Detection of Electrical Cable Fires

A Comparison of the Effectiveness of Photoelectric and Ionization Smoke Sensing

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This document was originally printed in September, 1993 to summarize the presentation "Photo vs Ion Detectors for Cable Fires" given on May 24, 1993 at the National Fire Protection Association meeting in Orlando Florida. It is based upon research performed by the Simplex Research and Development Engineering Department.

This revision, dated June, 1998, is a reproduction of the original information with minor layout changes added for electronic distribution. Although the original testing was performed using 1993 vintage Simplex products, we believe that the test results are an accurate representation of performance relationships based upon the fire detection technologies tested.

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1.0 Introduction

Telephone companies and the nuclear power industry have a critical need for early warning in the event of an electrical cable fire. Both of these industries were pioneers in installing ionization technology smoke detection when it was the only method available. In the past 25 years, photoelectric detection has experienced a remarkable evolution, the latest phase of which is analog smoke sensing with microprocessor analysis. Since ionization detection technology uses small quantities of nuclear material, and the handling and disposal of nuclear material has become a factor both environmentally and economically, it is important to determine whether photoelectric technology has proven itself suitable to replace ionization technology for this application.

This document summarizes extensive testing performed by Simplex Research and Development Engineering to evaluate smoke detection technologies for detecting electrical cable fires. Three types of smoke sensing technologies are compared: photoelectric, ionization, and projected photoelectric beam. Each was tested under standardized laboratory conditions to determine the time to sense overheating of a variety of insulated wires. Testing was performed with and without the test room HVAC system activated to determine the effect of air flow on the smoke detection times.

2.0 Summary of Test Results

The time required for each device to recognize a given smoke threshold varied with the presence of HVAC air flow, the distance from the smoke source, and the material used for the test. Ionization sensor response times varied from a low of 16 minutes, 17 seconds (Test 14) to a high of no activation, even at the most sensitive setting. Photoelectric beam detection response times varied from a low of 12 minutes, 10 seconds (Test 21, with extended beam distance) to a high of not activating at all for the test duration. Photoelectric sensor response times varied from a low of 6 minutes, 1 second to a high of 26 minutes, 20 seconds and responded at each sensitivity level tested for each test performed.

Further analysis of the test results begins on page 5.

3.0 Test Facility

All tests were performed in the Simplex Fire Research Laboratory located at Simplex Time Recorder Co. headquarters in Gardner, Massachusetts. It is a replica of the Underwriters Laboratories facility located in Northbrook, Illinois and is in conformance with UL Standard 268. [1] This laboratory has a dedicated HVAC system that maintains the test room ambient conditions as required for accurate testing. All recording equipment, such as computers and the data acquisition system, are located in the control room adjacent to the fire test room. With the HVAC system on, there are 10 room air changes per hour. The room layout, location of supply and exhaust air vents, and a complete list of test instrumentation is presented on pages 12 and 13.

4.0 Sensors and Detectors

Three types of smoke detection systems were used in the fire tests: spot type photoelectric, spot type ionization, and photoelectric beam. The photoelectric and ionization sensors are part of the Simplex TrueAlarm® analog detection system and reported data back to a data acquisition system for computer processing and logging. Although the beam detector utilizes analog detection technology, the data analysis is contained in the detector instead of in the fire alarm control software as occurs with the spot type devices tested.

Each of the tested smoke detection/sensing devices is a production model that has been demonstrated to be representative of similar devices presently in use in fire detection systems.

4.1 Photoelectric Sensor, Simplex Model 4098-9701

Photoelectric sensors operate on a light scattering principle. The sensing chamber contains an infrared LED source with a peak spectral emission of 880 nm. This source is placed at an angle from a spectrally matched photodiode receiver. A transimpedance amplifier circuit provides an output voltage to an 8 bit A to D (analog to digital) converter. As smoke particles enter the smoke sensing chamber and cross the light beam of the LED, more scattered (reflected) light reaches the receiver. A digital representation of the voltage output is then transmitted to the data acquisition system, along with the sensor type and address. This is called the sensor's analog value, which can be converted to a UL268 obscuration value expressed in %/ft.

4.2 Ionization Sensor, Simplex Model 4098-9716

The ionization sensor contains a radiation source of Americium 241 (0.5 µCi) inside a stainless steel chamber. This source emits alpha particles which ionize the air molecules in their path. By applying a DC voltage to this chamber, a small ionization current flows within the chamber. As smoke particles enter this chamber, a decrease in this current results. A field effect transistor is used to supervise the condition of the chamber and provide a representative analog output voltage. This output voltage is conditioned in the same way as with the photoelectric sensor. The data acquisition system logs the 8 bit analog output, sensor address, and type.

4.3 Photobeam Detector, Simplex Model 2098-9207

This detector works on the light obscuration principle. A transmitter unit placed on one side of the room sends an infrared light beam to a receiver unit on the other side of the room. Smoke crossing this beam reduces the received light intensity. When the intensity is reduced by a pre-determined amount, an alarm is initiated. For tests 1 through 20, the separation distance was 36 feet and the sensitivity was set at 30%. When the beam intensity, as viewed at the receiver, decreased by 30%, an alarm was initiated. The time that this occurred was logged by the computer. For test purposes only, in test 21, the separation distance was increased to approximately 70 feet, by using a 15" x 24" mirror. The transmitter and receiver units were on the same side of the room for this test. The sensitivity was kept at 30%.

5.0 Test Fires

Most electrical wiring in high value installations has a flame inhibitor in the insulation that prevents open flame fires. The representative electrical cable samples were subjected to test conditions to duplicate the likely fault mode of smoldering insulation that generates gases and particles of combustion.

The normal scenario of overheated electrical cable occurs due to conditions that cause overheating of the conductors themselves. However, testing with controlled overcurrents resulted in insulation smoldering in locations that varied with each test. This was not considered acceptable for repeatability throughout the test program. The use of an electric hotplate with a controlled and monitored temperature profile was selected as preferred since the conductors were uniformly subjected to high temperature.

All test fires were low energy, with relatively low smoke production rates. The heat source used was a series PH-400 Chromalox hotplate, rated at 240 volts, 1550 watts. The surface of the hotplate is 8 1/2 inches in diameter and approximately 8 inches from the floor. The temperature of the hotplate was monitored by a J-type 30 AWG thermocouple attached to the edge of the steel plate by placing its junction in a hole 0.015 inch in diameter, 1/4 inch deep, and peening over the opening to secure it. The thermocouple is connected to an Omega model CN2041 temperature controller. The hotplate and controller are then energized and the test time started (T = 0). The hotplate is then controlled to follow the temperature profile indicated in Table 2 on page 5.

6.0 Combustibles

The number of pieces used for each test was determined by obtaining the weight of 10 pieces of Belden #8760 cable which is a nominal 66 grams. The combustible samples were equally spaced on the hotplate prior to starting the test.

1. **PVC Jacketed Cable** - Belden #8760, 2 conductor with shield, approximately 0.2 inches in diameter (ref. Simplex part #563-256). Ten pieces, each six inches long.
2. **14-2 NM-B with Ground,** indoor type copper building wire from Diamond Wire and Cable Co. Ten pieces, each six inches long.
3. **PVC Jacketed Tray Cable,** type TC - West Penn #TC1990, 2 conductor, unshielded, approximately 0.27 inches in diameter. Ten pieces, each six inches long.
4. **#18 AWG, 300 Volt Wire** with polyvinyl chloride insulation material from Electronic Wire and Cable, Inc. (ref. Simplex part # 543-111). Insulation thickness is 0.016" nominal. This wire was also cut into 6 inch pieces. To prepare the wire for each test, 8 pieces were twisted together, with approximately one twist every two inches. Five of these wire assemblies, plus one piece, were equally spaced on the hotplate.
5. **Okonite 600 Volt Power Cable,** three conductor**,** number 4 AWG. The insulation material is an ethylene propylene rubber, with a cable jacket of heavy-duty chlorosulfonated polyethylene. This cable has a diameter of approximately one inch. The cable was cut into 1/2 inch pieces. Six pieces were used for each test.

7.0 Test Procedures

The photoelectric beam detector was installed with a distance of 36 feet from transmitter to receiver and approximately 8 inches from the top of the 10 ft ceiling height. The photoelectric and ionization sensor air inlets were mounted 2.5 inches down from the 10 ft high ceiling and at two horizontal spacing distances, 17.7 ft and 8.85 ft, consistent with the spacing guidelines of UL Standard 268. The same sensors were used at each distance. Refer to the fire test room layout on page 12 for additional location information.

A total of 21 tests were performed. Four tests were conducted with each type of combustible. The variables for each combustible included control of the HVAC system and changing the horizontal distance of the photoelectric and ionization sensors from 17.7 ft to 8.85 ft.

Test 21 was included to compare the beam detector sensitivity when the beam length was increased. For test 21, and for test purposes only, the effective beam length was increased to approximately 72 ft by reflecting the beam off of a mirror and back through the smoke plume path. All of the test conditions are summarized in TABLE 1, Fire Test List.

7.1 Fire Test List

Test Number	Combustible	Height (Feet)	HVAC
1	Belden # 8760 PVC jacketed 2 conductor cable w/shield	17.7	OFF
2		8.85	
3		17.7	ON
4		8.85	
5	14-2 NM - B with ground, indoor type	17.7	OFF
6		8.85	
7		17.7	ON
8		8.85	
9	West Penn #TC1990 2 conductor type TC cable, unshielded	17.7	OFF
10		8.85	
11		17.7	ON
12		8.85	
13	300V, #18 AWG single conductor hookup wire	17.7	OFF
14		8.85	
15		17.7	ON
16		8.85	
17	Okonite 600 Volt #4 AWG , 3 conductor power cable	17.7	OFF
18		8.85	
19		17.7	ON
20		8.85	
21	West Penn #TC1990 2 conductor type TC cable, unshielded	17.7	OFF (see note)

Note: Beam detector effective distance increased to 70 ft.

TABLE 1. Fire Test List

7.2 Hotplate Control

At the start of each test, the temperature profile controller began adjustment of the hotplate temperature according to TABLE 2. Data logging and the test result timer were also initiated at T = 0. The test was ended when smoke production had visibly ceased. This generally occurred between 25 to 30 minutes into the test. The room was then purged of all smoke and the hotplate allowed to cool to 70°F before starting the next test.

Time (Minutes)	Hotplate Temperature
0	70° F (21.1° C)
0 - 4	Increased at 83° F (28.33° C) per minute to 401° F (205° C)
4 - 25	Increased at 19.9° F (6.7° C) per minute to 818 ° F (437° C)
25 - 30	Maintain at 818° F (437° C)

TABLE 2. Hotplate Temperature Profile

8.0 Results

Actual test result times are presented in tables 3 through 8 starting on page 8. The columns are arranged to present the quicker response times first for each test pair of HVAC off vs. HVAC on. Discussion of the results is categorized with respect to factors that influenced the response times.

NOTE: the test result times are from the start of application of heat to the hotplate and are not intended to indicate elapsed time from the start of insulation smoldering.

8.1 HVAC System

Airflow was measured using the instrumentation listed on page 13. The readings were:

17.7 ft from fire, HVAC off = 8 fpm HVAC on = 14 - 40 fpm
8.85 ft from fire, HVAC off = 12 fpm HVAC on = 15 - 25 fpm.

Beam smoke detector activation was significantly affected by the HVAC system airflow. Two of the five different fires yielded no response with the HVAC system on (Tests 15, 16, and 19). The beam detector responded to all fires when the HVAC system was off. For fires that were detected, the beam smoke detector required an average of 6 minutes, 57 seconds longer with the HVAC system on than when off.

Photoelectric sensor response times, when mounted at 17.7 ft., with the HVAC on, were favorable at each sensitivity when burning PVC jacketed cable, Belden 8760 (Tests 1,2,3, and 4), and marginal for the other four fuels. With the Belden #8760 fire, response times at 17.7 ft were 3 to 6 minutes faster with the HVAC on. For the other four fuels, there was a time difference of a few seconds to about 7 minutes more with the HVAC system on.

Ionization sensor response was clearly unfavorable whenever the HVAC system was on. There were no responses for any ionization sensors located 17.7 feet from the fire when the HVAC system was on. Test 8, at 8.85 ft mounting distance experienced the only response with HVAC on. That response was 28 minutes, 56 seconds as compared to the beam detector at 23 minutes, 30 seconds and the 1.5% photoelectric sensor at 16 minutes, 4 seconds.

8.2 Fuel Material

Test result times did vary with the different electrical cable samples used for fuel material. The cable samples used for the different test fires were intended to be typical of those installed and no smoke performance comparison of the cable types was intended. The test results are most informative when comparing response times within each test.

For general reference, a smoke build-up curve for PVC jacketed tray cable (West Penn TC 1990), is shown on page 11, in the data section. This graph displays the activation times for the devices used in Test 9 and the smoke density level in obscuration (%/ft). Photoelectric sensor sensitivities for Tests 9 - 12 were recorded at 2.5%/ft and 3.7%/ft to gather additional data for this curve.

8.3 Sensor Distance

Decreasing the distance of the photoelectric and ionization sensors from 17.7 feet to 8.85 feet had a favorable effect during all fires, with the HVAC system on or off. It should also be noted that, even with this reduced distance, some ionization sensors did not activate. For the ionization sensor, the best results were obtained at the 8.85 foot distance, with the HVAC system off.

Although the beam detector separation distance did not change for tests 1 - 20, there were minor differences in beam detector response times between pairs of tests due to the difficulty in exactly duplicating test conditions. Factors such as room air currents and smoke plume shape cannot be exactly duplicated and resulted in time differences ranging from no difference between tests 9 and 10 (HVAC off) to 3 minutes, 50 seconds between tests 3 and 4 (HVAC on). The test pair of test 19 and 20 (HVAC on) yielded no activation on test 19, and a 28 minute, 30 second result for test 20 which is also the approximate burn-out time for the combustibles.

Table 8 gives the results obtained during test 21. For test purposes only, the separation distance between the transmitter and receiver of the beam smoke detector was increased to approximately 70 feet by using a mirror and routing the beam twice through the smoke. The results in this table must be compared with test 9 to evaluate this change. The beam detector response time improved by more than four minutes.

8.4 Corrosion Observation

Although not part of the test program, there is an important observation to be made concerning the effect of the smoldering insulation fires on the test laboratory. After the testing was completed, there was significant corrosion observed on all exposed metal surfaces, including the HVAC system. This resulted in extensive maintenance and further emphasizes the need for early warning of electrical cable fires.

9.0 Discussion

The test results were quite consistent and demonstrated that the ionization sensor displayed relatively poor responses to all of these test fires. Ionization technology tends to respond better to small particles from hotter fires compared to the response when detecting large particles generated by smoldering fires. (Although testing performed at other times has shown photoelectric technology to be equal or superior in hotter fire conditions as well, this test series only addresses the smoldering electrical cable insulation fire condition.)

Photoelectric beam smoke detector sensitivity was selected from the UL 268 recommended setting for the test distance. The total obscuration of the infrared beam depends upon the density and the width of the smoke plume within the beam path. As the width of the smoke plume increases within the beam path, less dense smoke is required for the same total obscuration. The result is that increasing the distance between the photo transmitter and receiver will result in a more sensitive detector.

The beam detector's sensitivity selection is usually decreased substantially as distance is increased (see graph on page 14). This is to avoid false alarms caused by airborne contaminants (typically dust). If these contaminants can be kept to a minimum, a much more sensitive system can result from increasing the beam detector length. In the fire tests summarized in this report, the beam smoke detector was set at a sensitivity of 30% obscuration. The graph on page 14 shows that a smoke density of approximately 1%/ft was needed over the entire 36 feet of the protected area to produce an alarm. For a separation distance of 130 feet and a setting of 30%, a smoke density of only 0.25%/ft is needed over the entire distance of the protected area to produce an alarm. This setting is within the allowable UL sensitivity for the tested photoelectric beam detector.

Beam separation distance was limited by the size of the fire test lab. If the beam separation distance had been 75 to 100 feet for the test fires, the beam smoke detector responses would have been much better. The results obtained from test 21 (page 10) show the beam detector alarmed more than four minutes faster when the separation distance was doubled. Although this distance was doubled by using a mirror, it demonstrates the principle of increasing beam separation distance to increase smoke detection sensitivity. (Note: the mirror was used for test purposes only, mirrors are not recommended for actual installations).

A photoelectric sensor sensitivity of 0.2%/ft was included in these tests. At this sensitivity, a pre-alarm indication and its location would be displayed at the fire alarm panel to allow investigation of a possible incipient fire condition. The first sensitivity level that would initiate an alarm at the fire alarm panel is 0.5%/ft. (The inherent design of ionization sensors does not support sensitivities below 0.5%/ft). The sensitivity of the photoelectric smoke sensor can be set this high because the Simplex TrueAlarm analog detection system is designed to compensate for dirt contamination. A conventional detector becomes more sensitive as it becomes contaminated and would soon cause false alarms. The TrueAlarm system maintains sensitivity even with accumulation of dirt and other contamination, and even with factors that may decrease sensitivity such as component aging. This is due to software analysis of the analog data where the change in analog level is compared to average values and evaluated for an accurate and reliable sensitivity threshold.

10.0 Conclusions

This document presents test results demonstrating that spot-type photoelectric technology responds significantly quicker and more reliably than ionization technology when detecting smoke from smoldering electrical cable fires. Under the same test conditions, photoelectric beam detectors also typically out-performed ionization detection.

Factors that influenced the detection times are: HVAC air flow rate, distance from the smoke, detection sensitivity, photo beam separation distance and path, and the type of combustible being tested. HVAC operation had the greatest effect upon the ionization sensor and the photoelectric beam smoke detector. Increasing the HVAC ventilation rate resulted in longer response times and, in some cases, no response for these two types of smoke sensors.

The effect of the HVAC operation upon the photoelectric sensor was less pronounced, but still substantial. With the photoelectric sensor, the response time increase with the HVAC system on varied from a few seconds to up to seven minutes. And, as the test results demonstrate, the photoelectric sensor responded during each test fire at each sensitivity level recorded.

Reducing the sensor distance from the test fires increased performance. This would be expected since the smoke density would be expected to be higher when closer to the smoke source.

The results from this testing also show that the photoelectric sensor selected at a pre-alarm sensitivity of 0.2%/ft can provide significantly earlier detection of smoldering electrical cable insulation fires.

11.0 Reference

[1] *Standard for Smoke Detectors for Fire Protective Signaling Systems*, UL268, second edition, Underwriters Laboratories, Inc., Northbrook, IL, 60062-2096.

TABLE 3. Test Results, Tests 1 - 4, Combustible = Belden #8760, PVC Jacketed 2 Conductor Cable with Shield (activation times in minutes : seconds)

		HVAC Off		HVAC On	
		Test 2	Test 1	Test 4	Test 3
Device	**Sensitivity**	**8.85 ft from Fire**	**17.7 ft from Fire**	**8.85 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	6:01	18:20	8:02	11:07
	0.5 %/ft	6:13	20:25	9:51	13:38
	1.0 %/ft	7:41	20:41	9:51	16:09
	1.5 %/ft	9:51	20:50	14:37	17:24
Ionization Sensor	0.5 %/ft	21:06	21:48	N.A.	N.A.
	0.9 %/ft	24:27	N.A.	N.A.	N.A.
	1.3 %/ft	N.A.	N.A.	N.A.	N.A.
Photo Beam*	30 %/ft	14:10	16:00	25:30	21:40

N.A. = No activation during test time period

* Photo Beam detector remained at fixed location.

TABLE 4. Test Results, Tests 7 - 8, Combustible = 14-2 NM-B with ground, indoor copper building wire (activation times in minutes : seconds)

		HVAC Off		HVAC On	
		Test 6	Test 5	Test 8	Test 7
Device	**Sensitivity**	**8.85 ft from Fire**	**17.7 ft from Fire**	**8.85 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	6:01	13:00	10:16	13:13
	0.5 %/ft	10:08	14:41	11:15	15:27
	1.0 %/ft	11:49	15:56	13:58	18:15
	1.5 %/ft	12:52	16:04	16:04	19:51
Ionization Sensor	0.5 %/ft	21:44	21:53	28:56	N.A.
	0.9 %/ft	25:10	24:40	N.A.	N.A.
	1.3 %/ft	26:13	26:50	N.A.	N.A.
Photo Beam*	30 %/ft	17:40	16:20	23:50	22:50

N.A. = No activation during test time period

* Photo Beam detector remained at fixed location.

TABLE 5. Test Results, Tests 9 - 12, Combustible = PVC Jacketed Tray Cable, West Penn #TC1990, 2 conductor type TC cable (activation times in minutes : seconds)

		HVAC Off		HVAC On	
		Test 10	**Test 9**	**Test 12**	**Test 11**
Device	**Sensitivity**	**8.85 ft from Fire**	**17.7 ft from Fire**	**8.85 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	9:56	12:43	10:24	14:32
	0.5 %/ft	10:21	13:16	12:01	15:51
	1.0 %/ft	12:18	14:49	13:04	17:36
	1.5 %/ft	13:42	17:07	14:40	19:08
	2.5 %/ft	15.23	17.36	16.21	22.13
	3.7 %/ft	15.52	20.12	17.32	26.20
Ionization Sensor	0.5 %/ft	22:47	26:00	N.A.	N.A.
	0.9 %/ft	24:11	N.A.	N.A.	N.A.
	1.3 %/ft	N.A.	N.A.	N.A.	N.A.
Photo Beam*	30 %/ft	16:20	16:20	23:50	21:50

N.A. = No activation during test time period

* Photo Beam detector remained at fixed location.

TABLE 6. test results, tests 13 - 16, Combustible = 300V, #18 AWG Single Conductor Hookup Wire (activation times in minutes : seconds)

		HVAC Off		HVAC On	
		Test 14	**Test 13**	**Test 16**	**Test 15**
Device	**Sensitivity**	**8.85 ft from Fire**	**17.7 ft from Fire**	**8.85 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	9:59	14:32	11:15	14:54
	0.5 %/ft	10:25	14:44	12:30	16:09
	1.0 %/ft	11:49	15:26	13:46	18:11
	1.5 %/ft	12:47	16:46	15:22	19:26
Ionization Sensor	0.5 %/ft	16:17	22:38	N.A.	N.A.
	0.9 %/ft	17:28	N.A.	N.A.	N.A.
	1.3 %/ft	19:05	N.A.	N.A.	N.A.
Photo Beam*	30 %/ft	16:30	17:20	N.A.	N.A.

N.A. = No activation during test time period

* Photo Beam detector remained at fixed location.

TABLE 7. Test Results, Tests 17 - 20, Combustible = Okonite 600 VOLT, #4 AWG, 3 Conductor Power Cable (activation times in minutes : seconds)

		HVAC Off		HVAC On	
		Test 18	Test 17	Test 20	Test 19
Device	**Sensitivity**	**8.85 ft from Fire**	**17.7 ft from Fire**	**8.85 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	9:51	15:56	11:24	16:13
	0.5 %/ft	11:06	16:59	14:49	18:39
	1.0 %/ft	13:29	17:45	16:42	23:24
	1.5 %/ft	15:31	19:01	16:42	26:08
Ionization Sensor	0.5 %/ft	21:06	22:51	25:01	N.A.
	0.9 %/ft	22:47	24:57	26:08	N.A.
	1.3 %/ft	25:05	N.A.	N.A.	N.A.
Photo Beam*	30 %	22:30	23:00	28:30	N.A.

N.A. = No activation during test time period

* Photo Beam detector remained at fixed location.

TABLE 8. Test Results, Test 21, Combustible = PVC Jacketed Tray Cable, West Penn #TC1990, 2 Conductor Type TC Cable (activation times in minutes : seconds)

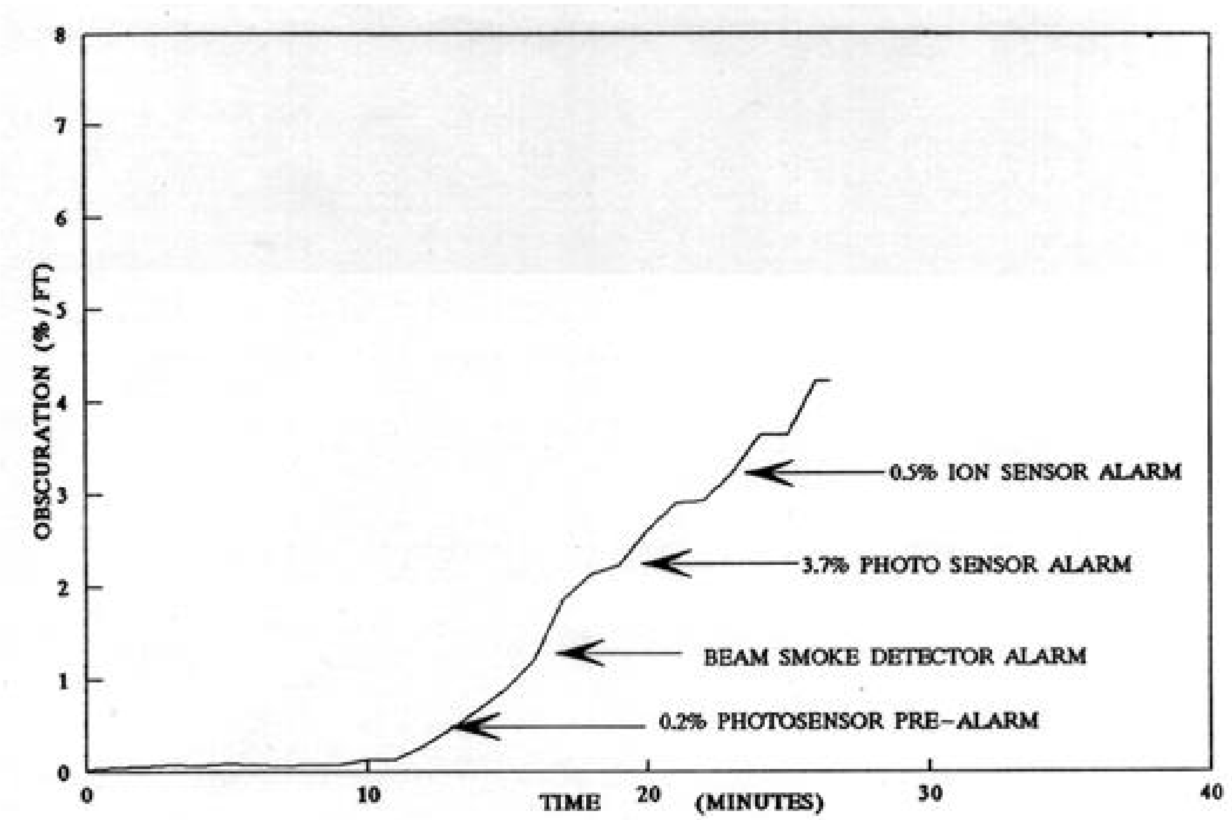
		HVAC Off	HVAC Off
		Test 21	Test 9 (reference)
Device	**Sensitivity**	**17.7 ft from Fire**	**17.7 ft from Fire**
Photo Sensor	0.2 %/ft	13:59	12:43
	0.5 %/ft	14:03	13:16
	1.0 %/ft	17:54	14:49
	1.5 %/ft	18:23	17:07
	2.5 %/ft	---	17:36
	3.7 %/ft	---	20:12
Ionization Sensor	0.5 %/ft	25:43	26:00
	0.9 %/ft	N.A.	N.A.
	1.3 %/ft	N.A.	N.A.
Photo Beam*	30 %	12:10	16:20

*** NOTE:**
For test 21 , the effective beam detector separation distance was increased to 70 feet using mirrors.

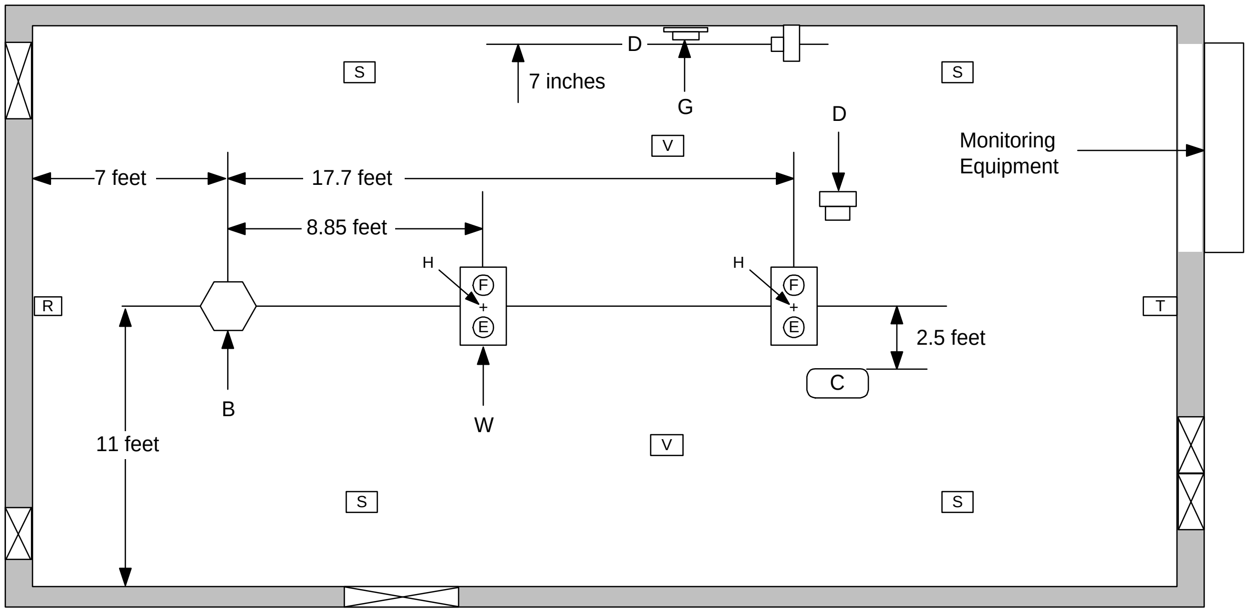
Test 9 data is repeated for reference only.

N.A. = No activation during test time period,
--- = data not recorded for this test

Response Graph, Ref. Data from Test 9
PVC Jacketed Tray Cable, Type TC - West Penn #TC1990



Fire Test Room



A. Fire Test Room Dimensions
   1. Length – 36 feet (11 m)
   2. Width – 22 feet (6.7 m)
   3. Ceiling – height 10 feet suspended type. Consists of 2 by 4 feet (0.6 by 1.2 m) by 5/8 inch (15.9 mm) thick incombustible fissured mineral fiber layer in panels.

B. Test Fire
   1. 8 inches (203 mm) above floor for Smoldering Smoke Test.

C. Lamp Assembly – 4 inches (102 mm) below ceiling, 7 inches (178 mm) from each side wall.

D. Photocell Assembly – spaced 5 feet (1.5 m) from lamp, photocell center 4 inches (102 mm) below ceiling, 7 inches (178 mm) from each side wall.

E. Ionization Sensor

F. Photoelectric Sensor

G. Test Panel, Sidewall Mounted Detectors – not used during these tests.

H. Air Velocity Probe 2 1/2 feet below ceiling

S. Air Supply

V. Exhaust Vents

R. Receiver of Beam Smoke Detector

T. Transmitter of Beam Smoke Detector

W. Area used for reduced spacing tests 8.85 feet from fire.

Fire Test Room Test Equipment List

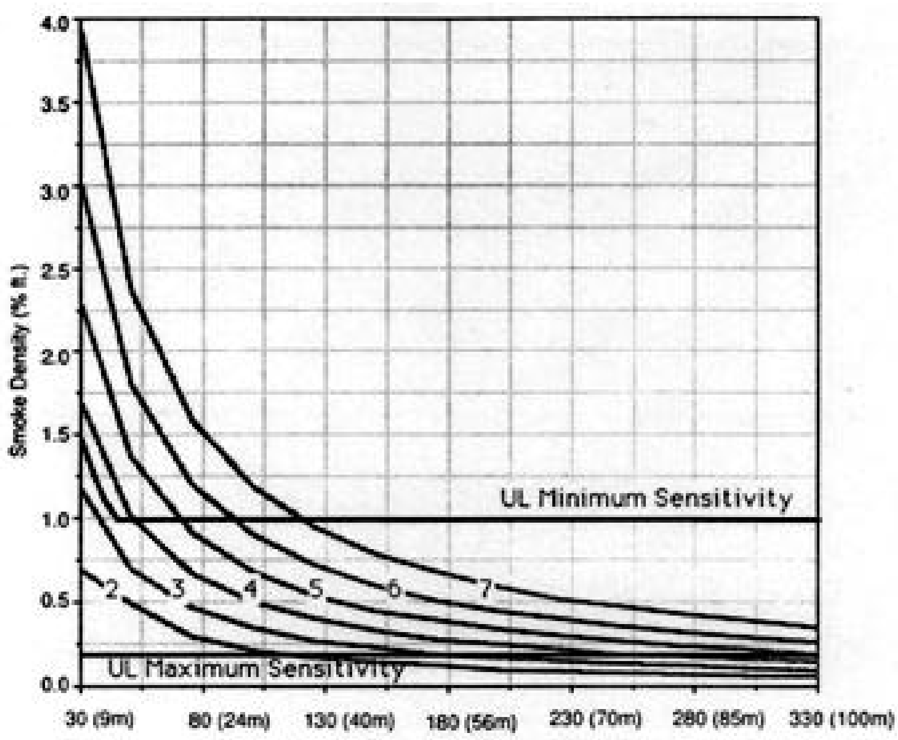
1. Hewlett Packard E1301A data acquisition mainframe, with a 5 1/2 digit multimeter and FET Multiplexer, used to monitor optical density, temperature, and the status of an optical beam smoke detector. This mainframe was linked to a computer via an IEEE 488 databus. Digital and analog data for the photoelectric and ionization sensors were monitored by a MetraByte DASH-8 board located in the computer.

2. Optical density was measured at two locations in the room. These locations were at the ceiling and right sidewall areas, as detailed on page 12. Each assembly consisted of a type 4515 automotive spot lamp and a selenium barrier layer type photocell, having a 1.5 inch diameter active surface. The photocell and lamp were separated by a distance of exactly 5 feet. The lamp voltage was adjusted to yield a lamp color temperature of 2373°K. The photocell was loaded with a nominal 100 ohm resistor. The output voltage across this resistor was connected to the Hewlett Packard data acquisition system via a shielded pair cable.

3. Temperature was measured at three locations by J-type thermocouples. These locations were at both photocell-lamp assemblies and directly above the hotplate at ceiling level.

4. Air velocity was measured with a TSI Model 1750 Constant Temperature Anemometer. The sensing element for this instrument was placed 2 1/2" below the ceiling level, which corresponds to the level where the photoelectric and ionization sensor intakes were located for all fires.

Photoelectric Beam Detector Smoke
Density/Obscuration Information



Sensitivity Pot Setting	**Total Obscuration at Alarm**
2	20%
3	30%
4	40%
5	50%
6	60%
7	70%

www.simplexnet.com

Gardner, Massachusetts 01441-0001

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