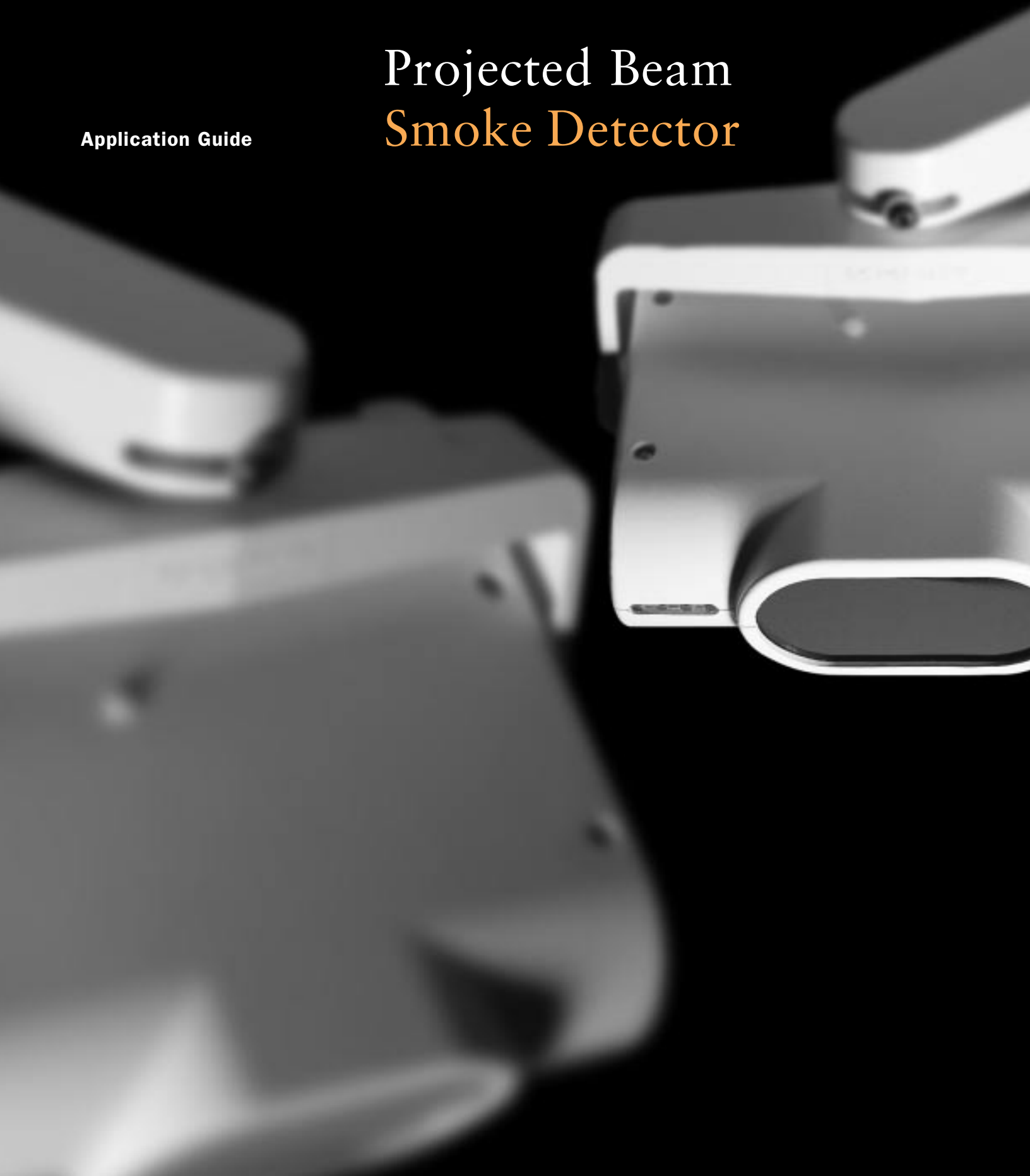
SYSTEM SENSOR®

Projected Beam Smoke Detector

Application Guide



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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 projected 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 many of the problems and limitations of spot type smoke detectors in some applications. 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.

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 (Projected Beam Smoke Detector)
A device which senses smoke or smoke and heat by projecting a light beam from a transmitter across the protected area to a receiver that monitors the light signal. Smoke and/or heat entering the beam path will decrease the light signal causing an alarm.

Beam Range
The distance between the transmitter and receiver. Where mirrors are used to direct the beam, the total beam range includes the distance between the mirrors and the transmitter and receiver.

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.

Receiver
The device, in a projected beam smoke detector system, which monitors the signal level of the light which is sent by the transmitter.

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 (Projector)
The device in a projected beam smoke detector which projects 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.

Projected beam smoke detectors consist of a transmitter that projects an infrared beam across the protected area to a receiver containing a photosensitive cell, which monitors the signal strength of the light beam.

The detector works on the principle of light obscuration. The photosensitive element of the beam smoke detector sees light produced by the receiver in a normal condition. The receiver 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 and receiver). Typically, more than one setting is available for selection by the installer based on the length of the beam used in a given application. For UL listed detectors the sensitivity setting must comply with UL Standard 268, "Smoke Detectors for Fire Protective Signaling Systems".

The transmitter on some units may be powered independently from the receiver, which can greatly reduce wiring runs and, therefore, installation cost. Since battery back up is required for fire alarm systems, battery back up would be required for the transmitter whether it is powered from the panel or independently.

Unlike spot type photoelectronic smoke detectors, beam smoke detectors are generally less response 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 to 95% 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 and/or receiver's optical assemblies. 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 or smoldering fires. When the AGC can no longer compensate for the loss of signal (as with an excessive accumulation of dirt) the detector will signal a trouble condition.

Accessories

Accessories to the beam smoke detector may include remote annunciators, remote test stations which allow for the periodic electronic testing of the detector, and transparencies (filters) used as a "go/no go" test of the detector's proper calibration. Some manufacturers provide for the use of mirrors to direct the beam. 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.

Heat Detection Feature

Some beam smoke detectors incorporate a heat sensing element in the receiver which monitors the frequency of the beam pulse. Heat attenuates or deflects the pulsed beam which can be received by the receiver, causing it to alarm. This deflection is generally greater when the fire is closer to the transmitter than the receiver. Care should be taken that frequency modulation from fluorescent lights does not interfere with this heat sensing feature. Follow the manufacturer's recommendations.

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.

Figure 1

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 the designer 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 30'x30'. 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 is generally decreased as its distance from the fire 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,

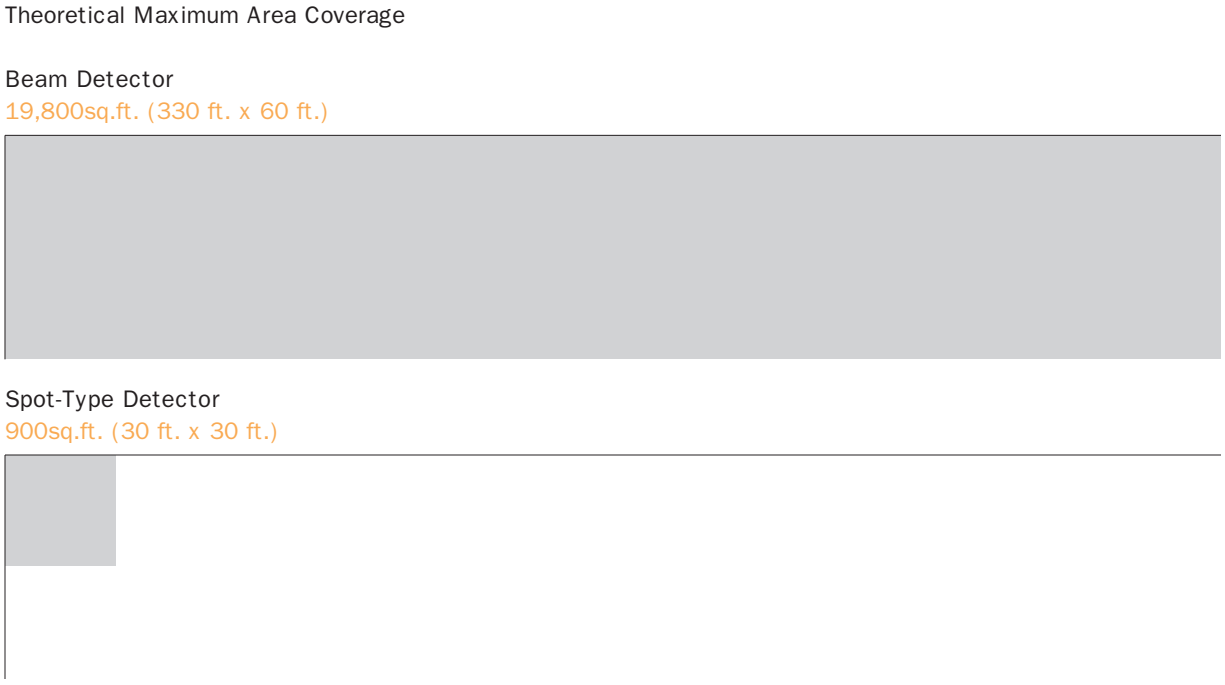


Figure 2
Beam vs. Spot-Type Detectors

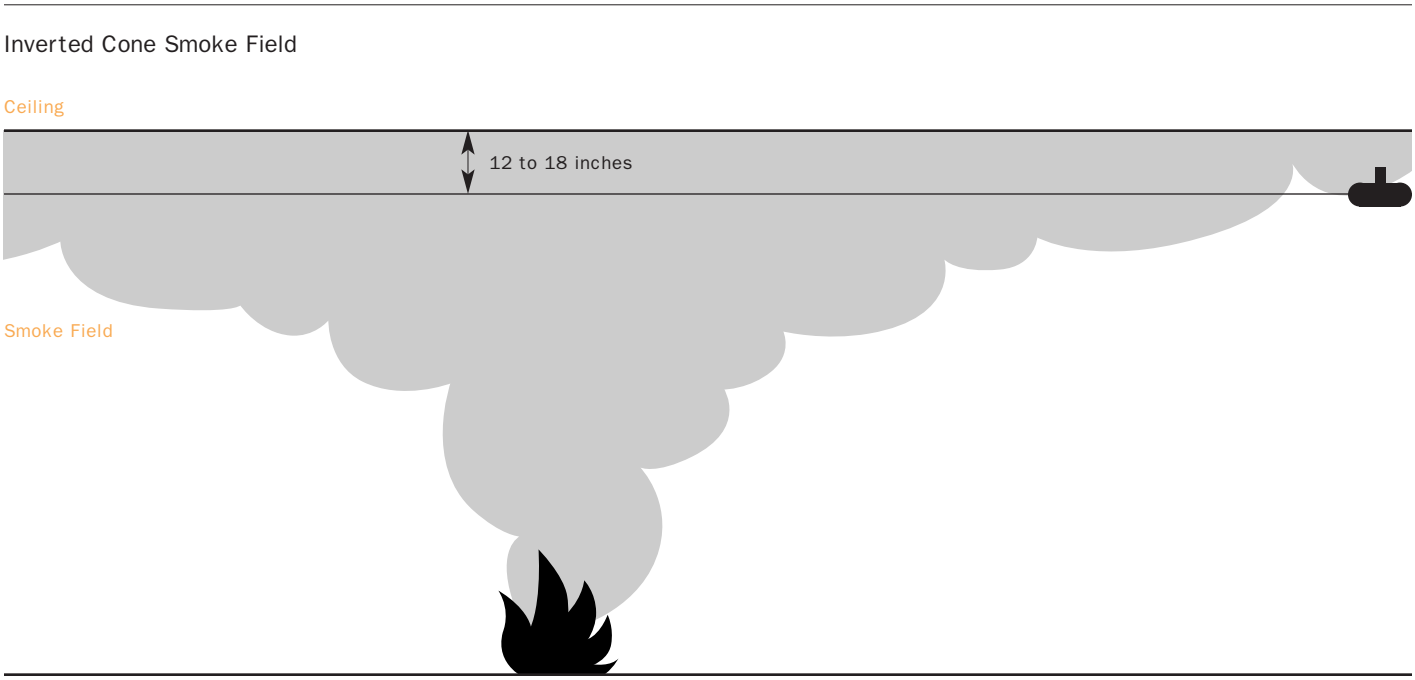


Figure 3
Typical smoke field in the shape of an inverted cone

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).

The major limitation of the projected beam smoke detector is that it is a line-of-sight device and is therefore subject to interference from any object or person which might enter the beam path. This makes its 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.

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. See NFPA 72-1999, 2-3.6.6.3. 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.

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 72-1999, A-2-3.6.1.4. 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 between 12 and 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.

Stratification

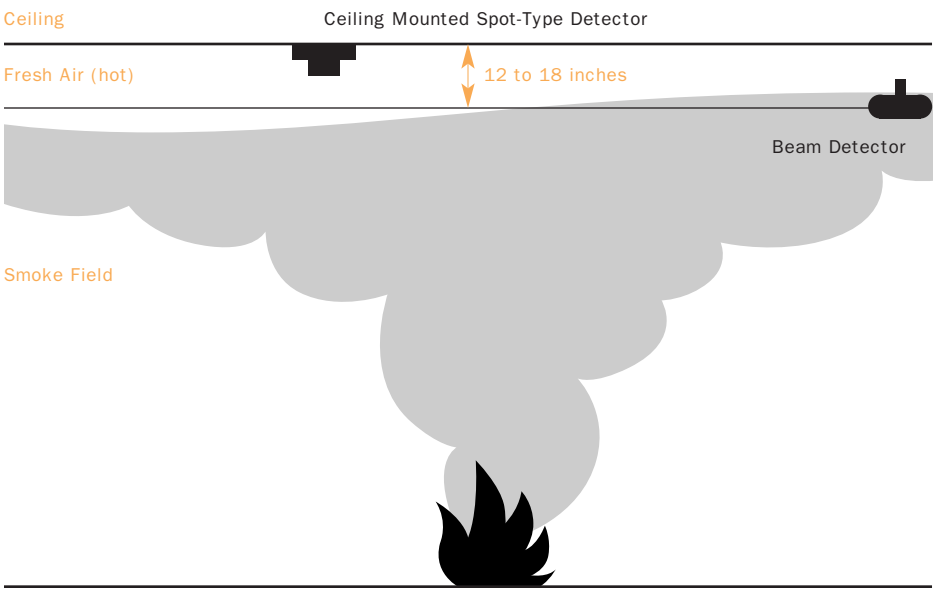


Figure 4

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 also be subject to some of these debilitating elements. Since the beam smoke detector can, in some applications, be placed behind clear glass windows outside the hazard, they can overcome these effects. However, windows must be kept clean and free of obstructions. This feature may also allow them to be used in applications where explosion protection is required.

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 optics can be kept behind windows which are easily cleaned on a regular basis. They may also have a much wider operating temperature range than spot-type smoke detectors.

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 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.

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:

"For location and spacing of projected beam smoke detectors, the manufacturer's installation instructions shall be followed."
NFPA 72-1999, 2-3.4.5.2

"Projected beam-type smoke detectors shall be located with their projected beams parallel to the ceiling and in accordance with the manufacturer's documented instructions. The effects of stratification shall be evaluated when locating the detectors."
NFPA 72-1999, 2-3.4.4

"Exception: Beams may be installed vertically, or at any angle needed to afford protection of the hazard involved (for example, vertical beams through the open shaft area of a stairwell where there is a clear vertical space inside the handrails)."
NFPA 72-1999, 2-3.4.4

For solid joist and beam construction (where the joist or beams are less than 1 foot deep and the ceiling is 12 feet or lower) no reduction in spacing is required if the beam is projected perpendicular to the joists or beams. (See NFPA 72-1999, 2-3.4.6.1)

"For beam depths exceeding 1 foot or for ceiling heights exceeding 12 feet, detectors shall be located on the ceiling in every beam pocket."
NFPA 72-1999, 2-3.4.6.1

Mounting

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

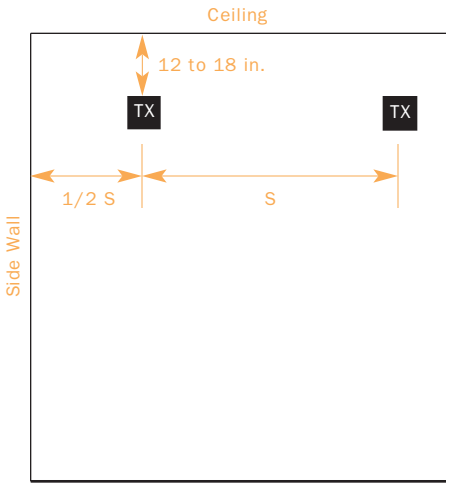
Because beam smoke detectors are line-of-sight devices which go into trouble on sudden and total loss of signal, care must be taken that all opaque obstacles be kept clear of the beam path at all times. (See NFPA 72-1999, 2-3.6.3.) This requirement could make the use of beam smoke detectors impractical 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 not more than one-half that 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 is mounted on one end wall, with the light beam receiver 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 72-1999, A-2-3.4.5.2

Spacing for Smooth Ceiling
Side View



Spacing for Smooth Ceiling
Top View

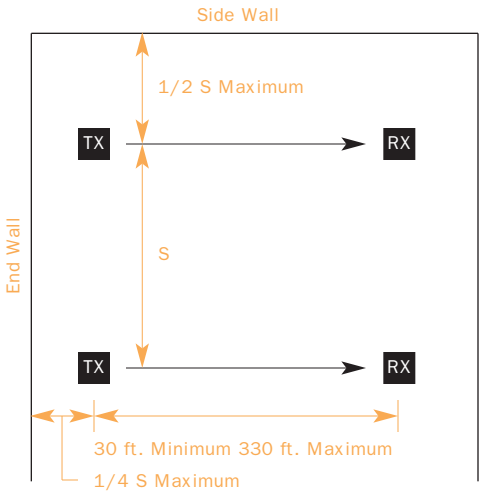
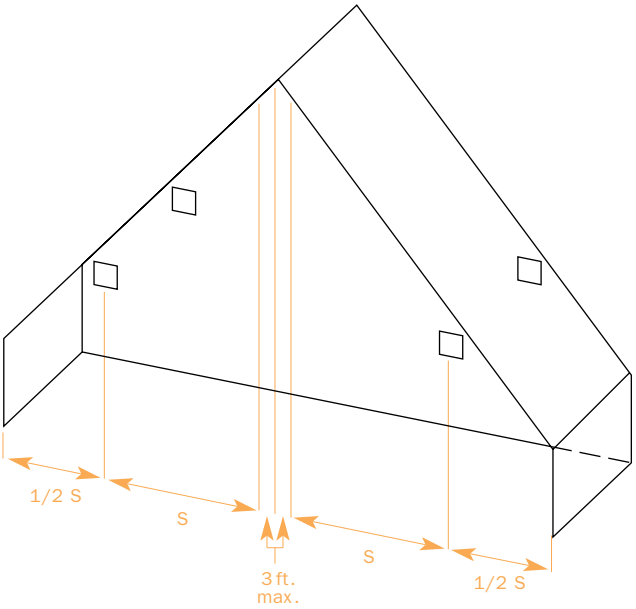


Figure 5
Spacing for Smooth Ceiling

Sloped Ceiling
Peaked Type



Sloped Ceiling
Shed Type

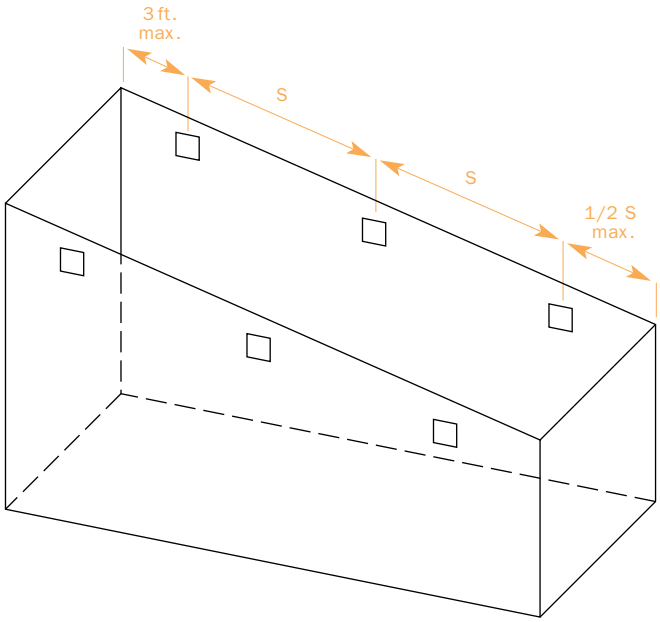


Figure 6

It should be noted that smoke originating behind the transmitter or receiver 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.

Some manufacturers may provide for the use of mirrors to direct the path of the beam. There may be requirements, however, to reduce the maximum length of the beam range.

NFPA 72 states that, where mirrors are used, they shall be installed in accordance with the manufacturer's instructions. While this technique may be useful in some applications, special attention must be given to the stability of mounting surfaces, as the possibility of misalignment increases with the number of devices to be aligned.

Beam smoke detector transmitters and receivers may be placed behind clear glass windows with little effect on performance. It is normally recommended that the maximum beam range be reduced by 10% for each window. Plastic should not be used in this application. Be sure to follow manufacturer's recommendations.

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

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