AUTOMATIC FIRE DETECTION

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1.0 SCOPE

This data sheet describes the basic types of automatic fire detectors and provides recommendations for the installation and testing of these devices. These detectors are the signal-initiating devices discussed in Data Sheet 5-40, *Automatic Fire Alarm Systems.*

1.1 Hazard

Automatic fire detection connected to a monitored fire alarm system has been shown to add value to property protection and can be considered an integral part of the overall protection scheme. Automatic fire detection is also at times interlocked to activate a preaction or deluge system. There have been cases where a fire was started accidentally or discovered by an occupant, yet initial notification was a result of automatic detection. People sometimes waste valuable time fighting a fire themselves or deciding what to do before calling the public fire service. Detectors also can be critical when they are interlocked with protection systems. In these cases, if the detection system is not properly designed, installed, and maintained, the protection system will be impaired.

Automatic fire detection may reduce the severity of a fire in a facility by providing warning of the fire before it has time to grow out of control. Early detection can help minimize property damage and business interruption. In the absence of adequate sprinkler protection, a fire can develop and spread rapidly, becoming difficult to fight manually.

During building design, fire protection engineers try to mitigate hazards with various goals in mind, such as preventing heat buildup around structural steel beams, containing fire damage to a single room or area, or minimizing damage to a critical machine or computer servers. There are some occupancies, including refrigerated warehouses, semiconductor fabrication plants, telecommunications centers, and large data centers, where smoke and water cannot be tolerated. Quick response due to early detection is one way to help accomplish these goals.

1.2 Changes

April 2025. Interim revision. Significant changes include the following:

Revised Section 2.2.3, Smoke Detectors, to include additional recommendations for duct detector location and interlocking. These recommendations are based upon FM Data Sheet 1-45, *Air Conditioning and Ventilating Systems*, which will be obsolete effective April 2025.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

An important factor in the reduction of loss from fire is reliable and prompt detection. Automatic fire detection devices can provide early warning of fire and smoke, initiate an alarm, and also activate extinguishing systems. Automatic fire detectors have many applications in commercial, institutional, and industrial facilities, as well as for residential use. Although automatic fire detection devices can be a valuable part of a property's fire protection system, they are not considered a substitute for automatic sprinklers or other automatic extinguishing systems. Automatic detection and proper notification may, however, provide firefighters with enough advance notice to improve their chances of controlling and extinguishing a fire. Otherwise, extensive fire, water, and smoke damage can result. A detection system may also be valuable where sprinklers are not installed. There are many different types of detectors on the market. Detectors vary in what they detect, how they detect it, how they are powered, and how they are managed by the fire alarm system.

The *Approval Guide*, an online resource of FM Approvals, lists FM Approved automatic fire detectors. Information and specific recommendations for unusual or hazardous occupancies are given in FM property loss prevention data sheets covering the particular occupancy or equipment involved.

2.2 Protection

2.2.1 General

2.2.1.1 Connect FM Approved automatic fire detectors to initiating device circuits or signaling alarm circuits on fire alarm panels having a secondary power supply in accordance with Data Sheet 5-40, *Fire Alarm Systems.*

2.2.1.2 If not connected to a control panel, provide detectors with backup or secondary power having a minimum of 24 hours capacity.

2.2.1.3 Base the selection of automatic detection devices on the type and size of fire to be detected and the response required.

2.2.1.4 To detect incipient fires in high-value or critical areas, such as cleanrooms, telecommunication centers, and critical computer rooms, before flame or noticeable smoke even develops, use very early warning fire detection such as an air-sampling system, or spot-type high-sensitivity smoke detectors. For fastest response, install detectors or sampling points inside electrical/electronic cabinets.

2.2.1.5 Provide spot-type fixed-temperature heat detectors in spaces that may reach high ambient temperatures under ordinary conditions (such as boiler and electrical wiring rooms), or as required by the applicable occupancy-specific data sheet.

2.2.1.6 Provide linear heat detection for conveyor belts, cable trays, and rack storage, or as required by the applicable occupancy-specific data sheet.

2.2.1.7 Use radiant energy sensing detectors to match the radiant emissions expected from the source to be detected as required by the applicable occupancy-specific data sheet. Since each fuel emits unique spectra, not all detectors are capable of detecting all fuels.

2.2.1.8 Use ionization smoke detectors to detect a flaming, well-ventilated, energetic fire, such as that involving a transformer.

2.2.1.9 Use photoelectric smoke detectors to detect a smoldering fire that produces smoke with large, super-micron particulates, such as that involving furniture, paper products, or commodities in cardboard boxes.

2.2.1.10 Use combination ionization/photoelectric smoke detectors for a slow, smoldering fire, such as that in switchgear and circuit breaker rooms.

2.2.1.11 Use video-imaging fire detection systems for the following commercial and industrial applications:

- Outdoor, open areas such as oil rigs, oil fields, mining operations, and forest products
- Indoor locations such as industrial plants, boiler or other large vessel protection, turbines, and some clean/chemical rooms

2.2.1.12 Protect detectors from mechanical damage; however, do not block detectors, which will make them less responsive. Support or mount them independent of their attachment to the circuit wiring.

2.2.1.13 Ensure signaling from automatic detection devices is received in a constantly attended area.

2.2.1.14 Detection for Preaction and Deluge Sprinkler Systems

Conditions of occupancy or special hazards may require quick application of large quantities of water. In such cases, preaction or deluge sprinkler systems may be needed. Fire detection devices to activate preaction and deluge systems may be selected to ensure operation yet guard against premature operation of sprinklers, based on normal room temperature and draft conditions. Apply the following recommendations for detection systems employed to activate preaction and deluge sprinkler systems.

2.2.1.14.1 Provide fixed-temperature, rate-of-rise, or combination fixed-temperature/rate of-rise detection devices. Do not use smoke or flame detectors unless recommended by the applicable occupancy-specific data sheet.

2.2.1.14.2 If heat detection is used to activate a preaction system in refrigerated areas, use fixed-temperature detectors. Rate-of-rise detectors may false trip when doors are opened or when other abrupt localized temperature changes occur.

2.2.1.14.3 For preaction or deluge system activation, use single-zone circuitry for detection and actuation devices. Cross-zoned circuits unnecessarily delay system activation. Ensure the circuitry is designed to be operational despite the occurrence of a single fault (ground fault or open circuit).

2.2.1.14.4 Provide separate detection systems, control panels, and release device circuitry for each sprinkler system. Control panels that can control multiple systems via separate modules in the same panel are acceptable.

2.2.1.14.5 Ensure wiring and control of detection for deluge and preaction systems are totally independent from that for other extinguishing systems, such as FM-200 and carbon dioxide, which are often installed along with a sprinkler system. The use of common components for any portion of the systems will compromise the reliability of one system backing up the other.

2.2.1.14.6 Ensure the spacing of heat detectors for activation of preaction systems under smooth ceilings does not exceed that for which it was FM Approved for the specific detector involved. For other than smooth ceilings, ensure the spacing of heat detectors does not exceed one-half the FM Approved linear detector spacing or the full allowable sprinkler spacing, whichever is greater (e.g., if a detector is FM Approved for 30 ft by 30 ft and allowable sprinkler spacing is 130 ft^2 [12 m^2] , then maximum allowable linear detector spacing is 15 ft by 15 ft).

2.2.1.14.7 Determine water demand designs for preaction and refrigerated area sprinkler systems as follows:

A. Base the design on the requirements of a wet system if a preaction system uses electric or pneumatic heat detection methods with detector spacing limited to the greater of 0.5 times the FM Approved linear detector spacing or the full allowable sprinkler spacing.

B. Base the design on the requirements of a dry system if:

1. a system is designed for a refrigerated area and the detector spacing does not exceed that for which it was FM Approved, or
2. a preaction system is using pilot sprinklers as the heat detection system, or
3. a preaction system is using electric or pneumatic heat detection methods with detectors spaced beyond the greater of (a) 0.5 times the linear spacing for which it was FM Approved, or (b) the full allowable sprinkler spacing.

2.2.2 Heat Detectors

2.2.2.1 General

Use a heat detector with a temperature rating slightly higher than the highest expected ambient temperature.

Table 1 gives the temperature ratings of detectors that can be used for various maximum expected ceiling temperatures.

Table 1. Selection of Detector Temperature Rating

Temperature Rating Range of Detector		*Maximum Expected Ceiling Temperature*	
°F	°C	°F	°C
135 to 174	57 to 79	100	38
175 to 249	79 to 121	150	66
250 to 324	121 to 162	225	107
325 to 399	163 to 204	300	149
400 to 499	204 to 260	375	191
500 to 575	260 to 302	475	246

2.2.2.2 Installation

2.2.2.2.1 Locate spot-type heat detectors on or under the ceiling (optimally at about 1%, but not more than 6%, of the ceiling height below the ceiling) and not less than 4% of the ceiling height from the side wall. For a low ceiling such as 10-ft (3-m), mounting the detector on the ceiling is acceptable because the detector sensing element may be at least 1% below the ceiling (1.2 in. for a 10-ft ceiling). A less-desirable alternative location is attached to the side wall between 4% and 12% of the ceiling height from the ceiling. (See Figure 1.)

2.2.2.2.2 Locate line-type heat detectors under the ceiling. The bulk of the detector wire may be hung optimally at about 1% (but not more than 6%) of the ceiling height below the ceiling (never firmly attached to ceiling). A less-desirable alternative location is attached to the side wall between 4% and 12% of the ceiling height from the ceiling. (See Figure 1.)

No matter what the detector wire is attached to (pipe, joists, etc.), do not firmly attach it. For example, if attached to a sprinkler pipe, use hangers to offset the wire from the pipe by at least one pipe diameter. The wire can be hung above or below a pipe, but if installed on the side of a pipe, hang it on the same side of every pipe.

2.2.2.2.3 For beamed construction, if D/H is greater than 0.10 and W/H is greater than 0.30, locate detectors in each pocket (where D = beam depth, H = ceiling height, and W = width between beams). Otherwise, mount detectors on the bottoms of the beams.

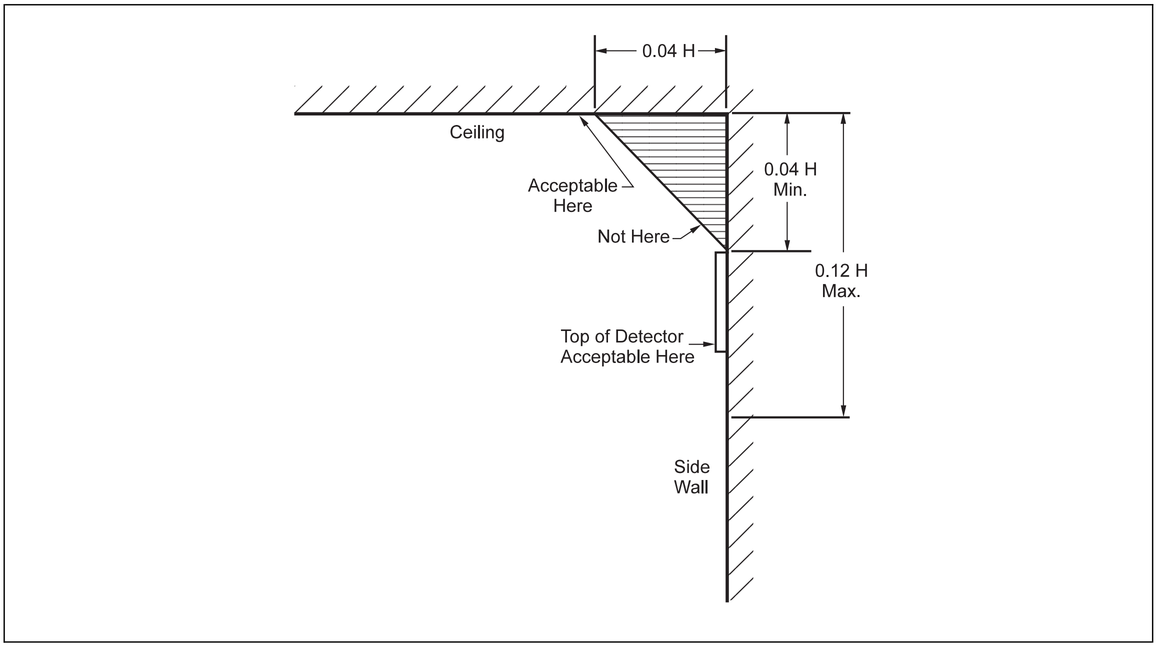

Fig. 1. Recommended location of spot-type heat detectors. Measurements shown are to the closest edge of the detector. H = ceiling height.

2.2.2.3 Spacing

2.2.2.3.1 For open joist construction, locate rows of detectors closest to walls no more than 1/2 of normal spacing from the walls. For example, if a room width is equal to 2.2S, then four rows of detectors are needed; if the room width is 2S, only two rows are needed. (See Figure 2)

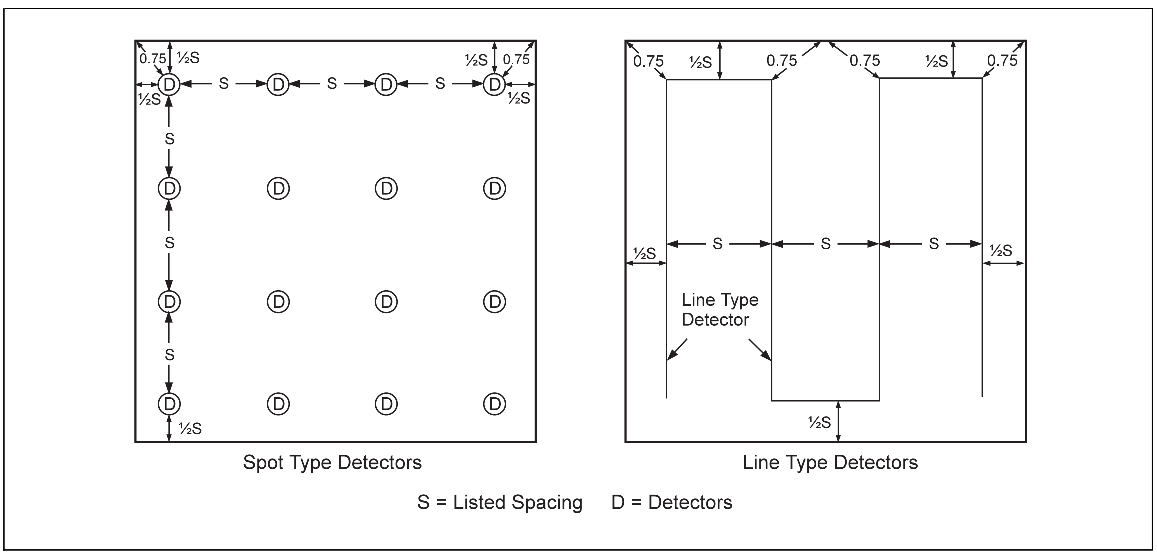

Fig. 2. Spacing of spot-type smoke and heat detectors under a joisted ceiling.

2.2.2.3.2 Do not exceed the FM Approved spacing between detectors. The spacing guide for FM Approved heat detectors on smooth ceilings is dependent on Response Time Index (RTI) of the detector. RTI is a measure of the sensitivity of the heat sensing element as it responds to rising temperature. Table 2 below provides the spacing guidelines for all spot-type detectors when placed in best case orientation on a smooth ceiling.

Table 2. Heat Detector Spacing

Detector Spacing Label	*Spacing, ft (m)*
SPECIAL	10 x 10 (3 x 3)
STANDARD	15 x 15 (4.5 x 4.5)
QUICK	20 x 20 (6 x 6)
FAST	25 x 25 (8 x 8)
V-FAST	30 x 30 (9 x 9)
V^2-FAST	35 x 35 (10.5 x 10.5)

2.2.2.3.3 For joisted and beamed ceilings deeper than 3% of the ceiling height, do not exceed 50% of the detector's smooth ceiling spacing, as measured at right angles to the joists and beams. Use smooth ceiling spacing in the direction parallel to beams (see Figure 2). If beams project more than 15% of the ceiling height, treat each section between beams as a separate area.

2.2.2.3.4 For peaked ceilings, locate the first row of detectors within 3 ft (0.9 m) of the peak (measured horizontally between the two sides of the roof. (See Figure 3.) Space the lower rows based on the horizontal projection of the ceiling. As slope increases, spaceing up the slope will increase by 1/cos(Θ), where Θ is the ceiling slope.

2.2.2.3.5 For shed ceilings, locate the first row of detectors within 3 ft (0.9 m) of the top of the ceiling (measured horizontally from the wall. (See Figure 3.) Space the lower rows based on the horizontal projection of the ceiling.

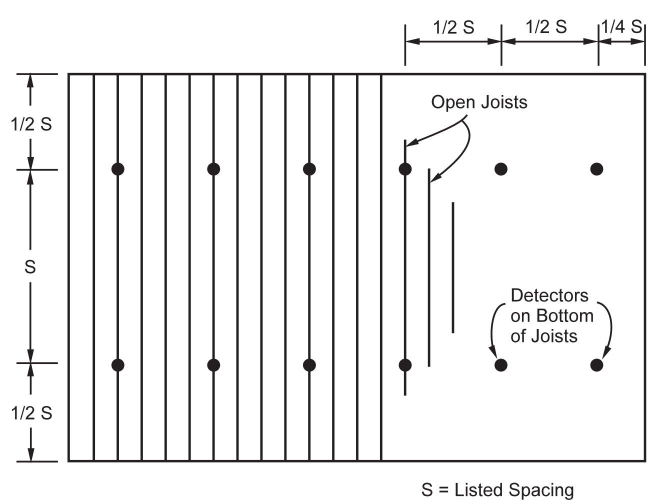

Fig. 3. Spacing of spot-type smoke and heat detectors under sloped ceilings (shed and peak type). Note: 1 ft = 0.3 m.

2.2.2.3.6 For irregularly shaped areas with smooth ceilings, the distance between detectors may be greater than the FM Approved spacing; however, ensure the maximum distance from any point on the ceiling to a detector is not greater than 70% of the FM Approved spacing. A detector will cover an area enclosed by any rectangle that fits in a circle having a radius equal to 0.7 of the FM Approved spacing. See Figure 4.

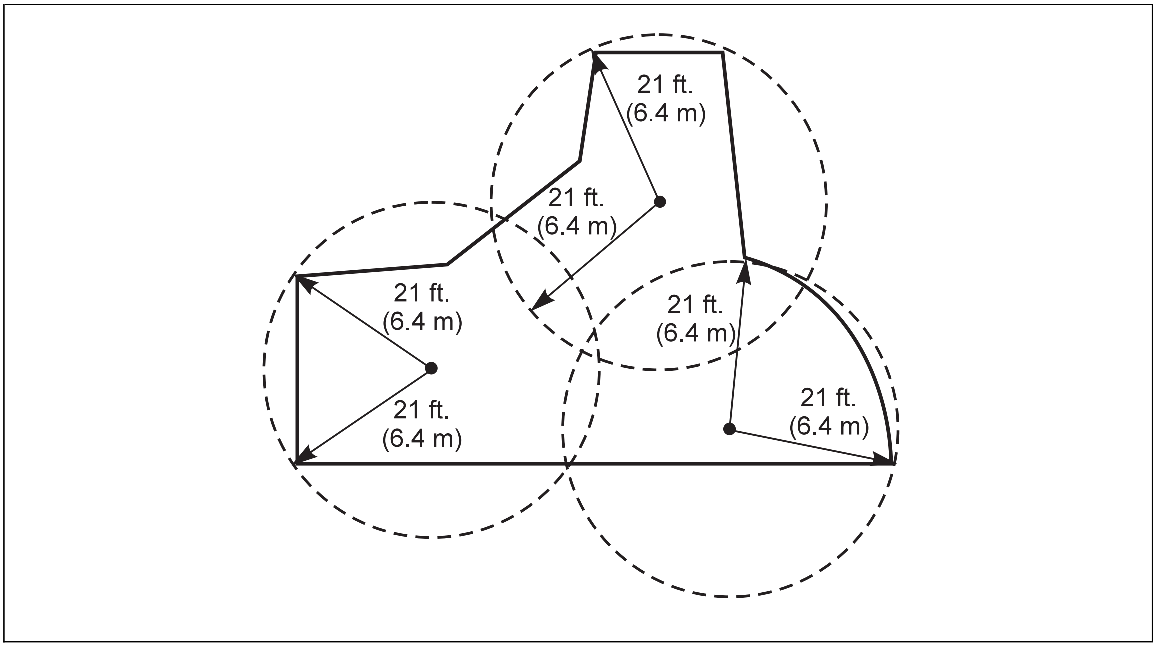

Fig. 4. Spacing of heat and smoke detectors in irregularly shaped areas.

2.2.2.3.7 Set detector spacing to the nearest wall or partition at no more than one-half of the spacing distance between detectors (see Figure 5). Locate detectors nearest to the room corners at no more than 0.7 of the FM Approved distance from each corner of a room.

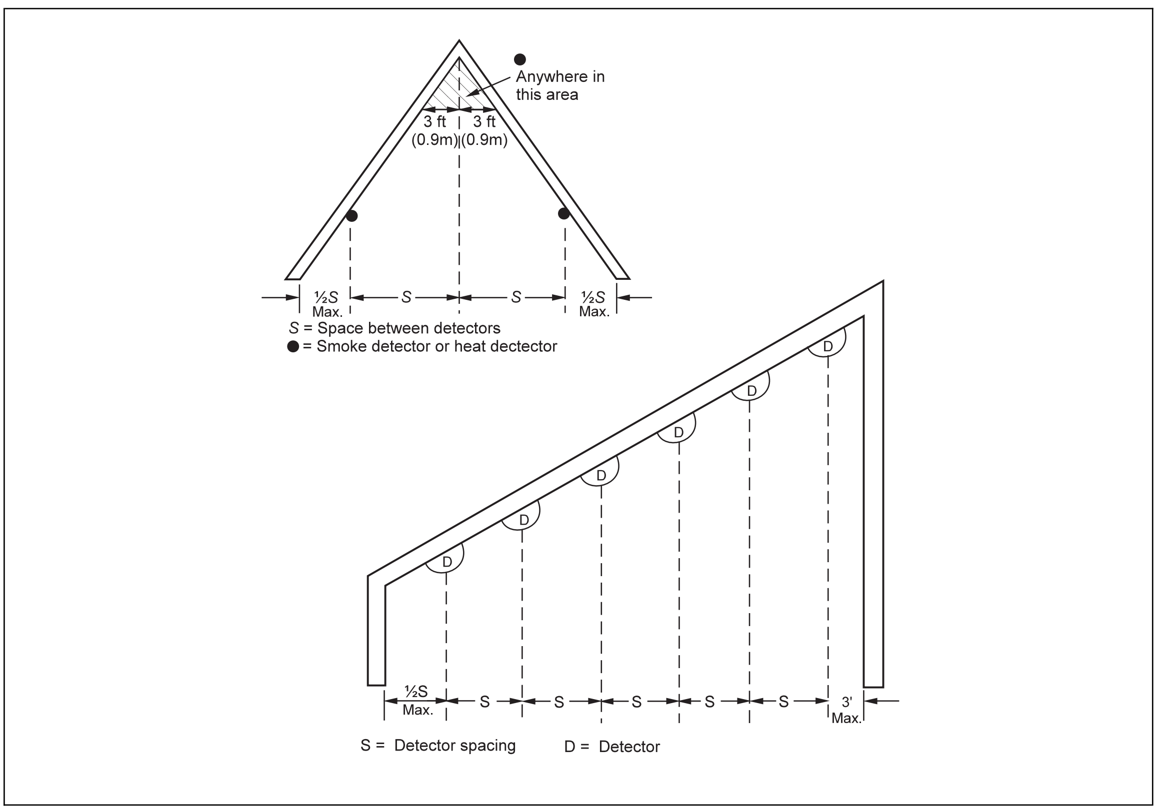

Fig. 5. Maximum suggested spacing of heat detectors on a smooth ceiling.

2.2.2.3.8 For ceilings higher than 10 ft (3 m) and up to 30 ft (9 m), prior to reductions made for beams, joists, or slopes, reduce spacing according to Table 3. This spacing reduction can be used in Hazard Category 1 (HC-1) and Hazard Category 2 (HC-2) occupancies (as defined in Data Sheet 3-26) where a small, steady-state fire might occur and where there are no sprinklers. Do not use this spacing reduction in warehouses where a fast-growing fire can be expected. The purpose of reducing spacing in accordance with Table 3 is to allow a 1000 kW fire to be detected in a certain amount of time regardless of ceiling height. This table does not apply to line-type detectors.

Table 3. Heat Detector Spacing Reductions for Ceilings Higher than 10 ft (3 m)

Ceiling Height (ft)	*Ceiling Height (m)*	*Multiply Spacing By*
>10 to 15	>3.0 to 4.5	0.85
>16 to 20	>4.5 to 6.0	0.70
>21 to 25	>6.0 to 7.5	0.55
>26 to 30	>7.5 to 9.0	0.40

2.2.3 Smoke Detectors

2.2.3.1 General

2.2.3.1.1 Install smoke detectors in accordance with the applicable occupancy-specific data sheet.

2.2.3.1.2 Consider spaces below raised floors and above suspended ceilings as separate rooms for the purpose of detector spacing.

2.2.3.1.3 Do not use smoke detectors where the temperature is expected to exceed 100°F (38°C), the relative humidity can exceed 93%, or the airflow is greater than 300 ft/min (91 m/min) unless the detector is FM Approved for these conditions. Note that ionization detectors do not work properly in areas with high air flows. In ducts and plenums, use detectors that are FM Approved for this application. Use heat detectors or flame detectors in areas where the environment makes it impractical to use smoke detectors.

2.2.3.1.4 For areas where cutting and welding is conducted, install motion detectors interlocked with the smoke detection system to lock out the detection system when occupants are present in the room. Or, use ″intelligent″ detectors that change sensitivity settings between day and night or occupied and unoccupied periods. Do not use these practices when detectors are interlocked with a protection system.

2.2.3.1.5 Perform a review of fire detection systems whenever there have been any structural or environmental changes.

2.2.3.1.6 Use beam detectors in long corridors (where ceiling height is at least 9 ft (2.75 m). Note that for low ceiling heights, trouble signals or fire alarms can occur if the beam becomes obstructed for too long.

2.2.3.2 Installation

2.2.3.2.1 Locate spot-type ceiling-mounted smoke detectors not less than 4% of the ceiling height from the side wall. See Figure 1.

2.2.3.2.2 For solid joisted and beamed ceilings deeper than 3% of the ceiling height, do not exceed 50% of the detector’s smooth ceiling spacing, as measured at right angles to the joists and beams.

2.2.3.2.3 Use smooth ceiling spacing in the direction parallel to beams. See Figure 2.

2.2.3.2.4 If beams project more than 15% of the ceiling height, treat each section between beams as a separate area.

2.2.3.2.5 In areas such as atriums and indoor stadiums, evaluate for stratification under the ceiling. Stratification may cause a heat barrier to form under a high ceiling, which could interfere with smoke reaching the ceiling. (See Section C.4 for a discussion on temperature stratification.)

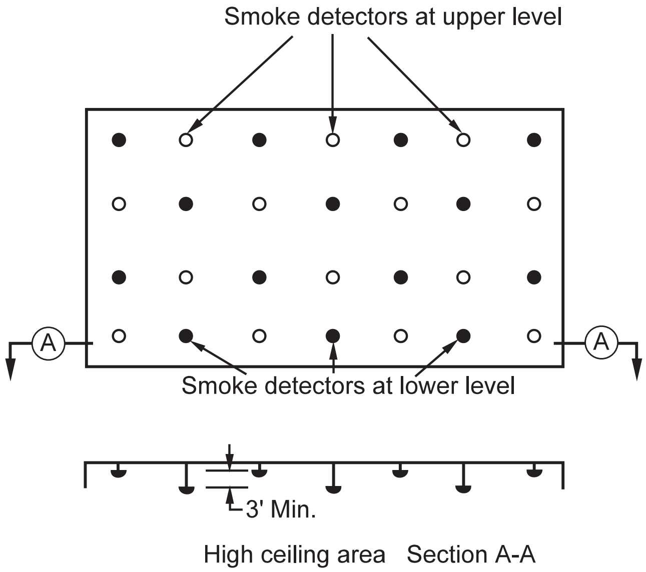

Fig. 6. Location of smoke detectors in high ceiling areas to reduce the effects of gas stratification. Note: 1 ft = 0.3 m.

2.2.3.3 Spacing

2.2.3.3.1 Follow the manufacturer's guidelines to assist with a determination of smoke detector spacing. The method of determining spacing of smoke detectors is not as exact as that used for heat detectors due to the lack of data and the number of variables that must be considered. See Section C.3 for a brief description of how to determine smoke detector spacing. When necessary, perform an engineering evaluation of the particular installation, supplemented, if feasible, by field smoke tests.

2.2.3.3.2 Reduce spacing by 50% where there are partitions if the distance between the top of a partition and the ceiling is less than 10% of the ceiling height. If closer than 5%, treat each partitioned area as a separate room.

2.2.3.3.3 Reduce the area covered by a detector by 50% when ceiling fans are used for de-stratification. See Section C.4 for guidance on stratification.

2.2.3.3.4 For spot-type smoke detectors on smooth ceilings with little or no forced air flow in the room (a maximum of six air changes per hour), use a maximum coverage of 900 ft^2 (84 m^2) per detector or a spacing of 30 ft (9 m) between detectors. Reduce to a maximum coverage of 125 ft^2 (12 m^2) per detector where the room air is changing at a rate of 60 air changes per hour. See Table 4 for suggested coverage as a function of air changes.

Table 4. Smoke Detector Spacing Based on Air Changes

Minutes per Air Change	*Air Changes per Hour*	*Spacing ft^2*	*Spacing m^2*
1	60	125	12
2	30	250	23
3	20	375	35
4	15	500	46
5	12	625	58
6	10	750	69
7	8.6	875	81
8	7.5	900	84
9	6.7	900	84
10	6	900	84

2.2.3.3.5 For beam-type photoelectric detectors on smooth ceilings with little or no forced air flow in the room, install the beam detectors 30 ft (9 m) or less apart with one-half or less spacing to side walls.

Faster response may result with closer spacing of the detectors depending on the ceiling height and type of fire. For high ceilings where stratification and ventilation can prevent smoke from reaching ceiling detectors, install beam detectors at lower levels. If installed at a lower elevation, do not exceed a spacing of 30% of the installation height (this will be less than the width of a fire plume). See Figure 6.

If mirrors are used to redirect a beam around corners so that one beam can monitor an area in several directions, reduce the FM Approved maximum beam length per manufacturer's instructions (about 2/3 L for two sides and 4/9 L for three sides). Mirrors will attenuate the beam, thus reducing its range.

2.2.3.3.6 If a system requires a response from two detectors (cross-zoned) to cause an alarm, then reduce the area protected by each detector such that it does not exceed 1/2 the maximum allowed area.

2.2.3.3.7 For sloped beamed ceilings with beams running up or across the slope, use flat beamed ceiling spacing. The ceiling height is equivalent to the average height over the slope. If the slope is greater than 10°, the bottom row of detectors at 1/2 spacing can be eliminated. See Figure 3.

2.2.3.3.8 For peaked ceilings, locate the first row of detectors within 3 ft (1 m) of the peak (measured horizontally between one side of the roof and a vertical line extending down from the peak). Space the lower rows based upon the horizontal projection of the ceiling. See Figure 3.

2.2.3.3.9 For shed ceilings, locate the first row of detectors within 3 ft (1 m) of the top of the ceiling (measured horizontally from the wall). See Figure 3. Space the lower rows based upon the horizontal projection of the ceiling.

2.2.3.3.10 Where smoke detectors are installed, install them near HVAC return diffusers. Do not install detectors within 3 ft (1 m) of supply diffusers with weak ventilation, and within 9 ft (3 m) of supply diffusers with strong ventilation. Where duct detectors are provided, provide at least 6 duct widths between a detector and a diffuser or bend.

2.2.3.3.11 Provide duct detectors where smoke can be transported to sensitive areas.

2.2.3.3.12 Provide duct detectors with interlocking fans when air supply systems have capacity greater than 2,000 ft^3/min (3,400 m^3/hr). In addition, provide the following:

- Install detectors upstream of branch connections for air supply systems.
- Install detectors downstream of fans and filters, and upstream of connections to a common return, on each floor of a building.
- Install detectors upstream of recirculation and fresh air inlet connections to the main duct for common air return systems having a capacity greater than 15,000 ft^3/min (25,500 m^3/hr) and serving more than one floor,
- Install listed, fire-rated dampers when passing through a fire-rated floor, ceiling or wall assembly.

2.2.3.3.12.1 Duct detectors in return ducts are not necessary if the room has complete detector coverage.

2.2.3.3.12.2 Ensure detectors installed in plenums are FM Approved for the environment and airflow. See NFPA 90A, *Installation of Air Conditioning and Ventilation Systems*, and NFPA 92A, *Recommended Practice for Smoke Control Systems*.

2.2.3.3.13 For air sampling systems, design the system so the sampling time from the farthest sampling point does not exceed 120 seconds. Depending on design and product, one sampling system may cover an area as large as 20,000 ft^2 (1900 m^2). Set the detector to signal a trouble condition when sampling airflow is outside of the manufacturer's specified range.

2.2.3.3.14 For large sampling systems, use multiple sensors, or use a system that can help narrow down the location of the fire source. Some air sampling systems accomplish this using a valve to alternate the sampling lines after smoke is sensed. Locating the fire source is difficult unless there is a fast-growing fire or the fire happens to be near a detector or sampling port.

2.2.4 Flame Detectors

2.2.4.1 General Installation and Spacing Guidelines

2.2.4.1.1 Base the specific locations and spacing for flame detectors on an engineering survey of the anticipated conditions in the area to be protected.

2.2.4.1.2 Consider the fuel, location of expected fire, distance, detector characteristics, and potential nuisance sources such as lighting, welding, or reflections from standing water.

2.2.4.1.3 Install the detectors so their field of vision will be adequate to ensure detection of a specified area of the fire. Test flames are sometimes necessary in order to determine the proper detector locations. The protection of an area can be improved by overlapping the areas of cone coverage from the detectors.

2.2.4.1.4 Match the spectral response of the detector to the spectral emissions of the expected fire source.

2.2.4.1.5 Arrange or shield flame detectors so they are not actuated by radiant energy sources that could produce nuisance alarms. Infrared lamps, matches, cigarette lighters, and sunlight may induce an unwanted alarm from an infrared detector. Nuisance alarms from ultraviolet detectors may be produced by germicidal lamps, X-ray machines, welding arcs, and arcing from electrical motors. FM Approved detectors are tested for susceptibility to false alarms from common sources.

2.2.4.1.6 Keep the sensors clean or use sensors that can detect a dirty detector window. When used out-of-doors, use detectors appropriate for this purpose and use shielding if necessary.

2.2.5 Gas-Sensing Fire Detectors

2.2.5.1 General Installation and Spacing Guidelines

2.2.5.1.1 Locate spot-type detectors on the ceiling no less than 4% of the ceiling height from the sidewall, or, if on the sidewall, between 4% and 12% of the ceiling height below the ceiling. On low ceilings, in general, use a 30 ft (9 m) spacing as a guide. Other spacings may be needed depending on ceiling height, conditions, and response requirements.

2.2.5.1.2 Where forced ventilation is present, do not locate detectors within a direct path of the forced ventilation.

2.2.5.1.3 To prevent false operation, select gas-sensing fire detectors based on the design of the detector and the normal environment of the area to be protected. Do not install them where concentrations of detectable gases are present under normal conditions. For instance, unexpected release of some aerosol sprays and hydrocarbon solvents may result in detector operation.

2.2.6 Arc Detectors

2.2.6.1 Provide an arc detection system inside electrical rooms where it is desired to detect damaging arc faults, which can cause fires and explosions. This type of system will detect an arc in several milliseconds and de-energize the equipment before any damage can be done.

2.2.7 Pilot Sprinkler Systems

2.2.7.1 Install dry or wet pilot sprinklers using the criteria in Data Sheet 2-0 for dry or wet automatic sprinkler systems for non-storage occupancies.

2.2.7.1.1 Choose the temperature rating of pilot-type sprinklers to be at least 50°F (28°C) above expected ambient temperatures.

2.2.7.1.2 The water distribution obstruction rules for automatic sprinklers do not apply to pilot sprinklers.

2.2.7.1.3 Pilot sprinklers can be supported by the water spray/deluge/pre-action system piping.

2.2.7.1.4 When installing pilot sprinklers below a ceiling, locate the pilot sprinklers within 12 in. (300 mm) of the open water spray nozzles/sprinklers.

2.2.7.1.5 When installing pilot sprinklers outdoors or for a multi-level water spray system, locate the pilot sprinklers near the open water spray nozzles/sprinklers.

2.2.7.1.5.1 Provide a maximum of 17 ft (5.2 m) vertical spacing between multiple levels of pilot sprinklers.

2.2.7.1.5.2 Lay out pilot sprinklers installed at multiple levels in a vertically staggered arrangement.

2.2.7.1.6 Install a valve with a deluge nozzle/open sprinkler at the most hydraulically remote point in the pilot sprinkler system for testing the system.

2.2.7.2 Arrange the piping system to activate the deluge/pre-action valve within 40 seconds of the most remote pilot sprinkler operation.

2.2.7.2.1 Provide a minimum pipe size of 1 in. (25 mm) for pilot sprinkler systems using steel or galvanized steel pipe, and ¾ in. (19 mm) for copper and stainless steel.

2.2.7.2.2 Use a tree-type piping layout for pilot sprinkler systems. Avoid gridded arrangement.

2.2.7.3 Protect pilot sprinkler systems against corrosion when installed outside or in the presence of corrosive vapor.

2.2.7.3.1 Select pipe and nozzles material suitable for the environment they will be exposed to.

2.2.7.4 Protect pilot sprinkler piping systems against mechanical damage.

2.2.7.5 Provide dry pilot sprinkler systems with a reliable source of system gas.

2.2.7.5.1 The gas used for maintaining internal pressure within the dry pilot sprinkler system can be dry air, an inert gas, or a gas that is FM Approved specifically for use in dry sprinkler systems this application.

2.2.7.5.2 Ensure the gas used is compatible with all system components.

2.2.7.5.3 Arrange the gas supply in accordance with the deluge valve manufacturer's specifications.

2.2.7.5.4 Install a check valve on the connection between the gas supply and the dry pilot sprinkler system.

2.2.7.5.5 Arrange the gas supply piping to permit tightness testing, including tightness of the check valve.

2.2.7.5.6 Ideally, provide a separate gas supply for each dry pilot sprinkler system. If multiple systems are fed by a single gas supply, provide check valves that will ensure the individual systems are isolated from other attached systems and the gas supply.

2.2.7.5.7 If the air supply feeds multiple dry pilot sprinkler systems, provide a backup air supply capable of maintaining system air pressure for at least 24 hours. This can be achieved by providing a secondary electric supply, a properly sized air receiver, or gas cylinders.

2.2.7.5.8 Provide a high and low gas pressure alarm to a constantly attended location. Set the alarm to be no less than 5 psi (0.3 bar) above the deluge valve trip pressure.

2.2.7.5.9 Ensure the gas supply can fill the dry-pilot system up to the minimum required system pressure within 30 minutes.

2.2.7.5.10 Arrange the gas supply to not exceed the maximum recommended gas pressure maintained in the dry pilot sprinkler system.

2.2.7.5.10.1 Install a relief valve between the gas supply and the dry pilot sprinkler system arranged to relieve at 5 psi (0.3 bar) above the maximum recommended gas pressure.

2.2.7.6 Inspect, test, and maintain gas generation equipment in accordance with Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance*.

2.3 Testing and Maintenance

2.3.1 General

2.3.1.1 Periodically inspect and test automatic fire detectors to ensure they are in reliable operating condition. Notify appropriate personnel in advance of testing. Document the test procedures and results. Where detection is interlocked with a protection system, secure the systems from inadvertent actuation, including disconnection of releasing solenoids or electric actuators, closing of valves, or combination thereof, for the system for the duration of the test. Return the suppression systems and releasing components to their functional operating condition when system testing is completed.

2.3.1.2 Perform visual inspections of automatic detection devices in accordance with Table 5.

Table 5. Visual Inspection Frequencies

Detector	*Initial/ Reacceptance*	*Monthly*	*Quarterly*	*Biannually*	*Annually*
Heat - Fixed temp - Rate compensate - Rate of Rise - linear	X			X	
Smoke - photoelectric - ionization - air sampling - duct - laser - beam	X			X	
Video Smoke/flame	X			X	
Radiant energy/flame	X		X		
Gas Sensing	X			X	
Arc	X		X		

2.3.2 Testing Methods and Frequency

2.3.2.1 Test automatic detection devices in accordance with Table 6.

Table 6. Testing Frequencies

Detector	*Initial/ Reacceptance*	*Monthly*	*Quarterly*	*Biannually*	*Annually*
Heat - Fixed temp - Rate compensate - Rate of Rise - linear	X				X
Smoke - photoelectric - ionization - air sampling - duct - laser - beam	X				X
Video Smoke/flame	X				X
Radiant energy/flame	X			X	
Gas Sensing	X				X
Arc	X			X	

2.3.2.2 Test the detection devices using the methods shown in Table 7, or in accordance with the manufacturer’s documented instructions.

Table 7. Test Methods

Device	*Method*
Heat Detectors Fixed-temperature, rate-of-rise, rate of compensation, restorable line, spot-type (excluding pneumatic tube type)	Use a heat source such as a hair dryer or shielded heat lamp in accordance with the manufacturer's instructions until the detector responds. Response should be received within one minute. Reset the detector after each test.
Fixed-temperature, non-restorable line or spot-type	Do not perform a heat test. Remove two of every 100 detectors 15 years from date of original installation for testing. If failure occurs on tested detectors, remove additional detectors and conduct further testing. Replace failed detectors.
Smoke Detectors Photoelectric and ionization	Conduct test in accordance with manufacturer's documented instructions.
Air sampling	Conduct test in accordance with manufacturer's documented instructions and through the end sampling port. Be sure to verify airflow through all other ports.
Duct-type	Verify functionality in accordance with the manufacturer's documented instructions.
Laser/beam	Test by introducing smoke, other aerosol, or an optical filter into the beam path.
Video image smoke and flame	Inspect, test, and maintain in accordance with the manufacturer's documented instructions.
Radiant energy/flame	Determine the detector's sensitivity and operability in accordance with the manufacturer's calibrated test method.
Gas sensing	Inspect, test, and maintain in accordance with the manufacturer's documented instructions.
Arc	Determine the detector's operability in accordance with the manufacturer's calibrated test method.

2.3.2.3 Heat Detectors

2.3.2.3.1 Do not heat-test non-restorable spot-type heat detectors because the sensing element would be destroyed by the test. Test the alarm circuit annually for electrical continuity. This type of detector is not preferred because it is not possible to perform a functional test on it. After 15 years, replace all non-restorable spot-type detectors, or test two per 100 in a certified test laboratory and repeat testing every 5 years.

2.3.2.3.2 For restorable spot-type heat detectors, choose different detectors for each test. The detector can be tested with a heat source.

2.3.1.3.3 Test pneumatic rate-of-rise line-type heat detectors for proper operation and leaks biannually. The detector can be tested with a heat source if a test chamber is available in the signal circuit, or pneumatically with a pressure pump in accordance with the manufacturer's instructions.

2.3.2.3.4 Measure fixed-temperature line-type heat detector loop resistance annually.

2.3.2.4 Smoke Detectors, Flame Detectors, and Fire-Gas Detectors

2.3.2.4.1 Check detector sensitivity at least one year after installation and every two years after that. After the second test, if sensitivity is within its FM Approved range, the sensitivity testing frequency can be reduced to five years. Use an FM Approved calibrated test method, or FM Approved or manufacturer's test equipment. Replace or recalibrate any detector that fails sensitivity testing.

2.3.2.4.2 Clean ionization and photoelectric smoke detectors at least annually to remove accumulated dust and dirt, which can increase sensitivity and result in false alarms. Increase the frequency of cleaning as necessary, depending on the operating environment.

2.3.2.4.3 Clean flame radiation detectors at least quarterly because slight accumulations of dust or other coatings on the lens or sensitive element can adversely affect performance. Increase the frequency of cleaning as necessary, depending on the operating environment and detector type. UV detectors are especially sensitive to dirt and dust.

2.3.2.4.4 For air sampling systems, periodically test for air tightness, and change filters as recommended by the manufacturer.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

While it is not required to have smoke or heat detectors installed with automatic sprinklers, it might be done where it is desired to have some advance notice before sprinkler activation.

In locations where ambient temperature at the ceiling is high from heat sources other than fire conditions, heat-responsive devices that operate at higher than ordinary temperature and are capable of withstanding the normal high temperature for long periods of time should be selected.

Fixed-temperature heat detectors that are categorized as spot-type have a detecting element or elements that respond to temperature conditions at a single point or in a small area.

Spacing of fixed, rate of compensation, or rate of rise spot-type heat detectors varies. The recommended spacing of heat detectors depends on the sensitivity of the specific detector, the ceiling construction, the normal room temperature, possible drafts, heating systems, the type of occupancy, and other factors, such as expected fire development. The FM Approved spacing is the maximum distance allowed between detectors and also an indication of the response time.

Heat-actuated devices used in preaction and deluge systems are subject to premature operation in certain locations. Such locations include near ovens and other heat-producing equipment and in freezer areas near freezing equipment also used for defrosting. In such cases, affected heat-actuated devices should be adjusted to accommodate expected temperature gradients.

4.0 REFERENCES

4.1 FM

Data Sheet 5-40, *Fire Alarm Systems*

4.2 Other

National Fire Protection Association (NFPA). *Installation of Air Conditioning and Ventilation Systems.* NFPA 90A.

National Fire Protection Association (NFPA). *National Electrical Code.* NFPA 70.

National Fire Protection Association (NFPA). *National Fire Alarm Code.* NFPA 72.

National Fire Protection Association (NFPA). *Recommended Practice for Smoke Control Systems.* NFPA 92A.

APPENDIX A GLOSSARY OF TERMS

Addressable Detector: A fire detector that can communicate a unique identification so that the exact location of an alarm can be identified at a control panel.

Air Sampling Smoke Detector: A system which draws air, via a pipe network, to a central detector which monitors for small amounts of smoke.

Alarm Verification: A feature used to reduce nuisance smoke alarms by confirming alarm conditions within a given time period after the detector has been automatically reset.

Approval Guide: An online resource of FM Approvals that lists FM Approved products and services.

FM Approved: References to ″FM Approved″ in this data sheet mean the products or services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Automatic Fire Detector: A device that senses or detects the presence of fires and initiates action.

Beam Detector: A light beam smoke detector with a beam source and receiver. The light beam is obscured when smoke or heat enter its path.

Ceiling Height: The height of the ceiling above the floor, mezzanine or platform where combustibles are stored and a fire can occur.

Characteristic Length: A characteristic of a particular smoke detector's geometry that can be helpful in determining spacing. A lower value of length indicates less resistance to smoke entry and a smaller time lag. The distance smoke would have to travel at a given velocity before the optical density inside the detector equals that outside.

Combination Detector: A fire detector that combines two or more sensing techniques such as heat and smoke, ionization and photoelectric, CO and ionization, etc., for the purpose of discriminating between real and non-fire sources.

Cooperative Algorithms: Algorithms that use input from several detectors.

Critical Fire Size: The maximum fire size at the time of detection that allows action to be taken to limit the fire size to the design limit or design fire size. The difference between the critical fire size and design fire size is the total response time, which consists of gas transport time, detection delays, verification delays, notification and evacuation delays and fire fighter response time.

Deluge system: Sprinkler system with open sprinklers, which is used where it is desirable to deliver water through all sprinklers simultaneously and to wet down the entire area protected, as at airport hangars, pyroxylin storage or working, and similar special hazards needing the immediate application of large quantities of water

Design Fire Size: The point at which extinguishing action must be initiated in order to control the fire. The property owner must decide first what and how much damage is acceptable, or what the acceptable risk is.

Drift Compensation: Automatic changes in smoke detector sensitivity to compensate for slow changes over time (for example, when a detector becomes dirty). Many advanced detectors have this feature. Panels accomplish this in analog systems.

Duct Detector: A smoke detector designed to work in high airflow HVAC ducts.

Fire Growth: Stages of a fire; incipient, smoldering, flaming and high heat release.

Fire Growth Time (tg): The amount of time needed for combustion of a specific material to reach a heat release of 1000 kW in a t-squared fire. Also called ″critical time″.

Flame Detector: A device that senses radiation from a fire, usually infrared or ultraviolet.

Heat Detector: A fire detector that senses an abnormally high temperature or a rate-of-temperature-rise.

Intelligent Smoke Detector: Detectors that can discriminate between fire and non-fire sources, also referred to as ″smart detectors″. These detectors are analog and can communicate information about actual levels of smoke to the panel. They may be programmable, and some can learn or have ″artificial intelligence″.

Inverted Cone: A fire plume that takes the shape of an upside down cone where the plume spreads out under the ceiling.

Ionization Smoke Detector: A detector with a small amount of radioactive Americium-241, which emits alpha particles that ionize the air. The ionized air causes a conductance of electrons between the negative and positive plates. Ions will attach to smoke particles and are slowed down, and some are carried out of the chamber with the smoke. This causes a current reduction and an alarm. Many ionization detectors use a second radioactive source in a reference chamber to account for atmospheric humidity and pressure changes.

Laser Smoke Detector: Similar to a photoelectric detector except that the light source is a laser, and light is reflected back to the sensor which is located next to the laser.

Photoelectric Detector: Consists of a light source and a sensor. When smoke enters the chamber, light is scattered and some of the light is redirected to the sensor which is off to the side.

Plume: Thermally-driven flow of products of combustion that rise from a flame.

Power Law Fire: See T-squared fire.

Preaction Sprinkler System: A sprinkler system that is located downstream of a preaction valve and is equipped with closed-type sprinklers (i.e. sprinklers equipped with a thermal sensing element and an orifice cap).

Pyrolysis: Chemical change brought about by the action of heat.

Refrigerated Area Systems: Hybrid preaction systems that require both a sprinkler and a heat actuated device to operate before the water control valve opens and admits water into the sprinkler piping. They are intended for use in freezers with extremely low temperatures.

Response Time Index (RTI): An expression of a heat detector's sensitivity, used to determine its time constant.

Spot Detector: A fire detector with a small element that senses heat or smoke at its location only. Spot detectors cover a specified area.

Smoke: Visible and invisible products of incomplete combustion, including solid and liquid particles and gases. Also referred to as aerosols.

Smoldering: Nonflaming combustion, which occurs in char-forming materials where the insulating nature of the char traps heat and maintains a glowing reaction zone.

Smooth Ceiling: A smooth ceiling is one where beams project below the ceiling no more than 3% of the ceiling height.

Stratification: Heat buildup near a ceiling, which can prevent smoke from rising to the ceiling and cause a layer of smoke at a lower elevation.

Supervision: Monitoring an alarm circuit for integrity and fault conditions.

Thermal Lag: The temperature difference of a fixed temperature heat detector element and the air outside the element. At detector activation, the air temperature will be higher than that of the element itself.

Threshold Fire Size: The size fire that will be detected within the intended response time.

T-squared fire (t2): A fire where the heat release rate is proportional to the square of the time.

Very Early Warning Fire Detection (VEWFD): Detectors using xenon or laser light detection chambers can be considered VEWFD detectors. These detectors may be spot-type or air sampling type detection systems. VEWFD detectors are an order of magnitude more sensitive than conventional smoke detectors, and can be set to alarm at smoke obscuration levels below 0.02%/ft (0.06%/m). Conventional smoke detectors alarm at 1 to 3%/ft (3.3 to 9.8%/m).

Wireless Smoke Detector: A battery-operated device with a radio transmitter for sending information including power level to a panel.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Interim revision. Significant changes include the following:

> Revised Section 2.2.3, Smoke Detectors, to include additional recommendations for duct detector location and interlocking. These recommendations are based upon FM Data Sheet 1-45, *Air Conditioning and Ventilating Systems*, which will be obsolete effective April 2025.

October 2021. Interim revision. Provided a new section 2.2.7 to cover wet and dry pilot sprinkler systems used to activate water spray systems.

January 2011. The following changes were made:

- Updated spacing recommendations for heat detectors using response time index (RTI).
- Added guidelines for new detection technologies.
- Provided detection installation recommendations for preaction sprinkler systems.

- Added testing method and frequency tables.

June 2009. Reference to Data Sheet 7-53, *Liquefied Natural Gas (LNG)*, was deleted.

January 2005. Updated with editorial changes.

May 2003. Recommendation 2.2.2.2.1 was changed to be in agreement with recommendation 2.2.2.2.2 that covers the installation of line-type heat detectors.

May 2002. Sections 2.2.2.2 and 2.2.3.2.1 were changed and are now consistent for heat and smoke detectors. The decision to install detectors on the bottom of beams now depends on the ratios of beam depth and beam spacing to ceiling height. A depth ratio of 0.10 and a spacing ratio of 0.30 has been used.

January 2002. The following changes were made:

1. A Support for Recommendations section has been created with loss experience.

2. A glossary and a reference section have been added.

3. An appendix has been added. Much of the information on detectors from the previous version of the data sheet has been placed in the appendix. New information on detectors and calculation methods for detector spacing, temperature rise during a fire and stratification have been added. The intent of the calculations is to help minimize response time.

4. New recommendations have been added as follows:

- distances of detectors from walls, corners, etc., have changed from specific distances to percentages of the ceiling height (H) above the base of a fire (the ceiling height in most cases).
- applications of various types of detectors.
- additional spacing guidelines.
- how to handle beams, joists and partitions.
- environmental considerations (adverse effects on detectors).
- table for heat detector spacing based on ceiling height.
- table on smoke detector spacing based on room air changes.

5. Information has been added on minimizing nuisance alarms.

APPENDIX C CHARACTERISTICS OF AND APPLICATIONS FOR AUTOMATIC FIRE DETECTORS

C.1 General Information

An automatic fire detector is a device that senses or detects the presence of fire and initiates action. The four principal classes of automatic fire detectors are heat detectors, smoke detectors, flame detectors, and fire-gas detectors. Temperature rise, radiation, CO_2 (except in a pure hydrogen fire), and H_2O are always found in a flaming fire. Smoke and CO are usually there, but the amount varies greatly depending on the type of fire. The three principal types of fire detectors are spot detectors, line-type detectors, and air sampling detectors. A spot-type detector is one in which the sensor is concentrated at a particular location. A line-type detector is one in which detection is continuous along a path. In an air sampling detector, a pump draws air from the protected area through a series of tubes to the sensor where it is analyzed for fire products.

The dimensions used to indicate the allowable coverage of the detector are called the spacing. The spacing may be stated as the horizontal distance between detectors, expressed in feet (meters), or the maximum coverage, expressed in square feet (square meters). The spacing figure mentioned by recognized testing laboratories for detectors is an indication of their relative sensitivity. However, detectors operating on various physical principles have different sensitivities to different types of fires and fuels. Fires may be fast or slow burning, flaming or smoldering (or pyrolizing).

Also important in a well-designed fire detection system is the elimination of false and nuisance alarms. False alarms are caused by things such as electromagnetic fields, dust, excessive heat, and radio frequency interference. The elimination of false alarms should be incorporated into the component design. Components such as detectors and panels should be FM Approved or listed by a nationally recognized testing laboratory. In North America, detectors must be compatible with the alarm panel, and must be wired properly according to NFPA 72, National Fire Alarm Code, and NFPA 70, National Electrical Code. See Data Sheet 5-40, *Fire Alarm Systems*. Outside North American, adhere to the comparable international standards.

Nuisance alarms can be caused by non-fire sources such as steam, cutting and welding, engine exhaust fumes, dust, lighting, and smoking. Nuisance alarms can be minimized through proper system design, application, installation, maintenance and cleaning, and also by using advanced detectors or systems that can differentiate between fire and non-fire sources. These things are as important as component design and are a significant part of total system reliability. Detectors alone can not be blamed for all false alarms. There are many other factors that can lead to false and nuisance alarms. Improper wiring, loose connections, and various types of faults can lead to false alarms.

C.2 Heat Detectors

C.2.1 Introduction

A heat detector senses abnormally high temperature or rate of temperature rise. Heat detectors can be classified according to their operating principle as fixed-temperature detectors, rate-compensation detectors, and rate-of-rise detectors. For fixed-temperature and rate-compensation detectors, as long as the temperature of the fire gases is above the detector rating, heat transferred from the ceiling gas flow to the detector will cause it to actuate when faster response is desired, detectors must be spaced closer than normal.

Rate-of-rise devices may alarm more quickly than fixed-temperature detectors, particularly in highly combustible occupancies, in unheated buildings in the winter, and in cold storage areas. Note that for rate-of-rise detectors, a false alarm may occur when temporary heaters are used or an interruption of refrigeration occurs. Fixed-temperature devices may be more reliable in detecting slowly developing fires, and they usually require less attention to prevent false alarms.

Heat detectors may employ more than one operating principle in order to respond quickly to both fast-acting and slow-acting fires. Such a unit could be a combination fixed-temperature and rate-of-rise heat detector. The fixed-temperature device in this combination detector operates in case the temperature rises too slowly to operate the rate-of-rise device.

A non-restorable heat detector has a sensing element that is destroyed when a fire is detected. The sensing element in a restorable detector is not ordinarily destroyed when a fire is detected. Some detectors are automatically self-restoring as the sensing element returns to normal.

C.2.2 Fixed-temperature Detectors

The fixed-temperature detector is designed to operate when the temperature of its operating element reaches a predetermined value. Because there is a thermal lag, the temperature of the surrounding air is higher than the operating temperature of the detector itself. The fixed-temperature sensing element for a detector may consist of two metals having different coefficients of thermal expansion (bimetallic), an electrical resistor whose resistance varies as a function of temperature (electric conductivity), a special composition metal that melts quickly at the rated temperature (fusible alloy), two current-carrying wires separated by heat sensitive insulation that softens at the rated temperature so that the wires make electrical contact (heat sensitive cable), or a liquid capable of expansion in response to the increase in temperature (liquid expansion).

C.2.3 Rate-compensation Detectors

The rate-compensation detector is designed to operate when the temperature of the air surrounding the detector reaches a predetermined value, regardless of the rate of temperature rise. This device is intended to reduce the effect of thermal lag that is present in a fixed-temperature detector.

C.2.4 Rate-of-rise Detectors

The rate-of-rise detector is designed to operate when the temperature of its operating element rises at a rate exceeding a predetermined amount (rate-of-rise set point value), regardless of the temperature level. The rate-of-rise set point is usually between 15°F (8.3°C) and 25°F (13.9°C) rise per minute. These detectors should not be used in an area where temperature can change rapidly such as near some machinery. A rate-of-rise detector may be a line-type unit consisting of small diameter pneumatic tubing which is terminated in a detector unit having calibrated vents, diaphragms, and contacts arranged to actuate at a predetermined pressure. The detection system is sealed except for the calibrated vents, which compensate for normal changes in temperature. A rate-of-rise detector can also consist of a spot-type unit with an air chamber, diaphragm, contacts, and vent contained in a single enclosure. A third type of rate-of-rise detector is the thermoelectric effect type. In this type the sensing element consists of a thermocouple or thermopile unit, which produces an increase in electric potential in response to an increase in temperature. An alarm is initiated when the potential increases at an abnormal rate. This type is subject to a lowering of sensitivity by corrosion.

C.2.5 FM Approved Heat Detectors

An FM Approved heat detector will operate at least as quickly as an FM Approved, comparably degree-rated, automatic sprinkler on 10 by 10 ft (3 by 3 m) spacing under the same conditions of heat exposure. An FM Approved detector is also designed to operate within 3% of its intended fixed temperature in °F or, if of the rate-of-rise type, to operate at an ambient temperature increase of between 15°F and 25°F (8.3°C and 13.9°C) per minute.

C.3 Smoke Detectors

C.3.1 Introduction

A smoke detector senses visible or invisible particles of combustion. Smoke detectors can be classified according to their operating principle as ionization detectors, photoelectric detectors, beam detectors, laser detectors and air sampling detectors. Smoke detectors will usually respond more quickly and to smaller fires than heat detectors. Care should be taken when applying FM Approved detector spacings because spacing is highly dependent on ceiling height and other factors.

Ceiling height, shape of ceiling, arrangement of contents, burning characteristics of the stored combustibles, ventilation, and environment must be considered when determining the spacing for smoke detectors in various applications. The expected fire size also is important. To detect a 100 kW fire in the same amount of time as a 1000 kW fire requires that detectors be spaced much closer.

The aerodynamic design of the detector can be important if it restricts smoke entry (see Heskestad, G., ″Generalized Characterization of Smoke Entry and Response for Products-of-Combustion Detectors,″ Fire Detection for Life Safety, Proceedings, March 31 to April 1, 1975, National Academy of Sciences, Washington D.C., 1977). A characteristic length, L, can be determined for a detector model using a ″smoke box″ approval apparatus. A characteristic length of 0 ft would mean no restriction to flow.

For a given fire source, tests have shown that, outside the detector, the mass concentration of smoke particles is approximately proportional to the local temperature rise. So it can be said that a smoke detector responds to a given temperature rise of the fire gases. This temperature rise depends on the fire source. The temperature rise that produces a response is dependent on the specific detector. For some years, 55°F (13°C) has been the benchmark for temperature rise at response. However, this was based on tests done with a certain ionization detector and a wood crib fire. This temperature rise can be either significantly lower, using cotton for example, in the case of ionization detectors, or significantly higher, using wood cribs for example, in the case of photoelectric detectors. More testing with various combinations of fuels and detector types is needed to correlate smoke density with local temperature rise.

To obtain a signal from a smoke detector, the smoke must enter the detector unit itself, or the smoke must interrupt or obscure a light beam. Although the protected area may appear to be filled with smoke, smoke is sometimes prevented from getting to the detector because of stratification (see Section C.4.), or because air currents carry smoke particles away from the detector. Other factors that influence the ability of the smoke to get to the detector in sufficient quantity to activate it are the location of ventilation inlet and exhaust openings in the protected area, rate of air change, room furnishings, and structural beams or other obstructions. High air flow (velocity > 300 ft (91 m) per minute) can actually make it difficult for smoke to enter a detector.

The maximum local temperature near the ceiling, and hence smoke concentration, usually occurs about 1% of the ceiling height below the ceiling, and remains near this value to a depth of approximately 5% of the ceiling height below the ceiling. The temperature will decrease to near room temperature at about 10% of the ceiling height below the ceiling if there is venting of the gases preventing an accumulation at the ceiling. Based on these findings, installing smoke detectors up to 5% of the ceiling height below the ceiling is acceptable.

C.3.2 Ionization Smoke Detectors

The ionization smoke detector contains a small amount of radioactive material, which ionizes the air in special chambers in the detector. This makes the air conductive, as positive and negative ions attract to the cathode and anode. When particles of combustion enter the sensing chamber in the detector, ions attach to the smoke particles and are slowed down. Some will exit the detector with the smoke. The normal ionization current drops, and a signal is initiated. Usually, ionization detectors are the spot-type and are mounted on the ceiling of the protected area, although they may be specially designed for installation in air ducts. Ionization detectors are especially sensitive to small and invisible particles from flaming combustion, but can be insensitive to smoldering fires. Ionization detectors are sensitive to atmospheric pressure and humidity changes. Some detectors have a dual chamber to account for this. The second chamber is used for reference. It has a very small opening to atmosphere so smoke can not enter, but is affected by atmospheric conditions. The reference measurement is compared to the sensing chamber measurement, and if both measurements are the same, they cancel each other. Therefore, pressure and humidity changes will not cause an alarm. Other contaminants such as dust and small insects will increase sensitivity of dual chamber detectors as well as single chamber detectors. See Figures 7 and 8.

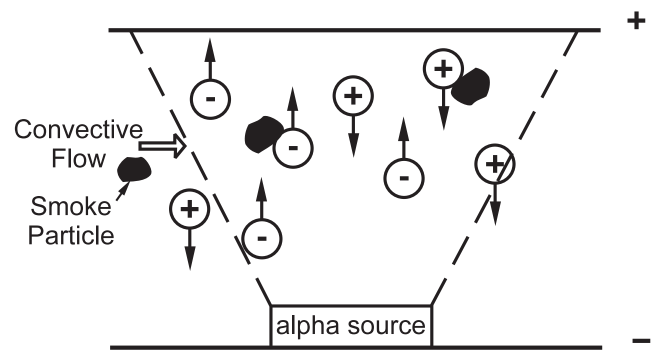

Fig. 7. Flow through an ionization smoke detector.

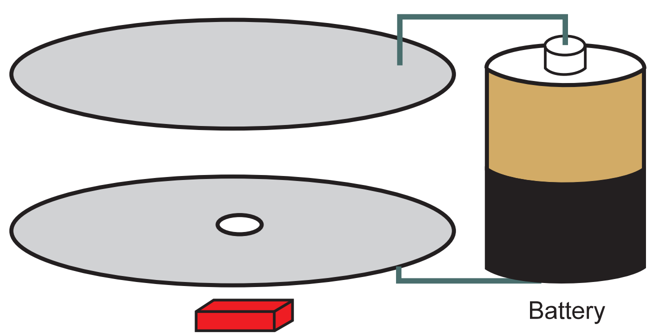

Fig. 8. Ionization smoke detector.

The following equation describes how ionization detector response time is a function of the change in current:

$$\text{Response} = f(\Delta I) = (1 - X_e)\, N_t r_m \qquad \text{Eq.(1)}$$

where ΔI is the change in ionization current
X_e is the particle charge fraction
N_t is the total number of smoke particles
r_m is the characteristic particle size

The above equation basically states that if smoke particles are highly charged before entering an ionization detector, the number of particles must be higher to get an equivalent response from smoke particles that are less charged (assuming particle size is the same). This is because the ions will not as readily attach to the more charged particles. For example, the particle size from a gasoline fire is about the same as that from a plastic fire, but the fractional charge is much higher for plastic (0.80 plastic and 0.20 gasoline). This means that Nt must be four times higher in a plastics fire to achieve the same response. (See Figure 9.)

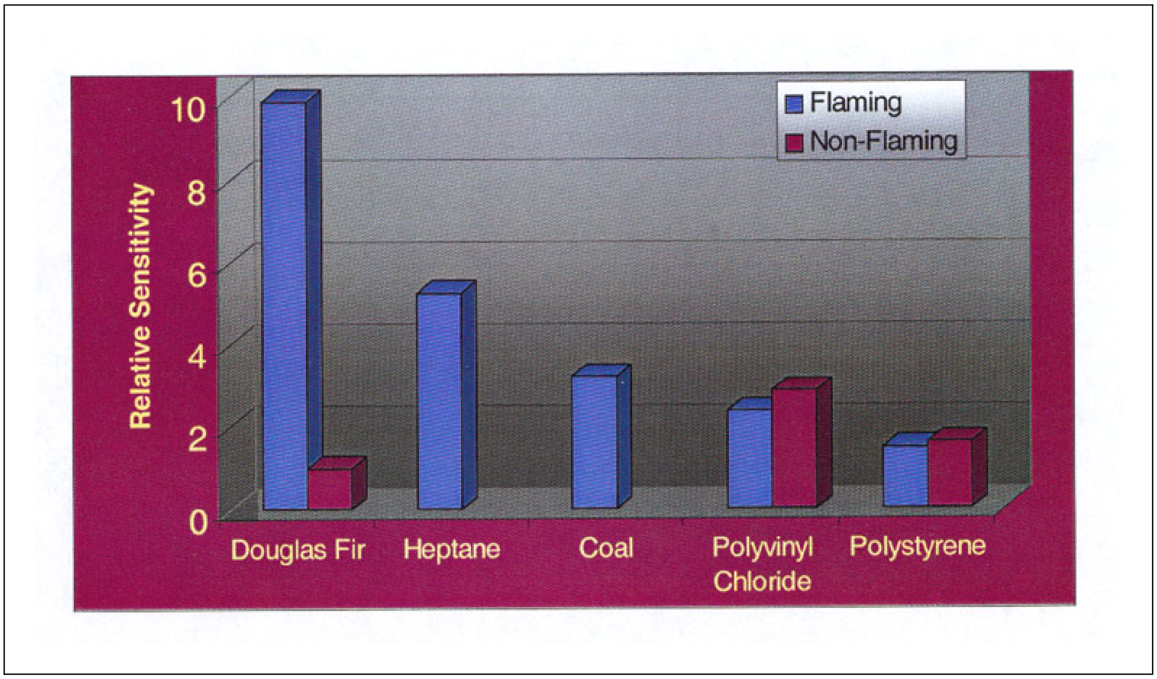

Fig. 9. Sensitivity of ionization smoke detectors to various materials for flaming and non-flaming fires.

C.3.3 Photoelectric Smoke Detectors

C.3.3.1 Beam Detectors

In the **beam-type** photoelectric detector, a light source is projected across the protected area into a photoelectric cell. Smoke obscuring the light beam reduces the light intensity reaching the cell, and a signal is initiated. A gradual dirt buildup on the receiver window is compensated for by automatic gain control, but when a certain percent of the original signal is lost (typically set at about 50% by the manufacturer), a trouble signal is initiated. A sudden blockage of the beam by an object will cause a trouble signal if 90 to 95% of the beam intensity is lost for a pre-determined amount of time. A rapid buildup of dense smoke can cause this. In one study, beam type detectors were found to be more sensitive to small fires, but transmitted trouble signals instead of fire alarms when exposed to dense smoke from a JP-5 pool fire. In locations where a fuel pool fire can occur, this problem can be eliminated by reducing the alarm window (response time) substantially. Beam detectors should be tested using smoke or aerosols.

Beam detectors have a maximum range of 330 ft (100 m) and a maximum distance between detector beams of 60 ft (18 m) which gives a coverage of 19,800 ft^2 (560 m^2). Using 900 ft^2 (25.5 m^2) as the maximum theoretical coverage of a spot detector, one beam detector should replace 22 spot detectors. In practice, however, one beam detector will replace about 12 or more spot detectors. Beam detectors are especially useful in locations with high ceilings such as atriums, gyms, auditoriums, museums, manufacturing plants and warehouses. Having a beam detector mounted on a wall is much easier to access for maintenance than spot detectors mounted below a high ceiling. They may also overcome stratification problems better than spot detectors because beam detectors can be installed more easily at lower elevations, and at least part of the stratified smoke may obstruct the beam. Beam detectors should not be attached to metal building walls because expansion and contraction due to temperature changes can cause misalignment of the beam.

In hazardous areas or in areas where the environment is harsh, beam detectors can be located outside the area behind a glass window. There may be applications where a vertical beam can be used such as inside pipe and cable chases and stairwells. Beam detectors also can be useful in long corridors such as in hotels provided the ceiling is not too low (at least 9 ft or 2.75 m). With the detector installed about 1 ft (0.9 m) below the ceiling, occupants might interfere with the beam and cause trouble or fire alarms if the ceiling is under 9 ft (2.75 m). One way to prevent these types of false alarms might be to use a microwave motion detector built into the beam detector. The microwaves will not be attenuated by smoke, but will sense a person's motion. If both detectors sense something at the same time, then an alarm output would be delayed. Some beam detector models monitor the beam wave frequency and thus can also sense heat which attenuates the beam.

C.3.3.2 Photoelectric Spot Detectors

A spot-type detector incorporates the light source and photoelectric cell in the same unit and depends on reflected light. A signal is initiated when the smoke, which has entered the unit, causes reflected light to strike the photoelectric cell which is located at an angle to the normal beam. The scattering of light by smoke particles depends on the optical density of the smoke at a specific wavelength of light. Photoelectric detectors sense large particles from smoldering fires or pyrolysis, but are not as sensitive to small particles as ionization detectors. Note that smoke particles may agglomerate and grow in size as smoke travels away from a fire and cools down. See Figures 10 and 11.

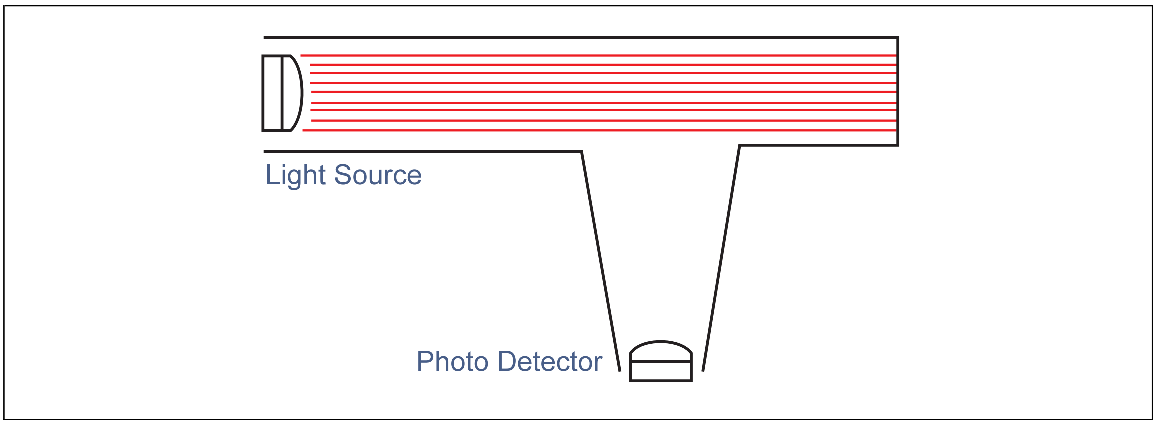

Fig. 10. Photoelectric smoke detector not in alarm.

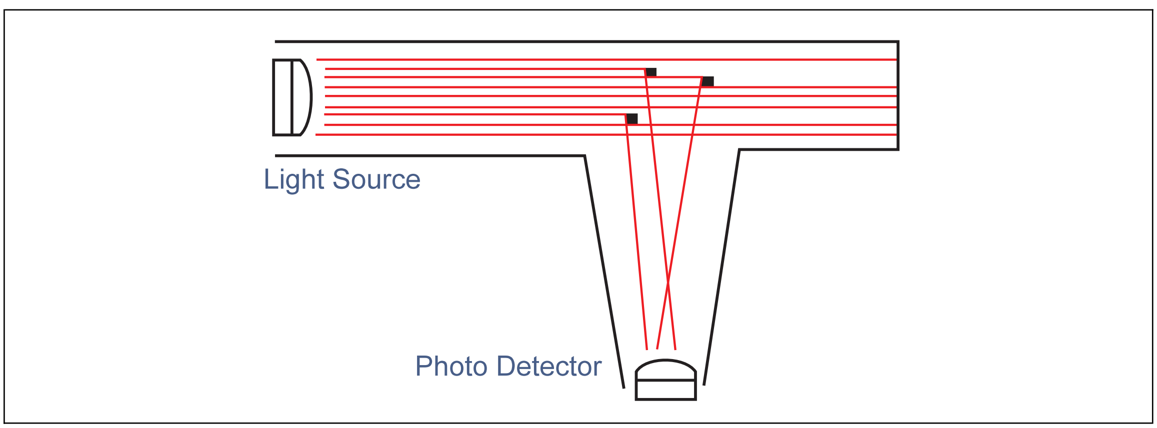

Fig. 11. Photoelectric smoke detector in alarm.

C.3.3.3 Laser Detectors

Laser detectors are very sensitive (about 100 times more sensitive than conventional detectors) and are as reliable as conventional detectors. Laser detectors are a type of light-scattering photoelectric detector. Smoke particles cause laser light to be reflected back to a sensor. This type of detector (rather than xenon light used in the older types) is also used with an air sampling system which aspirates air through a filter from many points. (See Figure 12.) Although very sensitive, these detectors are designed to be free of false alarms. They are also ″intelligent″ and can be used in groups in critical areas such as cleanrooms. In areas where high air flow can impede smoke detection, algorithms can be used with grouped laser detectors to make them very effective.

C.3.4 Combination Smoke Detectors

Combination smoke detectors combine the principles of ionization detection and photoelectric detection in a single unit. Smoldering fires as well as fires producing very little smoke can be readily detected. Units are available that require both inputs before initiating a signal in order to eliminate nuisance alarms.

C.3.5 Sampling Air Detectors

The **cloud chamber** smoke detector is one type of air sampling detector. An air pump draws a sample of air into a high humidity chamber where the pressure is slightly reduced. Moisture in the chamber condenses on the smoke particles, forming a cloud. The density of the cloud is then measured by the photoelectric principle.

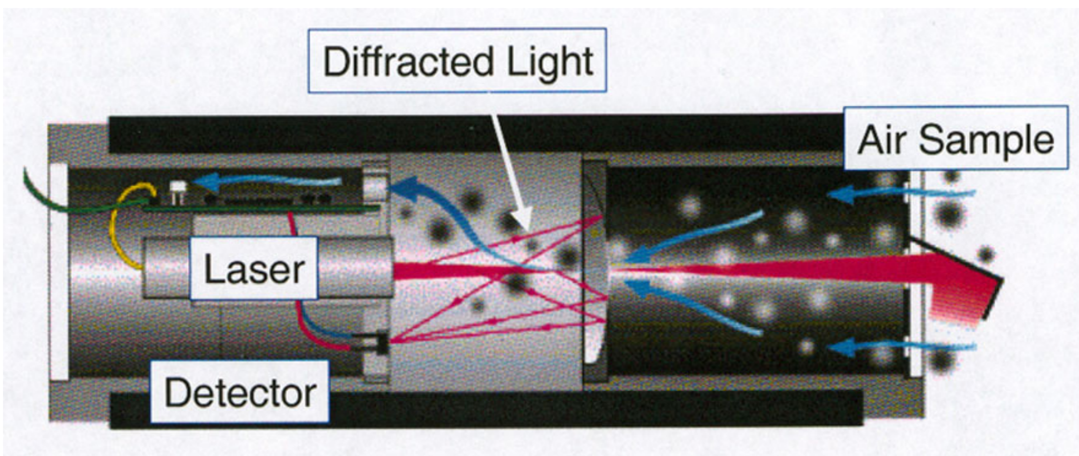

Fig. 12. Laser smoke detector.

The advantage of a **sampling system** is that only one sensor is needed. This is a cost benefit which can be used for a large, advanced detector system. This system might employ more than one type of detector such as smoke and gas analysis. Newer sampling systems use laser detectors.

C.3.6 Advanced Fire Detection

Some advanced systems employ fuzzy logic for pattern recognition or algorithms to recognize a preconceived fire signature or footprint.

There are many advanced methods of fire detection being developed that involve things such as platinum oxide sensors, remote Fourier Transform Infrared (FTIR), acoustics, fiber optics, and neural networks.

Human senses are the most advanced detectors. Individuals can see, smell, hear, or feel a fire very quickly and can discriminate between real and nuisance alarms. Humans are not always reliable, however, in responding properly once they detect something abnormal. In order to detect fires as quickly as a human without nuisance alarms, intelligent detectors that can sense an incipient fire are needed. Some detectors are multi-criteria. Others use analysis methods and algorithms and can actually learn about the environment where they are installed CO-ionization detectors with an algorithm greater than 10 will detect many fire sources and are prone to few nuisance alarms. The algorithm is calculated by multiplying the percent obscuration times the parts per million CO. For example, a 2% obscuration and 5 ppm CO would equate to an algorithm of 10. A combination CO-ionization detector will eliminate environmental conditions or ″noise″; signal fluctuations caused by environmental conditions are flattened when the CO and ionization signals are combined.

Multiplexing is used to allow information to flow back and forth between detectors and panels. Detectors also can be addressable, which allows a system to pinpoint the location of a fire. Analog-intelligent detectors can automatically compensate for drift and dust, and can even adjust sensitivity to account for daytime activities such as smoking or welding. Programming intelligent systems is very important to reliable operation. When changes are made, testing should be performed to verify that the program is error-free and performs as intended. A listed **Compare Program** should be used to verify changes. Some fire alarm panel manufacturers provide Compare Programs that compare the original program with the new one and shows the changes that were made.

Alarm verification or **cross-zoning** can be used in fire alarm systems to minimize nuisance alarms. See Data Sheet 5-40, *Fire Alarm Systems*, for information on these two methods.

Some fire detectors respond to **both smoke and heat**. They are usually selected for various applications according to the rating of their fixed temperature elements for the ceiling temperatures that can be expected. These combination detectors are often used where either a flaming fire or a smoldering fire could occur and where rapid detection is desirable. See Figure 13 for an illustration of fire growth stages and various detection methods.

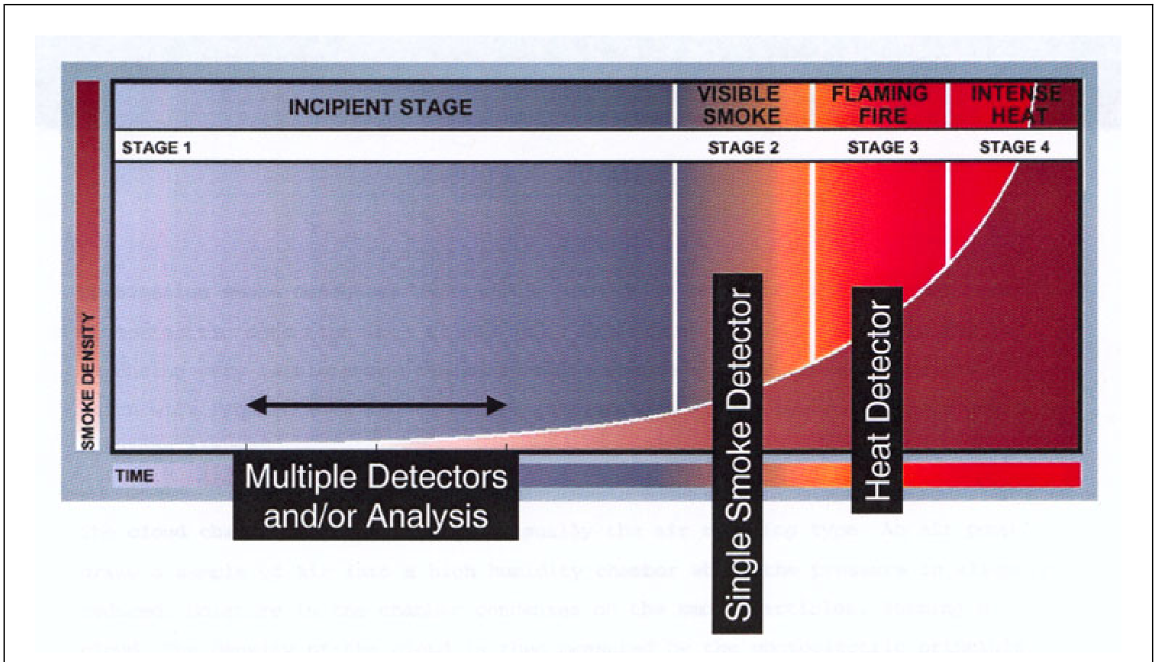

Fig. 13. Fire detector responses during various fire growth stages.

FM Approved smoke detectors are designed to respond to specified sources of smoke before the light obscuration exceeds 4% per ft (13.2% per m).

High sensitivity smoke detectors are valuable for detecting fires in occupancies highly susceptible to smoke and water damage, and especially those occupancies subject to slowly developing fires where a rapid alarm is desirable before the operation of sprinklers. Such occupancies include fur storage vaults, baled hops storage, computer installations, and electronic equipment test facilities. FM Approved smoke detectors for room or area protection can be expected to operate more quickly than an FM Approved heat sensitive device exposed to a slowly developing fire. Smoke detectors also are used to monitor air conditioning and ventilating systems, and to supervise and control fans and fire dampers, especially in areas where positive control of smoke is essential. Air duct smoke detectors are specially designed and FM Approved for this purpose, and should not be used as a substitute for open area protection. However, they can be one of the fastest forms of detection in a low heat release fire when exhaust systems are in operation. When detectors are required inside ducts, they must be properly located at least 6 duct widths from diffusers and bends, and before joining main return ducts. For example, if there is a certain concentration of smoke in a branch duct, and the branch joins a common return along with 3 other equally-sized branch ducts, the concentration will be reduced by a factor of four. See Section 2.2.3.3.13.

Spacing requirements for smoke detectors can be determined using the guidelines in NFPA 72, Appendix B. Methods are not as accurate as with heat detectors due to the lack of knowledge on detector response to various fire sources (many different detectors and fire sources).

Detection times of smoke detectors for flaming fires can be determined with the aid of Eq.(2) as the time to reach a certain temperature rise, ΔT, at activation, which is approximately in constant ratio to smoke particle concentration for a given fire source. A few values of temperature rise at activation have previously been measured for an ionization detector model and a photoelectric model as follows (Heskestad, G. and Delichatsios, M.A., ″Environments of Fire Detectors (Phase I: Effect of Fire Size, Ceiling Height and Material″ Volume II (″Analysis″: Technical Report, 2242T, FM Research, Norwood, MA, July 1977):

Ionization		*Photoelectric*
Wood Cribs	14°C [57°F]	42°C [108°F]
Polyurethane Foam	7°C [45°F]	7°C [45°F]
Cotton Fabric	2°C [36°F]	28°C [82°F]
PVC	7°C [45°F]	7°C [45°F]

The temperature rise at activation should be based on dedicated tests, or equivalent, for the combustible material associated with the occupancy and the detector model to be installed. Where such data are not available, a minimum temperature rise of [68°F] 20°C may be used.

Some new ideas under development to discriminate smoke from aerosols are:

- For optical scattering detectors, increase number of scattering angles, decrease solid angle in the field of view, measure the polarization ratio, or increase the spectral selectivity of the light source and detector.
- Pass the sample through a heated pyrolysis chamber. Smoke has a greater tendency to pyrolyze than exhaust.
- Measure smoke particle natural charge by measuring current across an electrostatic field. Current is proportional to charge distribution.
- For electromagnetic wave sensing type sensors, wide band detectors will respond to hot backgrounds, but will ignore the dc component, reducing non-fire signals. Or, near infrared sensors respond to emissions from certain soot particles in the primary combustion gases that emit signals of specified wavelengths.
- Gas analyzers with coated semiconductors can be used to measure conductance changes. Tin oxide sensors coated with platinum work at room temperature (do not need to be heated) and if used with multiple sensors and pattern recognition, will respond reliably in less than 10 seconds. Large arrays of silicon-based sensors will reliably respond to low gas concentrations; the selectivity and sensitivity are selected by programming the temperature of each element at which conductance will take place. Sensors output to a neural network to analyze readings.

C.3.7 In-rack Detection

Smoke detectors are not normally installed in rack storage. However, where smoke detectors are installed in rack storage, install them near the ceiling above each aisle and at several intermediate levels inside the racks (at the intersection of each transverse and longitudinal flue near the aisles for open racks). Detectors need not be installed at every flue intersection on each level, but can be alternated (staggered arrangement) between the intermediate levels so that 2 intermediate levels will cover all intersections. In open rack storage, consider the path that smoke may take through aisles and flues. Because of the various paths available for air movement, a smoke detector alarm may be misleading in determining the location of the fire if the detection system design is inadequate. In closed rack storage, smoke movement will be blocked, creating a need for detectors installed at many locations inside the racks. Note that in-rack smoke detectors are not an alternative but rather a supplement to in-rack sprinklers. An in-rack detection system may prove to be valuable, however, where in-rack sprinklers are not provided. The cost to wire an in-rack detection system may be high. A wireless system can be used to simplify installation and minimize installation cost.

C.4 Effects of Temperature Stratification

If the ambient temperature varies with height in a building space, the operation of fire detectors mounted under the ceiling may be delayed, which is explained as follows. As the buoyant, turbulent plume rises from a fire, it is cooled by entraining ambient air. The temperature difference between the plume and the ambient air, which gives the plume buoyancy, may vanish and actually reverse sign. Eventually the plume ceases to rise, and plume fluid moves out radially to eventually form a more or less horizontal layer. The critical value of ambient temperature rise, from the base of the fire to the ceiling, can be calculated from (Heskestad, G., Fire Plume Behavior in Temperature-Stratified Spaces, J.I 0Q4E2.RU(3), FM Research, Norwood, MA, November 1993; Heskestad, G., Note on Maximum Rise of Fire Plumes in Temperature-Stratified Ambients, Fire Safety Journal, Vol 15, 1989, p2.):

$$\Delta T_a = 190Q^{2/3} H^{-5/3} \qquad \text{Eq.(2)}$$

(ΔT in °C, Q in kW, H in m)

Alternatively, if the ambient temperature rise is known, the minimum heat release rate to drive plume fluid to the ceiling can be calculated from:

$$Q = \left[\Delta T_a H^{5/3} / 190 \right]^{3/2} \qquad \text{Eq.(3)}$$

For example, if the ceiling height is 10 m (33 ft) and the ambient temperature rise to the ceiling is 5°C (9°F), the minimum heat release rate to drive plume fluid to the ceiling is 1.3 kW (74 Btu/min) (using Eq. 3), the approximate equivalent of a 7 cm (2.75 in.) diameter methanol fire. For a 20 m (66 ft) ceiling height and a 10°C (18°F) ambient temperature rise, the minimum heat release rate is 22 kW (1252 Btu/min), the approximate equivalent of a 0.30 m (1 ft) diameter methanol fire.

If the ambient temperature rise is less than the critical value for the fire size at a given moment, plume fluid will spread under the ceiling. If the ambient temperature rise is less than approximately 0.3 times the critical ambient temperature rise, there is little effect of the stratification on the ceiling flow. In the intermediate range there is a significant effect.

Estimates have indicated that there could be a significant increase in fire size at response of a heat detector in a growing fire, due to stratification. In a particular example of a ceiling mounted fixed temperature detector operating at a local gas temperature rise of 63°F (35°C) and an ambient temperature rise from floor to ceiling of 22°F (12°C), a 40% increase in fire size at detection can be expected due to the stratification. For a weaker stratification, corresponding to 9°F ambient temperature rise at the ceiling level, the estimated increase in fire size is 15%.

It has been estimated that if temperature stratification were to be a factor in the response of smoke detectors that respond near a temperature rise of 18°F (10°C) in a uniform ambient, the ambient temperature rise at the ceiling would have to be greater than 68°F (38°C). This is very high and not likely to be encountered in the field.

Smoke detectors of very high sensitivity have entered the market, and an equivalent temperature rise at detection of 1°C (1.8°F) is possible. If temperature stratification were to be a factor in these cases, the ambient temperature rise at the ceiling would have to be greater than about 4°C (7°F), which clearly is not uncommon. Unless a detector happens to be fairly close to a fire, detection will probably be delayed in many practical cases.

C.5 Flame Detectors

A flame detector is sensitive to infrared, visible, or ultraviolet radiation produced by a fire, or to specific ranges of radiation that are modulated at characteristic flame flicker frequencies.

Flame detectors are essentially line-of-sight devices, and are usually designed to respond to a fire within the detector's cone of vision in approximately one second or less. The maximum response time of FM Approved detectors is 30 seconds. Depending on the combination of the fuel and frequency range of the detector, it is possible to have no response to a fire.

The **infrared detector** contains a sensing element that is responsive to radiant energy at wavelengths below the range of human vision. This is usually above approximately 7700 Angstroms. A very high speed infrared detector that senses a portion of the infrared energy of flame is available. This device responds in less than 5 milliseconds to produce a voltage sufficient to release an extinguishing agent and sound an alarm. Normally, the device is used to actuate an external explosive-operated release to discharge water or other extinguishing agent through associated equipment. The overall system provides specialized protection for hazards such as rocket fuel manufacture, where extremely fast fire detection and application of water is needed. Reflected infrared waves will be sensed. Spark/ember detection systems, commonly used in conveyors, chutes, etc. fall into this category of detection. An infrared (IR) detector is basically composed of a filter and system used to screen out unwanted wavelengths and focus the incoming energy on a photovoltaic or photo resistive cell sensitive to infrared radiation. IR detectors are sensitive to most hydrocarbon fires (liquid, gases and solids). Fires, such as burning metals, ammonia, hydrogen, and sulfur do not emit significant amounts of IP radiation in the 4.4 micron sensitivity range of most IR detectors.

The **ultraviolet detector** contains a sensing element that is responsive to radiant energy above the range of human vision. This is usually below approximately 4000 Angstroms. This type of detector will sense ultraviolet waves in a direct line-of-sight only and not reflected waves.

Ultraviolet (UV) detectors are sensitive to most fires, including hydrocarbon, metals, sulfur, hydrogen, hydrazine, and ammonia. Arc welding, electrical arcs, lightning, X-rays used in nondestructive metal testing equipment, and radio active materials can produce levels that will activate a UV detection system.

Ultraviolet (UV) detectors generally use either a solid-state device, such as silicone carbide or aluminum nitride, or a gas-filled tube as the sensing element. UV detectors are essentially sensitive to both, sunlight and artificial light. A UV flame radiates in the 1850 to 2450 angstrom range. Virtually all fires emit radiation in this band, while the sun's radiation at this band is absorbed by the Earth's atmosphere. The result is that the UV detector is solar blind, meaning it will not cause an alarm in response to radiation from the sun. The implication of this feature is that it can easily be used both indoors and outdoors. UV detectors are sensitive to most fires, including hydrocarbon, metals, sulfur, hydrogen, hydrazine, and ammonia. Arc welding, electrical arcs, lightning, X-rays used in nondestructive metal testing equipment, and radio active materials can produce levels that will activate a UV detection system. The presence of UV-absorbing gases and vapors will attenuate the UV radiation from a fire, adversely affecting the ability of the detector to 'see' a flame. Likewise, the presence of an oil mist in the air or an oil film on the detector window will have the same effect.

The **photoelectric flame detector** contains a sensing photocell which either changes its electrical conductivity or produces an electrical potential when exposed to radiant energy.

A **flame flicker detector** consists of a photoelectric flame detector including a means to prevent response to visible light unless the observed light is modulated at a frequency characteristic of the flicker of a flame (4-30 Hz).

Flame detectors may be used in a variety of fire detection applications. Applications include surveillance of conveyor housings, yard storage, and chemical plant yards; compressor decks and other areas prone to leakage of ignitable liquids at hydrocarbon and chemical plants; in combination with smoke detectors in cross zone systems; and automatic tripping of monitor nozzles used in large scale ignitable liquid storage applications.

Infrared or ultraviolet flame detectors are often used for actuating extinguishing systems for protection against fuel spill fires beneath the fuselage and wings of aircraft in hangars.

Where there is a good chance of false detection such as in an aircraft hanger, use dual wave length detectors or combined UV/IR detectors.

Note that an IR detector cannot detect a hydrogen fire. A very sensitive UV sensor must be used for this purpose.

C.6 Gas-Sensing Fire Detectors

Gas-sensing fire detectors, also known as fire-gas detectors, sense and respond to one or more of the gases produced by burning substances.

The location and spacing of fire-gas detectors should be based upon engineering judgment and consideration of the ceiling shape and surfaces, ceiling height, arrangement of contents in the area, burning characteristics of the combustible materials, ventilation, etc.

The semiconductor type fire-gas detector responds to either oxidizing or reducing gases by creating electrical changes in the semiconductor used for actuation.

The catalytic element type contains a material that accelerates oxidation of ignitable gases. Actuation is caused by the resultant temperature rise of the element.

Note that CO detector response to a fire is typically much slower than smoke detector response. There is one case where they respond faster. If a fire takes place in a closed room and oxygen is depleted, CO spillover from the room will be higher than smoke spillover. In this case, a CO detector located in a corridor outside the room will respond sooner than smoke detectors outside the room.

There are new types of detectors being developed. Tin oxide sensors coated with platinum work at room temperature (sensor does not have to be heated). Using pattern recognition together with multiple sensors can result in a response time less than 10 seconds.

Large arrays of silicon-based sensors will respond to low concentrations. Selectivity and sensitivity are controlled by programming the temperature of each element. The change in conductance is transmitted to a neural network.

Approval Standard Class 3230 C 3250 describes testing of various types of smoke detectors. The following lists some aspects of this testing:

Conventional smoke detectors are FM Approved in the *Approval Guide* in a separate section for smoke detectors. These detectors are compatible with any fire alarm panel with the same voltage rating.

Analog addressable smoke detectors are FM Approved in the *Approval Guide* with the alarm panels with which they were tested and compatible.

Approval Standard Class 3210 describes testing of heat detectors. Testing involves some of the following:

Approval Standard for Radiant Energy-Sensing Fire Detectors for Automatic Fire Alarm Signaling, Class Number 3260, describes testing of radiant energy sensing detectors. There are two categories: flame detectors and spark/ember detectors. Flame detectors are expected to work in normally illuminated environments. Spark/ember detectors are used in pneumatic conveyance ducts, conveyors, chutes and other areas of limited illumination.

Radiant energy sensors have a limited field of view and rely on line-of-sight transmission. The detector chosen must match the radiant emissions of the expected fuel source because each fuel emits a unique spectra.

The following tests are conducted: baseline sensitivity, flame-response, false stimuli, field of view, switching, humidity cycling and conditioning, voltage variation, temperature extremes, vibration, dielectric strength, bonding, durability, stability, extraneous transients, surge transient tests, and spark/ember detector tests.

Responses range from milliseconds to no more than 30 seconds. If intended for use in hazardous locations, detectors must be FM Approved for use in hazardous areas.

All manufacturer-specified sensitivities with regard to fuel, size, distance, and response time are tested. The sensitivity is expressed as the maximum distance from the fire center at which the flame detector will give consistent alarm responses in a specified time not to exceed 30 seconds. One or more of the following fires are used to define sensitivities:

a) 12 × 12 in. (0.3 × 0.3 m) N-heptane pan fire.

b) 12 × 12 in. (0.3 × 0.3 m) alcohol (type specific) pan fire.

c) 5 in. (127 mm) propane flame from a 0.021 inch (0.53 mm) orifice.

d) 4 in. (102 mm) and/or 8 in. (203 mm) diameter pan of polypropylene pellets for wet bench applications.

Tests also are performed for any other fuel a manufacturer specifies. Detectors are only FM Approved for use with fuels that were tested.

For spark/ember detectors, the manufacturer must specify the minimum size and velocity of the spark or ember of the given fuel that the detection system is to detect.

C.7 Arc Detectors

An arc detector system will detect an electrical arc and shut down an electrical system before it causes a fire. A smoke detector system will not detect an arc.

The only FM Approved arc detection system is the ABB Arc Guard System. This system employs optical sensors and will send a trip signal in about 1 to 2 milliseconds. Depending on the circuit breaker used, the electrical system power should be disconnected within 50 milliseconds. The Arc Guard System will initiate a trip much faster than normal overcurrent protection.

Detectors are typically installed in electrical switchgear rooms, but can be installed wherever arcing may be a problem. Metal enclosed capacitor banks, transformer load tap changer panels and non-segregated phase bus ducts are places where arcs can occur. Detectors are placed at the ceiling and inside cabinets. A detector has a range of view of nearly 360° and a small blindspot in the back. Detectors should be arranged so that all blindspots are eliminated. If detectors are partially blocked by cable trays or some other object, this loss of view should be compensated for by other detectors.

Up to nine detectors can be connected to each monitor, and several monitors can be connected together. Fiber optics are used to communicate between sensors and monitors so that the system is insensitive to electromagnetic interference.

To prevent nuisance trips due to light sources such as cutting and welding, camera flashes and direct sunlight, a current-sensing device can be used in series with the Arc Guard System to help determine if there is a real problem. The current sensor would be set just above normal unbalanced current in the neutral lead. The Arc Guard System would be wired into the normal protective relay system.

C.8 On-site Smoke Generation Tests

Smoke generation tests have been carried out at some critical locations such as telecommunications offices. Some tests were conducted using the British Standards Institute standard BS 6266, Code of Practice for Fire Protection for Electronic Data Processing Installations. NFPA 76, Recommended Practices for the Fire Protection of Telecommunications Facilities, is adopting procedures from this standard for the overheating wire test and the lactose/potassium chlorate fire test. NFPA 76 is in the public proposal stage at this time and should be published in 2002.

The purpose of these tests is to evaluate very early warning detection systems. Alarm verification and time delay features must be disabled during the tests because of the small amount of smoke produced. Only small amounts of smoke are generated in order to determine how well an early warning system can detect a fire in its initial stages. After tests results are analyzed, locations and spacing of early warning laser detectors or sampling system ports can be optimized.

Tests should be performed at various locations and elevations in the tested space and should also take obstacles into account. It is important that tests be performed in areas of both high and low air flow and near ventilation system supply and exhaust ducts. Tests should be done both with and without ventilation. Where detectors use cooperative algorithms, testing should be performed with the cooperation feature both on and disabled. Care should be taken that smoke is not generated near electronic equipment cabinet air intakes. It is acceptable to allow smoke to be entrained in the air from equipment cabinet exhaust.

Five tests that have been done are the overheated wire test, the lactose/chlorate test, printed circuit board failure, conductive heating and smoldering electrical coil test.

The lactose/chlorate test involves burning a small amount of an equal mixture of lactose and potassium chlorate in a small bowl. The mixture is very similar to the ingredients in a match head. The smoke produced by this test has more inertia than in the other tests and can rise to the ceiling without the assistance of ventilation air flow.

In the overheated wire test, one or two short lengths of wire are mounted on a noncombustible, nonconductive surface. Overcurrent is provided for 30 seconds to 3 minutes until the insulation breaks down and a small amount of smoke is produced. Most fires in telecommunications centers have been related to wiring.

In a printed circuit board failure test, a specially designed board is used with parallel power tracks bridged by a short high resistance track. The bridge is overheated and forms an arc as power is applied. The substrate materials are degraded and the pyrolysis gases are ignited to form a small flame. Air currents carry away the smoke.

In the conductive heating test, a loose cable connection is simulated. A loose connection can lead to an arc which will vaporize the metal in the connector. This will lead to an even looser connection and more arcing and overheating. Heat is conducted through the cable to the insulation, which eventually reaches its ignition temperature. A loose connection can be simulated by slipping a metal band heater over the end of the cable. A smoldering period of more than an hour is needed to conduct the test.

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