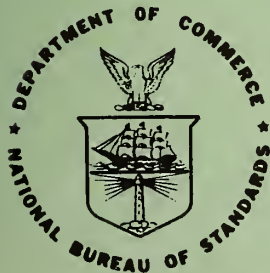NBSIR 76-1172

A New Test Method for Automatic Fire Detection Devices

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Washington, D. C. 20234

December 1976

Final Report

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PREFACE

This report is an adaptation of a paper presented by the author at the 80th Annual Meeting of the National Fire Protection Association, on May 18, 1976, in Houston, Texas.

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A NEW TEST METHOD FOR AUTOMATIC
FIRE DETECTION DEVICES

Richard G. Bright

Abstract

An analysis of the test methods for automatic
fire detection devices in the U.S. reveals the fact
that different types and different sizes of fires
are used to evaluate different classes of detectors.
The result is a lack of comparison test data for
each detector class and, as a consequence, intelli-
gent decisions can not be made in the selection of
automatic fire detectors for specific fire risks.
A new test method is proposed in which all auto-
matic fire detectors, regardless of sensor type,
would be subjected to a series of the same test
fires. In addition, each test fire series would
consist of three different test fire sizes. From
the results obtained, it should then be possible
to match a detector's characteristics against a
specific fire risk resulting in a more intelligent
application of automatic fire detectors.

Key words: Fire detector; test methods.

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Each hostile fire produces a multitude of physical and chemical characteristics. Some of these characteristics are unique to the fire. Other characteristics are already present in the environment and the fire only changes these background characteristics, usually by augmenting them. All of these fire-produced characteristics, or combinations thereof, can be used to identify the presence of the hostile fire. Some of these fire-produced characteristics give stronger signals earlier in the fire growth than others. As such, these signals are superior, as earlier, unambiguous fire indicators.

There are in excess of a dozen different types of automatic fire detection devices available to the fire safety engineer. Some of these detectors sense physical changes in the environment resulting from the fire. Other detectors sense chemical changes in the environment. Table No. 1 presents some, but not all, of the different types of detection devices.

All automatic fire detectors possess one common attribute. Each is expected to detect a hostile fire early enough to allow for effective counter measures, be it the evacuation of threatened persons and/or the extinguishment of the fire. But the different types of fire detectors do not detect all types of fires with the same degree of rapid-

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ity. This fact is fairly well known. What isn't well known, however, is the magnitude of difference in response of these different detectors to different fires. If, for example, one were to describe several hypothetical fires in a specific compartment and then ask at what point in the fire growth each of the different detector types could be expected to respond, it is quite likely that 9 out of 10 persons could not answer this question accurately.

Part of the reason for this is that the needed information is not readily available with which to answer questions such as these. Yet, some of us are called upon from time-to-time to select a fire detector for a specific fire risk. What do we do? Most likely, we listen to or read the claims of competing manufacturers and try to sort out the kernels from the husks. If the number of telephone calls our office receives is any indication, we are not too successful at this sorting process.

A portion of the problem lies in the way we test and approve automatic fire detection devices in the U.S. With our present system, a completely different series of test fires are used for each type of automatic fire detection device. In addition, there is no grading of the fire sizes, especially with regards to smoke detectors, so that the tests are essentially "go - no go" tests. The results,

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therefore, cannot be intelligently used to compare one
detector against another and, consequently, intelligent
utilization of the devices can not always be made. Wouldn't
it be nice if we had a test method which included one each
of all the representative types of fires a detector may
encounter and that these fires were graded in size so that
the discrimination level of each detector was readily apparent?
More on this in a moment but first I would like to review
the essentials in the testing of automatic fire detection
devices.

The best test of an automatic fire detection device —
and it probably will always be so — is their use in practice
over many years under the most diverse conditions. This is,
of course, not always possible, particularly with more
recent products. One clearly cannot wait, sometimes for
several years, for the experience to accumulate as to the
advantages and limitations of the fire detection device.

At the present time, laboratory tests of automatic fire
detection devices are designed to provide yes/no decisions
on the premise that unsuitable detectors are determined and
eliminated by these laboratory tests. One then waits to see
whether those detectors which have passed the tests subse-
quently prove themselves in the field.

Undoubtedly, such laboratory tests coupled with field experience are better than no tests. In the long run, however, a different type of test for automatic fire detection devices appears to be necessary. The aim of such a test should be to determine and fully describe the behavior of the automatic fire detection device. Here too, noncompliance with certain minimum requirements would disqualify the device. But in addition to establishing compliance with the basic requirements, an attempt should also be made to establish the limits of the capabilities of the detector and the conditions under which it can attain these limits. In so doing, not only would the detector be passed as meeting the basic requirements, but the results would give some indication as to the suitability, or unsuitability, of the detector for specific fire risks.

The requirements and associated test methods can be divided into two groups. In the first group, the influence of adverse environmental effects, to which a detector may be subjected, are investigated. We'll call this first group the basic tests. In most cases the procedure is as follows.

The automatic fire detector to be tested is exposed to a simulated, ever-increasing fire characteristic. The alarm point of the detector is determined. Then the detector is subjected to a series of environmental stresses such as high

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humidity, dust, high temperature, corrosion, vibration, etc.
The alarm point is again measured, using the procedure des-
cribed previously, to see whether and to what extent the
alarm point has changed.

Obviously, good repeatability of the simulated fire
characteristic and reliability of the measuring devices must
be obtained. Only in this way can one be sure that any
changes in the alarm point of the detector are due to changes
in the test specimen and not in changes in the simulated
fire characteristic or in changes in the measuring devices
themselves. There are some problems with our basic test
procedures, as presently conducted in the U.S., but they are
probably of less concern than the problems encountered in
the second group of tests.

This second group we'll call the trial test. In this
group of tests, several of the automatic fire detectors
under investigation are exposed to actual test fires, and
their behavior recorded. In principle, all automatic fire
detectors should be exposed to the same test fires. In this
way, comparisons can be made of the response characteristics
of the various fire detectors to differing fire types. As a
matter of fact, they are not. And herein lies the substance
of my talk.   )

I want to introduce today a proposed new test method for the evaluation of automatic fire detectors to real test fires. This test method, while new to the U.S., has been in use for about five years in West Germany. It has been formulated and published as the test method for Germany [1][1]. Also, this test method has been adopted by the European Insurance Association [2] as their standard for Europe. As a consequence, it seems safe to presume that many of the normal test anamolies have been eliminated from the test method.

The test method is composed of five types of fires. These fires, which are shown in table No. 2, have been selected to represent a broad spectrum of fire types. In addition, the five test fires are divided into three sizes. These three sizes have been selected to encompass the range of sensitivities which can be expected from automatic fire detection devices. Each fire is about twice the size of the next smaller fire. Table Nos. 3 to 7 present a description of the fuels as well as the three sizes used in each of the five test fires.

The Class I fire, the smallest in each type of fire, is representative of the smallest fire a detector can be expected

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[1]Bracketed notations refer to references listed at the end of this paper.

to respond to and still remain reasonably free from false alarms, at least in most cases. The Class III fire, the largest in each type of fire, is representative of the largest fire that can be tolerated and still have sufficient time to summon effective fire fighting assistance. Fires which grow at a rate exceeding the Class III fire are probably not suitable for automatic fire detection. Other fire safety means, such as automatic suppression, are called for in situations such as these.

The geometry of the room in which these fire tests are conducted is, as one would expect, crucial to the results obtained in the tests. Figure 1 is an isometric view of one suggested test structure. The test fires are located in the center of the room. The detectors to be tested are placed on the ceiling, 3 meters (10 feet) from the center of the room. Measuring instruments, consisting of a smoke meter, a reference ionization chamber measuring device, and thermo-couples, are also placed 3 meters (10 feet) from the center of the room. A ceiling plan of the detector and measuring instrument locations is shown in figure 2. The room should be at a temperature of 21 ± 3 °C (70 ± 5 °F) and free of smoke before each test. The specific dimensions chosen for the test structure are those used by West Germany for their test structure.

For tests of smoke detectors, test fires Nos. 1 through 5 would be conducted. Most of the presently available detectors which respond to smoke aerosols will not respond to test fire No. 5, the clean-burning alcohol fire. As a consequence, test fire No. 5 could be deleted for tests of generic classes of smoke detectors not responsive to clean-burning alcohol. This would include, for example, ionization chamber smoke detectors and optical smoke detectors.

For heat detectors, test fires Nos. 1, 3 and 5 would be conducted. Test fires Nos. 2 and 4 would not be conducted as these test fires produce only slight changes in the ambient temperatures at the detector location.

For other automatic fire detection devices, such as flame detectors, combustible gas detectors, and cloud chambers, for example, all five test fires would be conducted, at least, until it became apparent which test fires would be deleted from the test series due to lack of detector response to these fires.

The procedure would be to start with the first fire commencing in each case with the smallest fire or Class I fire. If all of the detectors do not respond to Class I, then the same fire is repeated at the Class II level. If in Class II, one or more detectors do not respond, then the

same fire is repeated at the Class III level. Following this, or as soon as all detectors have responded in either Class I or Class II, then the procedure is repeated for the next fire type.

A suitability table can then be prepared from the results of the tests of the automatic fire detector. This suitability table would show the response of the detector to each of the test fires in one of the classification grades. If all of the detector specimens tested responded to a Class II fire size of one of the test fires, then a mark would be placed in the appropriate column. If none of the detector specimens, or less than all of the specimens, responded to a Class III fire, then no mark would be entered on the line corresponding to this type of fire. Thus, a mark in any column will indicate the smallest fire size to which all detectors responded. No mark would indicate that one or more of the detectors tested did not respond to the largest fire size for a specific fire type. Table 8, taken from reference [2], represents a typical response of an ionization chamber smoke detector. Table 9, from reference [4], represents a typical response of a photoelectric smoke detector. Table 10, from reference [2], gives a typical response for a heat detector while table 11, from reference [4], gives the typical response for a flame detector.

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It should be reasonably obvious that the tabular pre-
sentation of the test results for a specific automatic fire
detector, as shown on these tables, yields useful information
with respect to the suitability or applicability of a given
detector for a specific fire risk. For instance, if the
most probable type of fire to be expected in an occupancy
can be forecast with reasonable accuracy, which is often
possible, then the type of detector offering the quickest
detection capabilities for that type of fire can be selected
from the results on the suitability table.

Another important feature of the test method I am
proposing here is that these tests can be performed in just
about any test facility without the need for large, expensive
testing facilities. Further, the proposed test method will
reduce all the many and varied test procedures we now have,
depending on the device to be tested, to a series of tests
having a large measure of commonality, a very desirable
objective, in my opinion.

Much work needs to be done before this proposed test
procedure for automatic fire detection devices will be ready
for consideration as a U.S. test standard. This is one of
the main objectives of the detection program at NBS and I

hope that others in the U.S. will take an earnest look at
this proposed test procedure, also.

It is likely that in time this same test method will be
proposed for international adoption through the International
Standards Organization (ISO) procedures. The test method
seems much superior to anything we have presently in the
U.S. As a consequence, it is my opinion that the faster we
can move towards adoption of this test method the better we
will be for it.

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[2] Test Methods for Point Smoke Detectors, Groupe de Travail Incendie du Comite Europeen des Assurances, Comite Technique Permanent, Paris (April 1974).

[3] Test Methods for Point Heat Detectors, Groupe de Travail Incendie du Comite Europeen des Assurances, Comite Technique Permanent, Paris (Nov. 1973).

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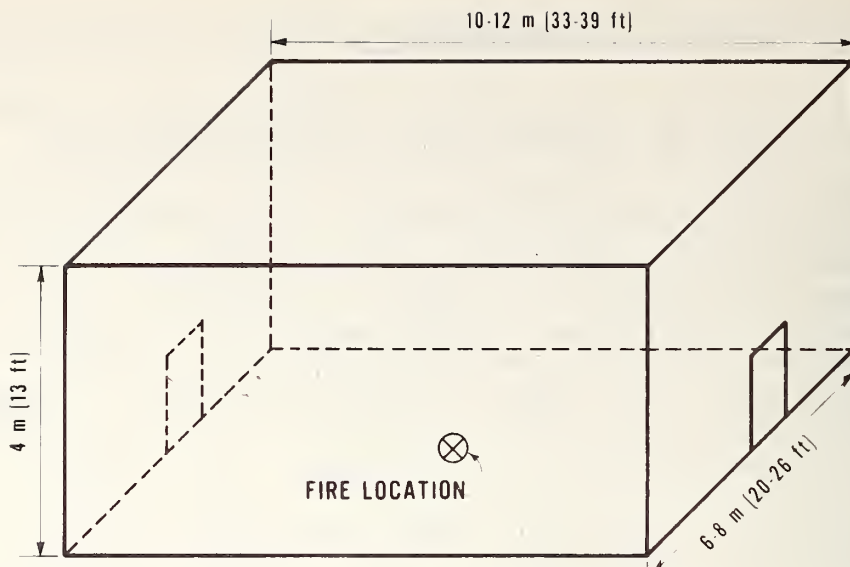
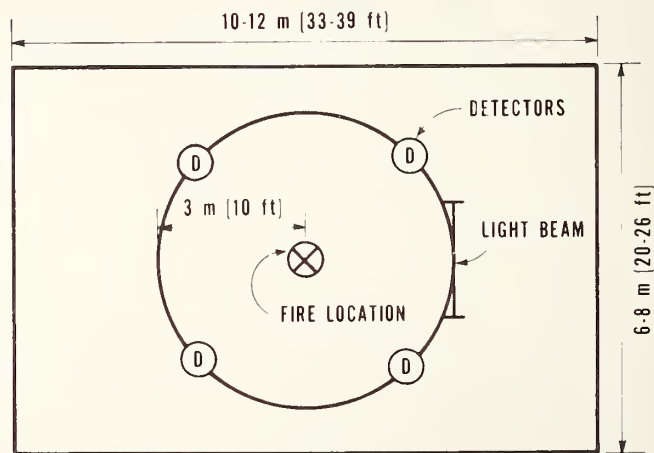Fig. 1. GEOMETRY OF DETECTOR TEST LABORATORY

Fig. 2. POSITION OF THE DETECTORS AND MEASURING DEVICES ON CEILING OF DETECTOR TEST LABORATORY

Table 1. Types of Automatic
Fire Detection Devices

<u>HEAT</u>

- Fixed Temperature
- Rate-of-Rise
- Combination of Above
- Laser Beam

<u>SMOKE</u>

- Photoelectric
- Ion Chamber
- Extinction Beam
- Cloud Chamber
- Laser Beam
- Taguchi
- Fuel Cell

<u>RADIATION</u>

- Infrared
- Ultra Violet
- Combination of Above

Table 2. Proposed Standard Test Fires

Test Fire	Type of Test Fire/Fuel Material
Test Fire No. 1	Flaming Cellulosic - Well-ventilated, Wood Crib
Test Fire No. 2	Smoldering Cellulosic - Wood Strips on a Hot Plate
Test Fire No. 3	Flaming Plastic - Flexible Polyurethane Mats
Test Fire No. 4	Flammable Liquid with Pronounced Smoke Production - Heating Oil or Kerosene
Test Fire No. 5	Flammable Liquid with Pronounced Heat but Little Smoke - Methyl Alcohol

Table 3. Test Fire No. 1 - Flaming Cellulosic

Fuel Description	Quantity of Fuel		
	Class I	Class II	Class III
Wood cribs - sticks 10 x 20 x 250 mm (0.39 x 0.79 x 9.8 in)	0.75 kg (1.65 lbs)	1.5 kg (3.3 lbs)	3.0 kg (6.6 lbs)
Base area of crib - mm (in)	250x250 (9.8x9.8)	250x250 (9.8x9.8)	250x400 (9.8x15.7)

Table 4. Test Fire No. 2 - Smoldering Cellulosic

Fuel Description	Quantity of Fuel		
	Class I	Class II	Class III
Wood strips on hot plate Strips, 10 x 20 x 50 mm, (0.39 x 0.79 x 2.0 in). No flame	3 Strips	6 Strips	12 Strips
Hot plate, 180 mm in diameter (7 in), 1.3 kW power, surface temperature - 400 to 450 °C (752 to 842 °F)			

Table 5. Test Fire No. 3 - Flaming Plastic

Fuel Description	Quantity of Fuel		
	Class I	Class II	Class III
Flexible polyurethane mats. No inhibitors Density - 20 kg/m^3 (1.25 lbs/ft^3) Size - 20 x 400 x 500 mm (0.79 x 15.7 x 19.7 in) Mats laid on aluminum foil with edges folded up. Ignition by 5 g of methyl alcohol.	1 Mats	2 Mats	3 Mats

Table 6. Test Fire No. 4 - Flammable Liquid w/Smoke

Fuel Description	Quantity of Fuel		
	Class I	Class II	Class III
Heating oil in square, metal trays with 20 mm (0.79 in) sides. Fuel quantities -	15 g (0.53 oz)	25 g (0.88 oz)	40 g (1.4 oz)
Tray areas -	25 cm^2 (3.9 in^2)	50 cm^2 (7.7 in^2)	100 cm^2 (15.5 in^2)
Ignition by hot wire or with 5 g of gasoline			

Table 7. Test Fire No. 5 - Flammable Liquid w/Heat

| | Quantity of Fuel | | |
Fuel Description	Class I	Class II	Class III
Methyl alcohol in square, metal trays w/50 mm (2 in) sides. Fuel quantities -	1.2 kg (2.6 lbs)	1.6 kg (3.5 lbs)	2.0 kg (4.4 lbs)
Tray areas -	1100 cm^2 (170 in^2)	1500 cm^2 (232 in^2)	1900 cm^2 (294 in^2)

Table 8. Fire Detector Classification Table —
Typical Results for: Ionization Smoke Detector

Type of Fire	Classification		
	I	II	III
No. 1 - Flaming Cellulosic	X		
No. 2 - Smoldering Cellulosic			X
No. 3 - Flaming Plastic		X	
No. 4 - Flammable Liquid (Fuel Oil)			X
No. 5 - Flammable Liquid (Alcohol)			

From: Reference [2]

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Table 9. Fire Detector Classification — Typical Results
for: Photoelectric Smoke Detector

Type of Fire	Classification		
	I	II	III
No. 1 - Flaming Cellulosic			X
No. 2 - Smoldering Cellulosic	X		
No. 3 - Flaming Plastic		X	
No. 4 - Flammable Liquid (Fuel Oil)		X	
No. 5 - Flammable Liquid (Alcohol)			

From: Reference [4]

Table 10. Fire Detector Classification — Typical Results
for: Heat Detector

Type of Fire	Classification		
	I	II	III
No. 1 - Flaming Cellulosic		X	
No. 2 - Smoldering Cellulosic			
No. 3 - Flaming Plastic			X
No. 4 - Flammable Liquid (Fuel Oil)			
No. 5 - Flammable Liquid (Alcohol)	X		

From: Reference [3]

Table 11. Fire Detector Classification — Typical Results for:
Infrared Flame Detector

Type of Fire	Classification		
	I	II	III
No. 1 - Flaming Cellulosic			
No. 2 - Smoldering Cellulosic			
No. 3 - Flaming Plastic	X		
No. 4 - Flammable Liquid (Fuel Oil)		X	
No. 5 - Flammable Liquid (Alcohol)	X		

From: Reference [4]

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

An analysis of the test methods for automatic fire detection devices in the U.S. reveals the fact that different types and different sizes of fires are used to evaluate different classes of detectors. The result is a lack of comparison test data for each detector class and, as a consequence, intelligent decisions can not be made in the selection of automatic fire detectors for specific fire risks. A new test method is proposed in which all automatic fire detectors, regardless of sensor type, would be subjected to a series of the same test fires. In addition, each test fire series would consist of three different test fire sizes. From the results obtained, it should then be possible to match a detector's characteristics against a specific fire risk resulting in a more intelligent application of automatic fire detectors.

17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)

Fire detector; test methods.

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