Single-Ended Reflective Beam Smoke Detector

SYSTEM SENSOR®

Single-Ended Reflective Beam Smoke Detector

Contents

Foreword

The purpose of this guide is to provide information on the proper utilization of beam smoke detectors in life-safety and property protection applications. This guide briefly summarizes the principles of operation of single-ended reflective beam smoke detectors, their design requirements, and practical applications for their use as a component of an automatic fire alarm system.

Beam smoke detectors can be important components of a well designed automatic fire alarm system. Because of their unique capabilities, beam smoke detectors can overcome some of the problems and limitations of spot type smoke detectors. This guide was developed to help the fire alarm designer gain an understanding of the beam smoke detector's capabilities and limitations, and how they differ from spot-type smoke detectors.

Since equipment from different manufacturers has varying specifications and listings, the information in this guide is general in nature and should not be used as a substitute for the manufacturer's recommendations or code requirements.

Section 1
Glossary of Terms

Annunciator
A device which gives a visible or audible indication of the condition or status, such as normal, trouble, or alarm, of a smoke detector or system.

Automatic Gain Control (AGC)
The ability of a beam smoke detector to compensate for light signal degradation due to dust or dirt. Rate of compensation is limited to insure that the detector is still sensitive to slow, smoldering fires.

Beam Smoke Detector (Reflective Beam Smoke Detector)
A device which senses smoke by projecting a light beam from a transmitter/receiver unit across the protected area to a reflector that returns the light signal back to the transmitter/reciever unit. Smoke entering the beam path will decrease the light signal causing an alarm.

Beam Range
The distance between the transmitter/reciever and reflector.

Detector Coverage
The area in which a smoke detector or heat detector is considered to effectively sense smoke and/or heat. This area is limited by applicable listings and codes.

Listed
The inclusion of a device in a list published by a recognized testing organization, indicating that the device has been successfully tested to meet the accepted standards.

Obscuration (Cumulative Obscuration)
The reduction of the ability of light to travel from one point to another due to the presence of solids, liquids, gases, or aerosols. CUMULATIVE OBSCURATION is a combination of the density of these light blocking particles per foot and the linear distance which these particles occupy, i.e., smoke density times the linear distance of the smoke field. (Usually expressed in units such as %/ft. or %/m).

Reflector
The device which returns the light signal back to the transmitter/reciever unit.

Sensitivity
The ability of a smoke detector to respond to a given level of smoke.

Smoke
The solid and gaseous airborne products of combustion.

Smoke Color
The relative lightness or darkness of smoke, ranging from invisible to white to gray to black.

Smoke Density
The relative quantity of solid and gaseous airborne products of combustion in a given volume.

Spot-Type Detector
A device which senses smoke and/or heat at its location only. Spot-type detectors have a defined area of coverage.

Stratification
The effect which occurs when smoke, which is hotter than the surrounding air, rises until equal to the temperature of the surrounding air, causing the smoke to stop rising.

Transmitter/Reciever
The device in a reflective beam smoke detector which projects and monitors the light across the protected area.

Transparencies (Filters)
A panel of glass or plastic having a known level of obscuration, which can be used to test the proper sensitivity level of a beam smoke detector.

Trouble Condition
The status of a device or system which impairs its proper operation, i.e., open circuit on an initiation loop. The notification of a trouble condition indicated on a control panel or annunciator is a “TROUBLE” SIGNAL.

Section 2
Principles of Operation

Reflective beam smoke detectors consist of a transmitter/reciever unit that projects and monitors an infrared beam across the protected area to a reflector.

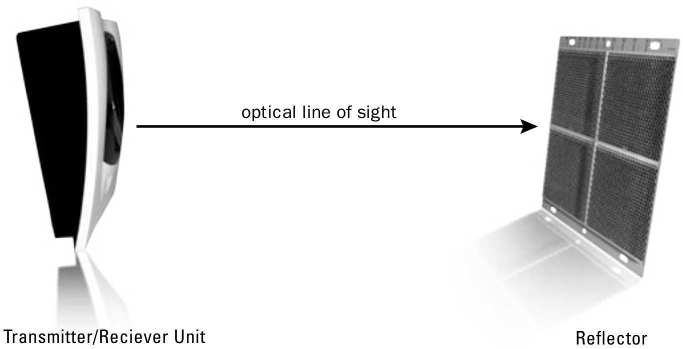


Figure 1

The detector works on the principle of light obscuration. The photosensitive element of the beam smoke detector sees light produced by the transmitter/receiver unit in a normal condition. The transmitter/receiver unit is calibrated to a preset sensitivity level based on a percentage of total obscuration. This sensitivity level is determined by the manufacturer based on the length of the beam (the distance between the transmitter/receiver unit and reflector). System sensor's reflective beam smoke detectors offer various sensitivity settings to choose from. For UL listed detectors the sensitivity setting must comply with UL Standard 268, "Smoke Detectors for Fire Protective Signaling Systems".

Unlike spot type photoelectric smoke detectors, beam smoke detectors are generally less sensitive to the color of smoke. Therefore, a beam smoke detector may be well suited to applications unsuitable for spot-type photoelectronic detectors, such as applications where the anticipated fire would produce black smoke. Beam smoke detectors do require visible smoke and therefore may not be as sensitive as ion detectors in some applications.

Beam smoke detectors are sensitive to the cumulative obscuration presented by a smoke field. This cumulative obscuration is created by a combination of smoke density and the linear distance of the smoke field across the projected light beam. Cumulative obscuration, then, is a measure of the percentage of light blockage.

Since the sudden and total obscuration of the light beam is not a typical smoke signature, the detector will see this as a trouble condition, not an alarm. This threshold is typically set by the manufacturer at a sensitivity level which exceeds 90% total obscuration. This minimizes the possibility of an unwanted alarm due to the blockage of the beam by a solid object, such as a sign or ladder, being inadvertently placed in the beam path.

Very small, slow changes in the quality of the light source also are not typical of a smoke signature. These changes may occur because of environmental conditions such as dust and dirt accumulation on the transmitter/receiver unit's optical assemblies or on the reflective surface. These changes are typically compensated for by an automatic gain control (AGC). When the detector is first turned on and put through its setup program, it assumes the light signal level at that time as a reference point for a normal condition.

As the quality of the light signal degrades over time, perhaps due to dust, the AGC will compensate for this change. The rate of compensation is limited to insure that the detector will still be sensitive to slow building or smoldering fires. When the AGC can no longer compensate for the loss of signal (as with an excessive accumulation of dust or dirt) the detector will signal a trouble condition.

Accessories

Accessories to the beam smoke detector may include remote annunciators, as well as remote test stations which allow for the periodic electronic and/or sensitivity testing of the detector. Intelligent fire alarm systems can give the beam smoke detector a discrete address to provide better annunciation of the fire location. Conventional systems may also remotely annunciate through the use of relays.

Additional accessories that can be used with reflective beam smoke detectors include surface mount kits, multi-mount kits, and long range kits. Surface mount kits allow reflective beam detectors to be mounted when surface wiring is used. Multi-mount kits allow reflective beam detectors and reflectors to be mounted to either vertical wall or the ceiling. The surface mount kit must also be used when installing the multi-mount kit to the detector. Long range kits allow the reflective beam detector to be installed at longer distances from the reflector (typically 230 to 328 feet or 70 to 100m).

Heaters allow the optical surface of the beam detector and reflector to maintain a slightly higher temperature than the surrounding air. This helps to minimize condensation in environments that experience temperature fluctuations.

Proper Application

Like spot-type smoke detectors, beam smoke detectors are inappropriate for outdoor applications. Environmental conditions such as temperature extremes, rain, snow, sleet, fog, and dew can interfere with the proper operation of the detector. Outdoor conditions make smoke behavior impossible to predict.

Section 3
Beam Smoke Detectors vs. Spot-Type Smoke Detectors

Even though beam and spot-type smoke detectors are governed by the same UL and NFPA standards, the requirements under these standards differ because the principle of their operation differs. It is important that designers understand and give full consideration to these differences when selecting and applying smoke detectors to fire alarm systems.

Coverage

Spot-type smoke detectors are considered to have a maximum coverage of 900 sq. ft. or 30x30’. The maximum length between detectors is 41 feet when the width of the area being protected does not exceed 10 feet, as in a hallway.

Beam smoke detectors generally have a maximum range of 330 feet and a maximum distance between detectors of 60 feet. This gives the beam smoke detector theoretical coverage of 19,800 sq. ft. (Figure 2). Manufacturer’s recommendations and other factors, such as room geometry, may impose practical reductions of this maximum coverage. Even with these reductions beam smoke detectors can cover an area which would require a dozen or more spot-type detectors. Fewer devices mean lower installation and maintenance cost.

Ceiling Height

A spot type smoke detector’s response time is generally increased as its distance from the fire/floor increases. When ceiling heights exceed 16 feet the designer should consider whether the spacing of spot-type detectors should be decreased.

This is not necessarily the case with beam smoke detectors, which are ideally suited for high ceiling applications. Some manufacturers allow increased coverage as the ceiling height increases. This is because of the anticipated behavior of a plume of smoke.

While not all fires start at the lower elevations of the hazard, at or near the floor level, this is a typical fire scenario. When this is the case the smoke produced by the fire will rise to, or near the ceiling. Typically the column of smoke begins to spread out as it travels from its point of origin, forming a smoke field in the shape of an inverted cone. The density of the smoke field can be affected by the rate of growth of the fire. Fast fires tend to produce more uniform density throughout the smoke field than slow burning fires where there may be dilution at the upper elevations of the smoke field.

In some applications, especially where high ceilings are present, beam smoke detectors may be more responsive to slow or smoldering fires than spot-type detectors because they are looking across the entire smoke field intersecting the beam. Spot-type detectors can only sample smoke at their particular “spot”. The smoke which enters the chamber may be diluted below the alarm threshold (level of smoke needed for an alarm).

Theoretical Maximum Area Coverage

Figure 2
Beam vs. Spot-Type Detectors

A limitation of the projected beam smoke detectors is that they are a line-of-sight devices is and are therefore subject to interference from any object or person which might enter the beam path. This makes their use impractical in most occupied areas with normal ceiling heights.

However, many facilities have areas where beam smoke detectors are not only acceptable, but are the detector of choice. High ceiling areas such as atriums, lobbies, gymnasiums, sports arenas, museums, church sanctuaries, as well as factories and warehouses might be candidates for beam smoke detectors. Many of these applications present special problems for the installation of spot-type detectors, and even greater problems for their proper maintenance. The use of beam smoke detectors in many of these areas may reduce these problems since fewer devices may be required, and the devices can be mounted on walls, which are more accessible than ceilings. Application for areas like these are explained in the NFPA 92B, Guide for Smoke Management in Malls, Atria and Large Areas.

High Air Velocity

High air movement areas present a special problem for detecting smoke for both spot-type and beam smoke detectors because the propagation of smoke developing under normal conditions may not occur. High air velocity may blow smoke out of the sensing chamber of a spot-type detector. Careful consideration should be given to the spot-type detector's performance where air velocities exceed 300 feet per minute (fpm) or when air changes in the protected area exceed 7.5 changes per hour. Beam smoke detectors are not tested for listing purposes for stability in high air flow because high air movement does not have as great an effect on a beam smoke detector. A beam smoke detector's sensing range can be as long as a football field (maximum beam range is typically 330') not the one or two inch dimension of a spot-type sensing chamber. It is therefore less likely that smoke will be blown out of the beam smoke detector's sensing range. Although reduced spacing is not required in high air flow areas, attention should be given to the anticipated behavior of smoke in these applications.

Inverted Cone Smoke Field

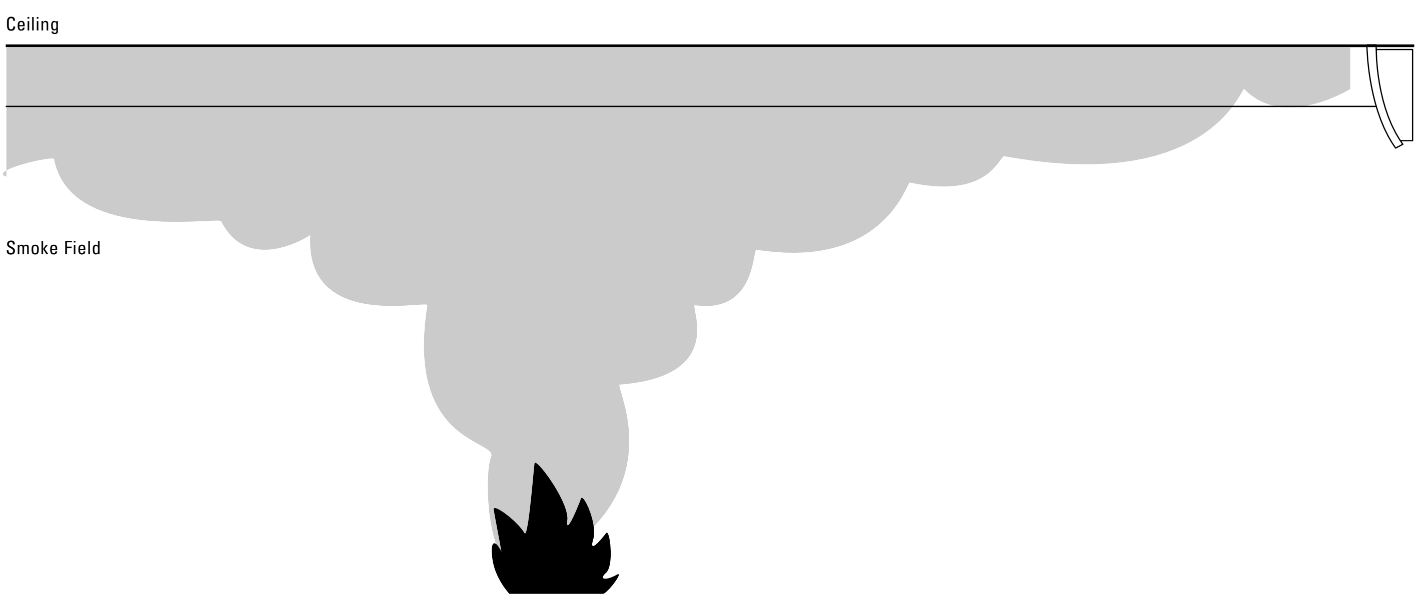


Figure 3
Typical smoke field in the shape of an inverted cone

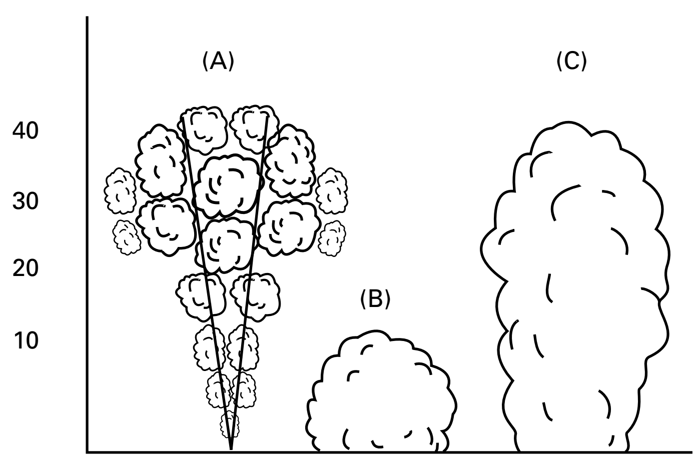
Stratification

Stratification occurs when smoke is heated by smoldering or burning materials and becomes less dense than surrounding cooler air. The smoke rises until there is no longer a difference in temperature between the smoke and the surrounding air. See NFPA 72-2002, A.5.7.1.10. Therefore, stratification may occur in areas where air temperature may be elevated at the ceiling level, but especially where there is a lack of ventilation. On smooth ceilings, beam smoke detectors should generally be mounted a minimum of 12 to 18 inches from the ceiling. In many cases, however, the location and sensitivity of the detectors shall be the result of an engineering evaluation that includes the following: structural features, size and shape of the room and bays, occupancy and uses of the area, ceiling height, ceiling shape, surface and obstructions, ventilation, ambient environment, burning characteristics of the combustible materials present, and the configuration of the contents in the area to be protected. The results of an engineering evaluation may require an installation farther from the ceiling to defeat the effects of stratification or other obstructions. NFPA 72, 2002 Section A.5.7.1.10 – "In high ceiling areas, projected beam-type detectors at different levels also should be considered." (See also NFPA 92B 2000, section 3.4) See attached Annex A.

Hostile Environments

One of the major limitations of spot-type smoke detectors is their inability to survive in hostile environments, such as temperature extremes, dirt, humidity, and corrosive gases. Beam smoke detectors may be subject to some of these debilitating elements.

Barns and stables housing animals or equipment are good examples where early warning is required but where spot-type smoke detectors are unsuited because of temperature extremes and dusty, dirty conditions. Beam smoke detectors may be a good alternative because their operating temperature range may be much wider than spot-type smoke detectors.



(A) The design of this plume is narrow at the ground level. It expands at higher levels and can be detected readily at these levels.
(B) This design is slow to develop and at the temperature of the plume cools around 10 to 15 feet causing it to stratify at this level.
(C) The design of this plume develops at lower levels and doesn't cool until it reaches higher elevations. Due to the high temperature its size is equal from floor to ceiling.

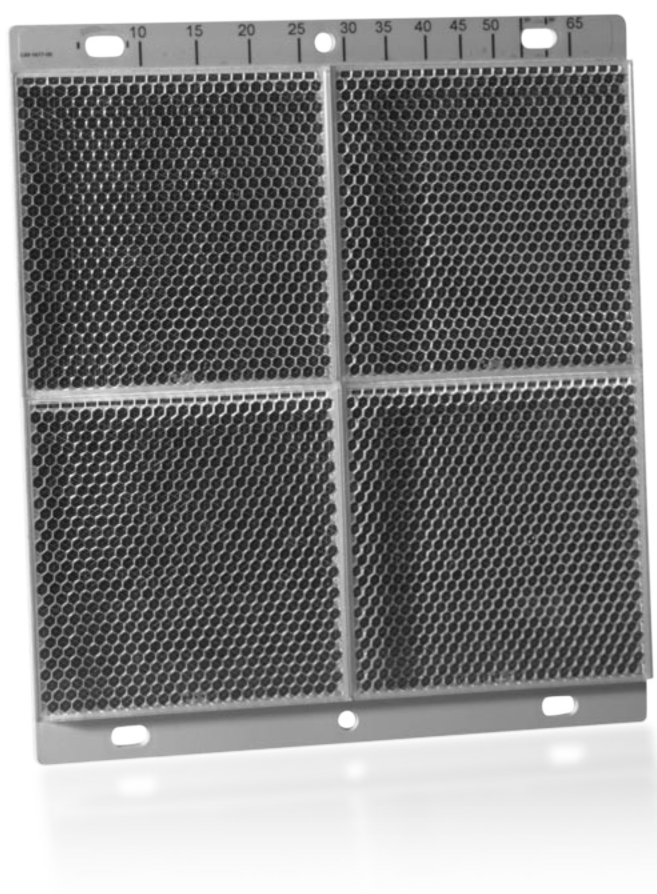
Figure 4

Special Applications

Due to the inherent capabilities of projected type beam detectors they are often installed in locations where spot-type detection is impractical. Projected type beam smoke detectors are ideally suited for environmental conditions that might include high ceilings, dusty and dirty environments, or environments that experience temperature extremes. Often these conditions present special problems for the installation of spot-type detectors and even greater problems for their proper maintenance. Due to the inherent flexibility of mounting locations and large coverage area of projected type beam detectors often the conditions above can be addressed or minimized.

Some examples of applications for beam detectors might include freezers, aircraft hangars, cold storage warehouses, shipping warehouses, enclosed parking facilities, sporting arenas and stadiums, concert halls, barns, or stables. Some of these environments might be considered too hostile for spot-type smoke detectors. If the environment is considered to be hostile, more insensitive alarm threshold settings should be used.

Before installing the transmitter/receiver unit or reflector in these types of applications special consideration should be given to insure proper operation of the beam detector. The beam detector should not be installed in environments where there is no temperature control and condensation or icing is likely. Condensation or icing of the reflector surface or the outer surface of the transmitter/receiver unit will obscure the light beam resulting in a false alarm. If elevated humidity levels and rapidly changing temperatures can be expected then condensation will likely form and the application should not be considered acceptable for the beam detector. The beam detector should not be installed in locations where the transmitter/receiver unit, the reflector, or the optical pathway between them may be exposed to outdoor conditions such as rain, snow, sleet, or fog. These conditions will impair the proper operation of the detector and must be avoided.



Section 4
Design Requirements

Many factors affect the performance of smoke detectors of all types. The type and amount of combustibles, the rate of fire growth, the proximity of the detector to the fire, and ventilation factors are all important considerations.

UL Listed beam smoke detectors are tested using the UL 268 Standard, "Smoke Detectors for Fire Protective Signaling Systems" and should be installed and maintained in accordance with NFPA 72, The National Fire Alarm Code and the manufacturer's instruction.

Sensitivity

Each manufacturer requires that the detector's sensitivity be set with reference to the length of the beam used on a given application. The detector should be installed within the minimum and maximum beam length allowed by the manufacturer's instructions which are limited by the UL listing.

Location and Spacing

NFPA 72 is the standard for location and spacing of detectors. The following design criteria are quoted or summarized from NFPA 72, The National Fire Alarm Code:

"Projected beam-type smoke detectors shall be located in accordance with the manufacturer's documented instructions."
NFPA 72-2002, 5.7.3.4.1

"The effects of stratification shall be evaluated when locating the detectors."
NFPA 72-2002, 5.7.3.4.2

Beam smoke detectors must be mounted on stable stationary surfaces to prevent movement and subsequent misalignment.

Mounting Consideration for Reflective Beam Detectors

Beam detectors require a stable mounting surface for proper operation. A surface that moves, shifts, vibrates, or warps over time will cause false alarm or trouble conditions. Initial selection of a proper mounting surface will eliminate false alarms and nuisance trouble signals.

Mount the detector on a stable mounting surface, such as brick, concrete, a sturdy load-bearing wall, support column, structural beam, or other surface that is not expected to experience vibration or movement over time. DO NOT MOUNT the beam detector on corrugated metal walls, sheet metal walls, external building sheathing, external siding, suspended ceilings, steel web trusses, rafters, nonstructural beam, joists, or other such surfaces.

In cases where only one stable mounting surface as defined above can be used, the transmitter/receiver unit should be mounted to the stable surface and the reflector should be mounted to the less stable surface. The reflector has a much greater tolerance for the unstable mounting locations defined above.

Spacing for Smooth Ceiling
Side View

Spacing for Smooth Ceiling
Top View

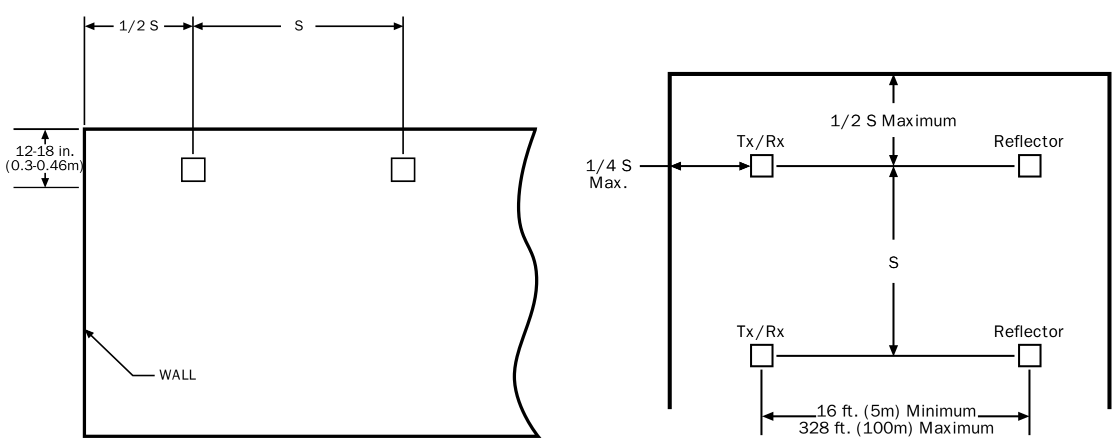


Figure 5
Spacing for Smooth Ceiling

Because beam smoke detectors are line-of-sight devices which go into trouble on sudden and total loss of signal, care must be taken that all opaque obstacles be kept clear of the beam path at all times. (See NFPA 72-2002, 5.7.3.4.8) This requirement could make the use of beam smoke detectors impractical in factory applications where overhead cranes and hoists are present and in warehouses where high fork lifts may block the beam. This factor should also be considered in occupied areas where normal ceiling heights exist.

Location and spacing limitations are also outlined in NFPA 72 as follows: On smooth ceilings, a space of not more than 60 ft. (18.3m) between projected beams, and one-half of the maximum spacing between a projected beam and a sidewall (wall parallel to the beam travel) may be used as a guide.

Other spacing may be determined depending on the ceiling height, airflow characteristics, and response requirements. (See Figure 5.)

"In some cases, the light beam projector (same as transmitter/reciever) is mounted on one end wall, with the light beam receiver (same as reflector) mounted on the opposite wall. However, it is also permitted to suspend the projector and receiver from the ceiling at a distance from the end walls not exceeding one-quarter the selected spacing." NFPA 72-2002, A-5.7.3.4

It should be noted that smoke originating behind the transmitter/receiver or reflector cannot be sensed by the detector unless and until the smoke migrates into the beam path. Therefore, consideration should be given to keeping this dimension to a minimum where possible.
Although the above example allows a maximum of 60 foot spacing between detectors, manufacturer's recommendations may limit this criterion. Other design factors also need to be considered when spacing detectors. (See Figures 5 and 6.)

Consideration must also be given to the need for a rapid response due to life safety factors, or the high value of the hazard. Spacing should be reduced where these factors apply, or where the anticipated fire will produce limited smoke, especially in its early stages. Ceiling mounted detectors in a very high atrium of a hotel, for instance, may need to be supplemented by additional detectors at lower elevations.

In applications where reduced spacing is required, care should be taken to keep two parallel beams at a minimum distance so that the receiver from one detector cannot see the light source from another detector. Where two or more detectors are installed with their respective beams at angles, care should be taken that the receiver of each detector can sense only the light from its own transmitter. Follow the manufacturer's testing procedures in the manual to insure that this does not occur.

Sloped Ceiling
Peaked Type

Sloped Ceiling
Shed Type

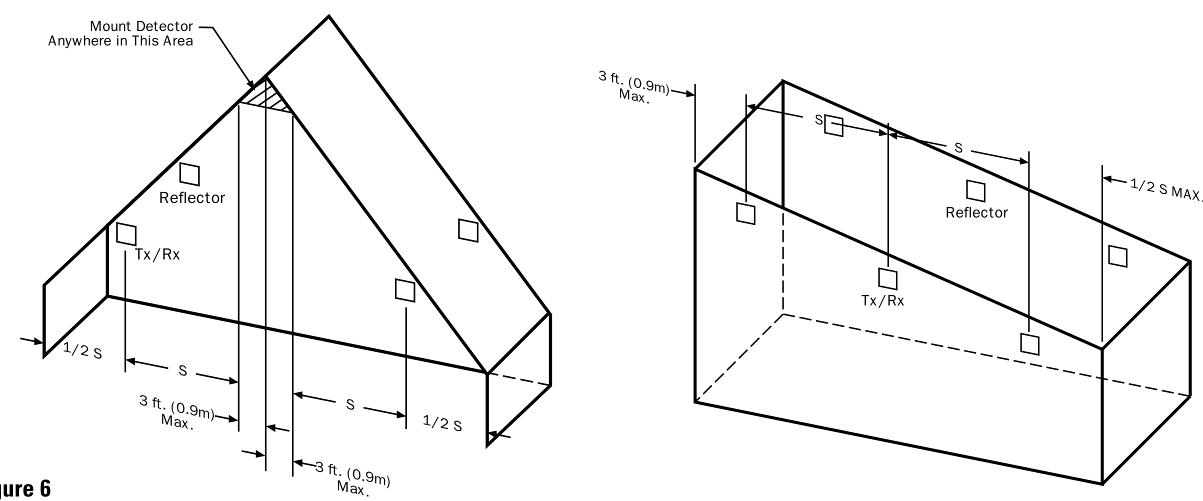


Figure 6

Additional Mounting Considerations for Reflective Beam Detectors

There must be a permanent clear line of vision between the detector and the reflector. Reflective objects must not be near the line of vision between the detector and reflector. Reflective objects too near to the line of sight can reflect the light beam from the transmitter to the receiver. If this occurs, the detector will not be able to distinguish these reflections from those of the reflector and the protected space will be compromised. Reflective objects should be a minimum of 4 feet (1.2m) from the line of sight between the detector and reflector.

Light sources of extreme intensity such as sunlight and halogen lamps, if directed at the receiver, can cause a dramatic signal change resulting in fault and alarm signals. To prevent this problem, direct sunlight into the transmitter/receiver unit should be avoided. There should be a minimum of 10° between the pathway of the light source and detector and the line of sight between detector and reflector.

Operation of the detector through panes of glass should be avoided. Since single ended beam detectors operate on a reflection principle, a pane of glass perpendicular to the line of sight between the detector and the reflector can reflect the light beam from the transmitter to the receiver. If this occurs, the detector will not be able to distinguish these reflections from those of the reflector and the protected space will be compromised.

Panes of glass will also absorb some of the light as it passes through it. This absorption of light will reduce the acceptable installed distance between the detector and the reflector.

In cases where operation through panes of glass cannot be avoided some specific installation practices can help to minimize the effects of the glass. These practices include: avoid penetration of multiple panes of glass, position the glass so that it is not perpendicular to the line of sight between the detector and the reflector, (A minimum of 10° off perpendicular should be considered), and make certain that the glass is smooth, clear and mounted securely. The complete reflector blockage test can be used to determine if the installation is acceptable.

Where high ceilings (in excess of 30 feet or 9.1 meters) are present additional beams may be required to detect smoke at lower levels.

Section 5

Single Ended Reflective Beam Smoke Detectors

While beam smoke detectors are not suited for all applications, they can be the detector of choice in many applications where spot-type detectors are not practical. Recognizing the capabilities and limitations of all types of smoke detectors is essential to the proper design of any automatic fire alarm system.

Notes

Annex A

NFPA 92B 3.4.3 Impact of Stratification of Smoke on Smoke Management System Design.

There is no sure way of identifying what condition will be present at the start of a fire. Any of the following detection schemes can provide for prompt detection regardless of the condition present at the time of fire initiation:

(a) **An Upward Beam to Detect the Smoke Layer.** The purpose of this approach is to quickly detect the development of a smoke layer at whatever temperature condition exists. One or more beams are aimed at an upward angle to intersect the smoke layer regardless of the level of smoke stratification. For redundancy when using this approach, more than one beam smoke detector is recommended.

(b) **Horizontal Beams to Detect the Smoke Layer at Various Levels.** The purpose of this approach is to quickly detect the development of a smoke layer at whatever temperature condition exists. One or more beam detectors are located at the ceiling. Additional detectors are located at other levels lower in the volume. The exact positioning of the beams is a function of the specific design but should include beams at the bottom of any identified unconditioned (dead-air) spaces and at or near the design smoke level with several intermediate beam positions at other levels.

(c) **Horizontal Beams to Detect the Smoke Plume.** The purpose of this approach is to detect the rising plume rather than the smoke layer. For this approach, an arrangement of beams close enough to each other to assure intersection of the plume is installed at a level below the lowest expected stratification level. The spacing between beams is based on the narrowest potential width of the plume at the level of detection.

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