomite 90 as test dust matches the specifications. 99 % of the particles are smaller than 100 µm, 90% are smaller than 50 µm and 10% are smaller than 2 µm. DMT Dolomite 90 test dust consists of particles in the same range as the ISO test dusts. It covers the whole dust range of "ISO ultrafine" (A1) and "ISO fine" (A2). However it shows the advantage of being quartz-free.

The presented test apparatus is a very helpful and important tool for developers as well as for system designers giving the possibility of performing reproducible and well characterized dust tests. It will find its application in the field of detector development, detector calibration, and having now a quantitative decision criterion to find the optimal detector for a specific scenario.

The test apparatus consists of a test duct, an aerosol generator (Palas RBG 1000), a bipolar corona discharger to neutralize the charge of the generated dust and to reduce the dust accumulation at the channel walls, the obscuration meter (Lorenz AML) and a LabView software for controlling and timing of the aerosol generator. The duct consists of two concentric stainless steel rings with a diameter of 12 in and 24 in respectively and a linear connection between the left and right semi-circles, the cross-section is 6 in × 6 in. The flow velocity of 1 m/s is generated by an encapsulated motor with a mounted airscrew.

Based on the EN54 test-standard for the directionality or the response behavior of a smoke detector the increase of the aerosol concentration was set in the range $0.015 \leq \Delta m / \Delta t \leq 0.1$ (dB m^{-1} min^{-1}). Due to the implemented feed control, a linear slope of the dust concentration in the test apparatus could be achieved, similar to smoke tests according to EN54. Typically the increase is about 0.06 dB m^{-1} min^{-1} to simulate a slowly increasing pollution. On the other hand, construction works close to an optical smoke detector may cause a fast increasing dust exposure. For this reason a second linear increasing ramp of 0.5 dB m^{-1} min^{-1} was implemented.

The development of a test apparatus for the evaluation of the behavior of smoke detectors in non-fire situations is a first step to provide an important tool for developers as well as system designers. Due to the fact that dust is the major source of false alarms in airborne applications the developed test apparatus became part of a test standard for optical smoke detectors in aircraft applications. The main topics of the developed test apparatus have been adopted by the Aerospace Standard AS 8036. The goal is that no alarm or at least a much later alarm shall occur as a result of normal dust present at the detectors' location. This standard specifies minimum performance standards for optical smoke detectors intended for use in protecting aircraft cargo compartments, galleries, electronic equipment bays and other similar installations.

The second part of the presentation describes an investigation of typical false alarm scenarios for smoke detectors produced by water aerosols and introduces an apparatus for testing detectors in a high humidity environment with suspended fog.

The particle size produced by the showering process was analyzed in a second extended field campaign. A common shower cubicle with the size of 6 ft x 6 ft was used. The particle size distribution of water aerosols was measured by the HELOS measuring system and the light extinction by the MIREX device at detector position in a height of 7.5 ft. The aerosols were measured in two different distances from the bathroom door (3 ft and 6 ft). Before the measurement the shower was turned on for several minutes to create a typical vapour saturated environment in the bathroom. After 5 minutes the bathroom door was opened and the particle size distribution as well as the extinction was measured. The peak value of the measured (volume based) particle size distribution was at a diameter of about 15 μm.

In a second step the aerosol characteristic of different water fog and steam sources have been analyzed in a field campaign finding the proper source to reproduce the showering steam situation. False alarms triggered in foggy environments could be the effect of two processes: (i) the condensation of water on the optics due to a high dew point temperature of the optics or (ii) the light scattering process of the fog aerosol. Focus of the test apparatus is the second process, i.e. the production of a foggy aerosol. As aerosol generator a high end airbrush pistol as source for water mist showed the best match to the requirements. The peak value of the produced particle size distribution matches the measured values of the performed measuring campaign. The airbrush works with compressed air and distilled water to prevent calcification of the airbrush nozzle.

The developed test apparatus is similar to the test apparatus for dust tests. The duct consists of two concentric stainless steel rings with a diameter of 12 in and 24 in respectively. The cross-section of the duct is 6 in × 6 in. The flow velocity of 1 m/s is generated by an encapsulated motor with a mounted airscrew. The whole apparatus consists of an obscuration meter (Lorenz AML), humidity and temperature sensors and a LabView software for controlling and timing. For reproducible test conditions a linear increasing water steam ramp of 0.5 dB m^{-1} min^{-1} was implemented. Depending on user requirements also special scenarios like very fast concentration slopes comparable to a realistic shower scenario can be performed.

In high humidity environments evaporation and saturation processes play an important role for the life time of water droplets and are mainly determined through temperature and relative humidity. The life time of droplets increases at higher humidity and temperature values and thus has a strong influence on the control. This climatic control is implemented in the CPU of the duct and it provides constant start conditions for each test, e.g. a relative humidity about 50 % to 60 %.

Two test systems for the evaluation of the behavior of optical smoke detectors in non-fire situations were designed, set up and analyzed. Both devices allow tests with a controlled linear increase of dust concentration and water droplet concentration respectively in a reproducible manner. But the ramps are not limited to the linear behavior. Due to the control systems also other ramp shapes can be performed.

The presentation describes two test methods based on results made with the dust and water steam apparatus and is rounded up with several plots showing the behavior and the reproducibility of the two systems, giving an outlook for further investigations.