AUBE '01

12TH INTERNATIONAL

CONFERENCE ON AUTOMATIC FIRE DETECTION

March 25 - 28, 2001
National Institute Of Standards and Technology
Gaithersburg, Maryland U.S.A.

PROCEEDINGS

Editors: Kellie Beall, William Grosshandler and Heinz Luck

NIST CENTENNIAL 1901-2001

EUSAS

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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Concepts for the test of volumetric fire detectors

Abstract
This paper covers the question, if it is possible to apply to volumetric fire detectors a testing concept, which was introduced in intrusion detector testing. The concept follows a so-called 'solid-state' approach, leading to the stimulation of detectors by means of electronically controllable signals in such a way that the detector cannot distinguish between an artificial stimulation and a situation with a real fire. The application of this technique for the test of video fire detectors and other fire detectors, possibly coming up in the future is discussed.

1 Introduction

Since many years for traditional types of fire detectors test procedures and suitable test apparatus exist, which are specified in national and international standards. These standards rely on evaluating the detectors performance in a) a set of basic tests, which determine the response threshold of detectors before and after environmental tests and b) check the detector in a set of full scale tests [1]. The corresponding test equipment and fire test rooms are available in all major test laboratories.

In a project sponsored by the European Commission, for the basic test of intrusion detectors, testing concepts were worked out and prototypes were set-up, which aim at an apparatus for the determination of the response threshold of such detectors. Although intrusion detectors are designed for the detection of the motion of a human within the detection range, the stimulation of such detectors within the test is carried out without any motion inside the test chamber [2].

The apparatus is designed to be the counterpart of the smoke and heat tunnel, which enables to determine the response threshold for smoke and heat detectors.

One key feature of this equipment is the fact that all physical stimulation signals can be controlled by electronic signals. Thus in a certain range any arbitrary stimulation of the detector is produced. So a stimulation following very closely to a normal motion of humans can be realised.

After the introduction of such a ‘solid state’ testing concept for intrusion detector tests, the question came up to what extent such a method could be applied to the test of fire detectors. In detail: Is it possible (and reasonable) to consider a test equipment, which determines the relative or absolute response threshold of a smoke detector e.g. without producing any smoke or flames. An investigation into these questions led to some first answers and the following considerations.

2 The stimulation concept

In a full scale test fire detectors have to prove their ability to respond to a set of artificial fires in a more or less well defined environment. To some degree such tests do not rely on the special operating principle of detectors, so a kind of black-box testing is given.

The concept of ‘solid state’ detector stimulation can be considered as a white-box testing method. Such test methods must perfectly match the required detector type and its design parameters. Different detector types need to be stimulated by different test set-ups. The test apparatus therefore might require a sophisticated construction. Also some essential design details of detectors have to be known in order to select the proper stimulation method and to efficiently carry out such tests. But a clear benefit of such tests is that the detector stimulation is to a very high extent easily adaptable to different test scenarios and superior repeatability is given. Electronic control of the detector stimulation provides also a means of down-scaling the tests with respect to detection range and test chamber dimensions. So the test equipment might be reduced in size to a minimum.

3 Applicability to point-type detectors

This paper essentially covers test methods on volumetric detectors. For point-type detectors test methods are in use for many years, so significant improvements cannot be expected. For newer detector types such as gas detectors the situation is a bit different, improvements of test methods are under discussion.

An important example of such improvements in the test methods for point-type detectors is a test facility, developed at NIST, called in short FE/DE [3]. The apparatus is essentially based on the smoke & heat tunnel and is able to stimulate fire detectors in a very flexible and controlled way. Also the evaluation of gas detectors and multi-sensor detectors is implemented. The stimulation of fire detectors with this system covers the detector response in fire alarm and in some false-alarm situations.

Another reason for the restriction of the following considerations only on volumetric detectors is given by practical limitations for the stimulation of point-type detectors. If an optical point smoke detector for instance is considered, the detector principle requires that inside of the detector housing and inside its measurement chamber the stimulation has to be produced. This chamber is of course always optically shielded very well against environmental light so that an optical stimulation from the outside cannot work.

One might take into consideration that a scattering effect might be realised by inserting a fibre, which carries an optical receiver and transmitter, producing a defined radiation intensity as a function of the received radiation level whilst keeping the signal form. Today's technology allows for such intelligent fibres, but without precise information of the design of the tiny measurement chamber, without a suitable opening and without micro manipulation techniques such a stimulation cannot repeatably be produced.

On the other hand it has to be expected that advances in sensor and processor technology and improvements in signal processing will in the future lead to new cost-effective products with volumetric operating principles.

Volumetric principles open up the possibility of including much more information about the spread of a fire than point type detectors due to the additional spatial information. Also the location estimation of a fire can be enhanced using a volumetric detection.

4 Some testing aspects concerning early volumetric detectors - flame detectors

For flame detectors a standardised test method is in use since many years. The concept of 'solid state' stimulation could be realised using an appropriate IR /UV source and a modulator for producing the flickering effect of flames. Various options exist for the light modulator. A solid-state solution would implement a micro-mirror spatial light modulator, which offers full digital control, wide spectral response from IR to UV and cut-off frequencies up to 500 Hz [4].

But the limited advantages of easier control, more flexibility of the detectors stimulation and the expected costs do not predict lots of success for such a concept over the existing test method. For other volumetric detectors a possible introduction of an alternative testing concept is much more promising.

5 Volumetric ultrasonic fire detector and a corresponding test concept

By Appleby and Ellwood [5] in 1995 a number of volumetric fire detection techniques were described. One very interesting technique makes use of the Doppler effect of ultrasonic waves produced by the convection of hot air above a fire. Although such ultrasonic fire detectors don't play any role in fire detection up to now, the potential advantages of the described testing concepts are highlighted very well.

The Doppler signal of such a detector is dependent on the type of the heat source, so a stimulation of an ultrasonic fire detector has to produce a signal form very close to that gained in a real open fire. For an ultrasonic detector the concept of 'solid state' stimulation signals can be applied without problems. Scaling down the scenario with a scale down factor of 5 to 10 leads a compact test chamber.

The stimulation can be produced by means of an IQ modulator, an ultrasonic transducer and a suitable microphone, which have to be located in front of the detector.

If appropriate generation of the I- and Q-signals is provided, the ultrasonic transducer is able to generate any arbitrary low-frequency Doppler signal in the specified frequency range. Typical ultrasonic frequency bands for long range operation and low-cost cover the range of about 25 kHz to 40 kHz Doppler. As the ultrasonic Doppler signals exhibit dominant spectral components of about 40 Hz, it is sufficient to produce Doppler signals with a cut-off frequency of less than 300 Hz. Main cost driving components for such a test apparatus will be the microphone, alignment components for the detector and a test enclosure covered with absorbers.

6 Testing of state-of-the-art video fire detectors

The application areas for video fire detection systems are developing fast. Detecting smoke plumes in forests, fire in aircraft hangars have been the first applications. Video surveillance in manufacturing plants and tunnels are additional areas [6], [7]. Video fire detection systems usually consist of a video control unit to which a number of video cameras are connected and which perform the detection algorithms. Such a system structure opens up the possibility of repeatable test procedures, which follow the same principles as for video motion detection systems [8]. The signals of a predefined set of digital video sequences are fed into the control unit instead of the video camera outputs. By this means perfectly repeatable stimulation signals are fed into the system. Such sets include fire and non-fire situations.

Also the determination of response threshold values can be carried out. Different methods for its determination might be applied. One example of such a method makes use of the response time of the video detection system to a typical fire test scenario as the key parameter for the response threshold determination. A more sophisticated, but also more time consuming onset would use a set of test fire videos produced with different amounts of burning material.

The response threshold can then be defined by that test fire video sequence with the minimum of burning material leading to a detector response.

7 Self contained video fire detectors

Self contained video fire detectors, which integrate the video signal processing components in the detector housing are no product for the mass market of the year 2001. But in the far future the situation might change. Self contained video motion detectors are already on the way. They can make use of CMOS image sensors offering superior performance in several aspects on CCD chips, e.g. in terms of power consumption of less than 35 mW. For the moment the higher price level is the one exception of the long list of benefits. But it is expected that the price level will follow the same development as for CCD chips. It can also be expected that fire detection algorithm might then be offered as on add-on to such components or perhaps as their main function.

In such a situation the presently used techniques for video fire detector tests will not always work because CMOS image sensor and signal processing circuitry will due to cost reasons be implemented on the same chip. So in general an access to internal input signals to the signal processing components is not given. Advanced locally adaptive CMOS image sensor designs already combine local pixel signal processing features, where the local image processing circuits are located inside the pixel cells.

So for such detectors an external stimulation has to be provided using a real or an artificial image. It is proposed to provide such an image by a screen placed in front of the video detector. Onto such a screen video sequences should be played back using a suitable display. The response threshold determination method then need no changes compared to normal video detectors. Because of the usual small focal length of the cameras the screen might be placed quite close to the detector without the risk of a blurred image, so scale-down factors of 10 to 20 might be applied given a rather small size of the corresponding test chamber.

8 Microwave detector testing

Let us assume that also microwave fire detectors find their way in applications with the need for hot spot detection. How could a testing concept look like for such detectors? A more repeatable stimulation than by means of a real fire with enough embers might be carried out using a hot plate of defined temperature placed in front of the detector at a fixed distance and orientation. The problem is to find a material with high emissivity and easy, electrically controllable temperature.

These problems can be overcome in stimulating the detector by means of a microwave signal generator and an antenna at the location of the hot plate. Such tests could be carried out in a small chamber, equipped with microwave absorbing material or in a fire test room. The main requirement is, that few details on the evaluated microwave band have to be known in order to select the proper antenna and signal generator settings.

9 Conclusion

For point smoke detectors a solid-state test concept seems to be far from applicable. For volumetric fire detectors the situation is different. For IR and UV flame detectors the application is possible, but leads to no significant improvements. For future fire detectors, such as self contained video fire detectors and microwave detectors the ‘solid state’ approach is quite promising.

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