SUPPLEMENT 2

Fire Alarm Systems for Life Safety Code Users

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Editor’s Note: This supplement is an introduction to fire alarm systems. It explains the various types of systems addressed by the Life Safety Code and describes their components in detail. In this supplement the term fire alarm is intended to include detection systems and systems that provide control functions, such as elevator recall, and alarm information or notification to occupants and emergency forces.

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INTRODUCTION

This supplement starts with an overview that describes how NFPA codes and standards categorize the various types of fire detection and alarm systems. A section on fire signatures reviews the sensible or detectable physical and environmental changes that take place during a fire. A review of fire detection devices emphasizes proper selection in order to meet fire safety goals and to reduce the likelihood of false and nuisance alarms. Power sources permitted by the Life Safety Code for household smoke alarms are discussed in the context of their reliability. The discussion of circuit types and allowable wiring methods includes references to other NFPA codes and standards. The signaling section describes the goals and methods for both occupant notification and off-premises signaling for staff and emergency forces notification. A review of testing and maintenance needs for fire detection and signaling systems provides the reader with an understanding of how to extend a system’s life, reduce nuisance alarms, and ensure system operation during a fire emergency. A section new to the 2006 edition of this supplement introduces the concept of Mass Notification Systems used for emergency communication and management.

Specific requirements and designs for various occupancies are not discussed in this supplement. The occupancy chapters of the Life Safety Code should be consulted for specific requirements. The additional commentary contained in other chapters of this handbook provides a good explanation of the requirements and the philosophy behind their intent. This supplement provides an introduction to the operation of required devices and systems. Designers, owners, installers, and inspectors will find useful information to assist them in choosing among options not specifically addressed within the Code. For example, a choice might need to be made between using photoelectric or ionization smoke detectors, or information might be required on how to reduce the likelihood of false and nuisance alarms.

OVERVIEW OF FIRE ALARM SYSTEMS

Four principal types of fire alarm systems are required or recommended by various chapters of the Life Safety Code:
1. Smoke alarms or household fire alarm equipment
2. Manual fire alarm systems
3. Automatic fire alarm systems
4. Supervisory systems for extinguishing systems or other fire or building systems

Each of these categories can be viewed as consisting of three components, as shown in Exhibit S2.1. Detection and initiating devices are either manual or automatic, as shown in the illustration, and are referred to as input devices. Manual initiating devices, such as manual fire alarm boxes, are operated by people and in turn signal the control system. Automatic detection devices sense a change in the environment or equipment that is monitored and signal the control portion of the system. The control or processing section receives the incoming signals and initiates output signals. The control system can also supply power to and supervise the system's various components and circuits and provide output signals when a fault occurs or maintenance is needed. The control or processor interfaces with people and other systems through output signals.

The simplest form of system described in Exhibit S2.1 is a self-contained smoke alarm. This alarm contains a smoke sensor and a control system, which includes a power source and a notification system, usually a horn, used for occupant notification. In more complex systems, initiating devices and notification appliances are separate, self-contained units connected to a control panel by electrical circuits or radio waves. In these component systems, power is usually provided to the input and output devices through the control unit. However, it is also possible for power to be provided directly to those units that require it. Each of these three principal components (input, control, and output) is discussed in more detail in later sections of this supplement.

The occupancy chapters of the Life Safety Code specify fire alarm requirements where appropriate. Those sections that contain requirements include subsections that provide the requirements for initiation and notification. Where initiation is addressed, the occupancy chapter refers to either a complete system or a partial system. In addition, the system will be described as manual, automatic, or both.

Chapter 9, Building Service and Fire Protection Equipment, defines complete, partial, manual, and automatic systems. Where automatic detection is required, most chapters of the Code specify either partial or complete smoke detection. If an automatic fire detection system is required, but the type of detection is not specified, any automatic units that comply with NFPA 72®, National Fire Alarm Code®, are permitted to be used interchangeably. An occupancy chapter might also require separate smoke detection within dwelling units in addition to any required partial or complete system for the public or tenantless sections of the building.

Household fire alarm equipment is intended for use within dwelling units such as apartments, hotel rooms, dormitory rooms, and one- or two-family dwellings. These devices or systems are intended to detect smoke conditions and alert the occupants of the dwelling units. In occupancies such as hotels, apartment buildings, and dormitories, these devices are not intended to be connected to the overall building fire alarm system.

Within the dwelling unit, household fire alarm equipment might be self-contained smoke alarms, or it might be a small system with detectors, a control panel, and notification appliances such as bells, horns, or strobe lights. The building system can consist of manual and automatic initiating devices, extinguishing system supervisory devices, and notification appliances that are all connected to a control unit. Therefore, there are two categories of fire alarm: one that is located within the family dwelling unit and one that is intended to protect the entire building.

In some cases, an occupancy chapter of the Code might require a partial automatic detection system that covers all common spaces. In addition, house-
Fire signatures are changes in the normal environment caused by a fire. Understanding fire signatures is important because it affects the choice of fire detector for a given area. The objective is to choose a fire detector that will respond to an expected fire signature without responding to similar signatures that might normally present in the area. At the same time, the response time of the detector in reaction to the range of expected fires must meet the fire safety goals and objectives of the system.

Fire signatures can be placed in two categories, as shown in Exhibit S2.2. The first group is categorized by the energy produced by the fire, which is transferred by conduction, convection, and radiation. The second signature group is categorized by the physical/chemical changes that take place. This group is comprised of solids, liquids, and gases produced by the fire. The solid and liquid particles are grouped together and called smoke or aerosols.

Conduction occurs when, during the combustion process, some of the energy released is conducted through the fuel to further the combustion process. Any time the temperature of one part of a material differs from another part, heat energy is conducted from the hotter portion to the cooler portion.

Convection occurs when heat is transferred by fluid motion. During combustion, hot fire gases rise, entraining fresh air, which then heats and also rises until the mixture either collects at the ceiling or cools to approximately room temperature. The energy carried away by the hot gases is referred to as convected energy.

Electromagnetic radiation is the third mode of energy transfer that occurs during the combustion process. Thermal radiation is one form of electromagnetic radiation and is proportional to an object’s temperature. Light is another form of electromagnetic radiation produced during the combustion process. Unlike conduction and convection, a solid, liquid, or gaseous material is not needed to transfer energy by radiation. Electromagnetic radiation can travel through a vacuum such as space. Radiation travels in all directions and in straight lines. Thermal radiation behaves in the same way as visible light radiation; if you turn your back to it, you can’t “see” it. Therefore, when you stand in front of a fire, your face is warmed by thermal radiation, but your back is not heated. You might, however, see or feel the effects of reflected radiation.
All fires produce smoke and gases in varying quantities. Perfect combustion of most (hydrocarbon-based) fuels produces only carbon dioxide and water, in addition to the energy released. Other materials are produced when combustion is not 100 percent efficient. These materials include gases such as carbon monoxide, and liquids and solids such as tar, carbon soot, and more complex hydrocarbon particles.

The solid and liquid particles, which together are called smoke, are produced in a wide range of sizes. Some are small and invisible to the human eye, and others are large and obscure our vision. Some particle sizes are produced in larger quantities than others. The color of the smoke also varies. Many of these factors depend on the fuel and also on the efficiency of the combustion process. For instance, well-ventilated, hot, efficient fires produce mostly small, invisible, grayish particles in large quantities. Compared to flaming fires, inefficient, smoldering combustion produces mainly a smaller number of large black particles.

INITIATING DEVICES

Manual Fire Alarm Boxes

Manual fire alarm boxes are either coded or non-coded. Noncoded manual fire alarm boxes are the most common in use on new systems. When a non-coded fire alarm box is operated, a switch closes. All noncoded devices produce the same single bit of information — a switch closure. Therefore, if more than one switch is on a circuit, the circuit does not know which switch operated. The exception is addressable, microprocessor-based systems that can “talk” to and recognize each device.

Coded manual fire alarm boxes house a mechanical code wheel that turns when the alarm is operated. Through its teeth, the wheel taps out a coded signal on a circuit. These coded wheels are essentially automatic telegraph keys, and each box has a different code through which information is transmitted. This code might be transferred to a bell circuit in order to notify the occupants of a building which box has been operated.

Today’s addressable systems act like the older manually coded systems. Because the control unit knows exactly which device has originated an alarm, it can generate unique alarm signals. The control unit can also activate or actuate a unique set of output functions, such as starting or stopping certain fans and closing some doors but not others.

Manual fire alarm boxes, coded or noncoded, can be single action or double action. When operating a single-action box, the hand is used to pull the station. When operating a double-action station, two actions are required — either the door is opened and the station is pulled, or the glass is broken and a button is pushed. Double-action manual fire alarm boxes tend to reduce false alarms caused by accidental operation. They also reduce nuisance alarms to some degree.

Pull station protectors are clear plastic covers that are mounted over manual boxes to provide protection from weather, dust, dirt, and mechanical damage. They also serve to convert a single-action station into a double-action station. When these covers are placed over a double-action station, three actions are required to initiate an alarm signal — the protector must be lifted, the cover must be opened, and the box must be pulled.

Some versions of pull station protectors are available with an internal battery-operated buzzer. This feature has been shown to greatly reduce nuisance alarms in schools, shopping centers, and other public areas. When the cover is lifted, the local buzzer sounds, which tends to scare away vandals before they can operate the station. In locations such as schools or other crowded public areas, someone is likely to see or catch a vandal before the station is operated. However, when the cover is removed and the local buzzer sounds, a person might think the building’s fire alarm system has been initiated. For this reason, it is important that pull station protectors be labeled properly and that the usual occupants of the area be instructed in their use.

The Life Safety Code permits either single- or double-action manual fire alarm boxes. The use of pull station protectors is neither required nor restricted. The choice for both is up to the designer, the owner, and the authority having jurisdiction (AHJ).

Where an occupancy chapter of the Life Safety Code requires manual fire alarm boxes, Chapter 9 describes the quantity and location. NFPA 72 also contains requirements concerning the location and operation of manual fire alarm boxes. Essentially, manual fire alarm boxes are located at each required exit in the natural path of egress.

In a corridor with exits at each end, a manual fire alarm box is located at the door to each exit. The box should be located on the same side as the door handle so that someone exiting from the space will see it easily. In most cases, it is best to locate the box within the corridor, not on the other side of the door, so that the pull station is located within the space it serves. If a manual box were located on the other side of the door — for instance, in the stair tower — an occupant
from the fifth floor might pull the box on the second floor, possibly slowing discovery of the fire’s location.

In addition to locations at required exits, additional manual fire alarm boxes are required to ensure that there is less than a 200 ft (60 m) travel distance to a station. It is good practice to provide manual fire alarm boxes near the telephone operator’s area of a hotel or hospital and near portable extinguishers placed adjacent to hazardous operations in a factory. NFPA 72 requires the mounting height of boxes to be between 3½ ft (1.1 m) and 4½ ft (1.4 m), although some locally adopted codes for the disabled might limit the height to no more than 4 ft (1.2 m).

**Automatic Fire Detectors — General**

NFPA 72 classifies automatic fire detectors as either spot-type, line-type, or air-sampling detectors. Spot-type detectors include conventional smoke and heat detectors. A spot-type detector’s response to a given fire varies with the radial distance from the detector. The farther a fire is from the detector, the slower the response time of that detector. To illustrate, if a circle were drawn and the detector placed in the center, a given fire anywhere along the perimeter of the circle would result in the same response time. If the same fire were moved closer to the detector at the center of the circle, the response time would decrease. If placed farther away from the same fire, the same detector would have a longer response time. Engineers may adjust detector spacing in order to change the coverage radius and achieve shorter detection times for expected fires. Conversely, the spacing, and hence the radius, may be increased where longer response times are tolerable.

Projected beam smoke detectors and heat-sensitive cable are examples of line-type detectors. The response time for a line-type detector is about the same when a particular fire is burning anywhere directly under the line, except close to the ends. If that same fire were to move farther away to a position perpendicular to the line-type detector, response time would increase. Similarly, response time for a given fire would be about the same anywhere along a line parallel to the line-type detector, except at the ends.

Air-sampling detectors draw air samples from the protected area, through a tube or pipe, back to a remotely located detector. The tube or pipe might have several holes or sampling ports, or it might have only one. In any case, NFPA 72 treats the sampling port like a spot-type detector with respect to its location and spacing.

Spot- and line-type detectors can be restorable or nonrestorable. Restorable detectors reset themselves after the fire signature is no longer present, provided they are not severely exposed to a fire. For instance, some heat detectors absorb heat until they respond, and may then cool off until they return to their original state. Self-contained household smoke alarms automatically reset after the smoke has cleared from their chamber (a slight time delay is generally built into the detector to ensure a minimum ring time). Nonrestorable detectors are destroyed upon activation and must be replaced after exposure to the fire signature for which they were designed.

There are advantages and disadvantages to both restorable and nonrestorable detectors. Nonrestorable detectors generally provide a positive visual indication of operation, whereas a restorable detector might not have any visual cue that it is or has been in the alarm state. This is true of most heat detectors but not of smoke detectors, which have visual alarm indicators. Restorable heat detectors can also be provided with visual indicators, although this feature greatly increases the cost of an otherwise relatively inexpensive detector. One key advantage to restorable detectors is their ability to test the units with the same signature for which they are designed to respond. Most addressable heat detectors are restorable and include an indicator light on the unit.

**Heat Detection**

Three basic types of heat detectors are available commercially — fixed-temperature, rate-of-rise, and rate compensation detectors. The Life Safety Code allows any of these units to be used interchangeably wherever heat detection is required. Addressable, analog, thermistor type heat detectors may exhibit a combination of conventional detector characteristics, depending on how they are programmed by the manufacturer.

Heat detectors respond to hot smoke and fire gases — that is, to convected energy. Because it takes time for a heat detector to absorb heat and therefore to respond, the air and fire gases surrounding a detector might be much hotter than the detector element. This response delay is called thermal lag. Thermal lag can be illustrated by imagining a fixed-temperature heat detector, such as a 165°F (74°C) sprinkler, that is dropped into a pan of boiling water. Although the water is 212°F (100°C), there is a time delay or thermal lag before the sprinkler link melts. The smaller the mass of the link or detector element, the shorter the thermal lag. Thermal lag is a measure of detector sensitivity. The shorter the thermal lag, the greater the sensitivity of the unit.
Thermal lag enables a detector with a fixed temperature of 200°F (93°C) to respond to a fire more quickly than a sprinkler with a fixed temperature of 165°F (74°C). It is detector sensitivity that determines the number of detectors needed for a particular application.

There are several ways to measure detector sensitivity. The term response time index (RTI) is used to measure sprinkler sensitivity. The smaller the RTI, the more sensitive the unit. The RTI of a unit can be used in calculations to determine when that unit will respond to a given fire scenario. For heat detectors, the current measurement of sensitivity is the Underwriters Laboratories listed spacing or Factory Mutual approved spacing. The higher the spacing rating, the more sensitive the detector. For instance, a detector with a listed spacing of 50 ft (15 m) is more sensitive than one with a listed spacing of 30 ft (9 m). The listed spacing of a detector is determined by fire testing and cannot be used directly as part of any engineering calculations. Testing laboratories may soon test and report the RTI of heat detectors.

Where heat detectors are used, NFPA 72 requires that they be spaced on smooth ceilings less than 10 ft (3 m) high, in accordance with their listed spacing. The installed spacing is equal to the listed or approved spacing. For ceilings higher than 10 ft (3 m), NFPA 72 contains reduction factors to be applied to the listed spacing. Therefore, as ceiling height increases, the installed spacing becomes less than the listed spacing. Reduction factors for joisted, beam, and sloped ceilings are also contained in NFPA 72. The beams or joists must be at least 4 in. (10.1 cm) deep before reductions are required for heat detectors. Each of these features (high ceilings, ceilings that are not smooth, and so on) affects detector response. The reduction and correction factors contained in NFPA 72 are intended to provide some adjustments for these features. NFPA 72 should be referenced for a list of all the various correction factors. Designers, installers, and inspectors often miss spacing reductions; yet these reductions can have a dramatic effect on detector response time during a fire. NFPA offers a three-day seminar on fire detection and alarm systems that covers these requirements in detail.

Fixed-Temperature Detectors. Fixed-temperature heat detectors respond when the temperature of their element reaches a preset level. To reduce the likelihood of false alarms, the temperature rating selected for an application should be at least 20°F (11°C) above the maximum expected ambient temperature. These detectors are available in a wide range of temperature ratings, the most common being 135°F to 140°F (57°C to 60°C) and 190°F to 200°F (88°C to 93°C). Fixed-temperature detectors are available as spot-type and as line-type.

Fixed-temperature heat detectors use several methods of operation. The two most common methods use a fusible or bi-metal element. Fusible elements melt at a preset temperature and are spring-loaded to close or open a set of electrical contacts. Bi-metal units use two or more metals that expand at different rates, causing the element to change shape and initiate operation of a set of electrical contacts. Line-type, fixed-temperature heat detectors generally operate either when insulation melts, allowing two conductors to short circuit, or when heat causes a decrease in electrical resistance and an increase in conductivity between two conductors.

NFPA 72 contains basic operational descriptions of these and other detection principles. For a more detailed discussion of the many different types of heat detectors available, consult NFPA’s Fire Protection Handbook or Fire Alarm Signaling Systems.

Rate-of-Rise Detectors. Rate-of-rise heat detectors respond when their temperature or the temperature of the air surrounding them rises faster than some preset rate — regardless of their actual fixed temperature. Units are available with various alarm rates, a common one being 15°F/min (8°C/min). The speed with which a detector responds depends on how hot the fire gases are compared to the detector’s starting temperature, and also on the detector’s sensitivity. Therefore, if a rate-of-rise detector is initially monitoring a room temperature of 65°F (18°C), and a fire causes the temperature around the detector to rise quickly, it will respond in a given time. If the detector is in a freezer at –20°F (–29°C) and the temperature rises at the same rate, the response time would be about the same.

Depending on environmental conditions, detector sensitivity, and the fire growth rate, rate-of-rise detectors can respond much faster than fixed-temperature units. In many real fire situations, however — such as a slowly developing fire — a rate-of-rise detector may not respond. For this reason, testing laboratories, codes, and standards require these detectors to be backed up with fixed-temperature elements.

As with fixed-temperature detectors, rate-of-rise heat detectors are available in many different configurations. The most common spot-type unit works on a pneumatic principle. As the detector is heated, air inside a chamber is heated and expands. The air escapes through a vent hole when heated slowly. How-
ever, when heated faster than its preset rate, the air cannot escape quickly enough, and pressure builds up in the detector. As the pressure increases, a diaphragm moves and activates a set of electrical contacts. Line-type rate-of-rise detectors are also available using this pneumatic principle. Other rate-of-rise detectors use bi-metal elements or electrical conductivity to detect rapid temperature changes.

When using rate-of-rise heat detectors, it is important to ensure that they will not be subjected to changes in ambient conditions that might cause false alarms. For instance, rate-of-rise detectors should not be located too close to air supply vents or directly over heat sources such as ovens, radiators, or large sinks where hot steam might set them off. Heat detectors can be used in high-temperature areas, but caution should be used in situations where the temperature might cool rapidly then rise again quickly enough to set off the rate-of-rise units. In a large boiler house, for example, the temperature at the ceiling might be 100°F to 150°F (38°C to 66°C) under normal circumstances. As long as the fixed-temperature backup to the rate-of-rise detector is at least 170°F (77°C), there should be no false actuation. However, if a large door is opened in the winter, the temperature could drop quickly. When the door is closed, the temperature at the ceiling could rise fast enough to set off the rate-of-rise portion of the detector.

**Rate Compensation Detectors.** Rate compensation heat detectors are more complex in operation than either fixed-temperature or rate-of-rise devices. In short, they combine the principles of both in order to compensate for thermal lag. When the air temperature is rising at a rate of about 40°F/min (22°C/min) or less, the unit is designed to respond almost exactly at the point when the air temperature reaches the unit's rated fixed temperature. The detector element does not lag while it absorbs the heat and rises to that temperature. At faster rates of temperature rise, the unit responds more quickly than most fixed-temperature detectors, even though some thermal lag does occur. In addition, with these very fast temperature rises, rate-of-rise detectors generally respond more quickly than either fixed-temperature or rate compensation detectors.

Because of the precision associated with their operation, rate compensation heat detectors are well suited for use in areas where thermal lag must be minimized to provide fast response when temperatures exceed a certain level. At the same time, they are stable even in areas where temperatures fluctuate but do not exceed the preset alarm level. Therefore, rate compensation detectors respond more quickly to most fires than do fixed-temperature detectors, without producing false alarms due to moderate temperature fluctuations as can occur with the use of rate-of-rise units. Rate compensation units are also suitable where precise temperature actuation is needed.

**Smoke Detection**

**General.** Four principal types of smoke detection equipment are currently on the market:

1. **Spot-type ionization detectors**
2. **Spot-type, light-scattering, photoelectric detectors**
3. **Line-type, projected beam, light obscuration detectors**
4. **Air-sampling detectors**

The *Life Safety Code* allows each of these types to be used interchangeably wherever smoke detection is required.

By definition and by design, smoke detectors respond to the solid and liquid aerosols produced by a fire. Each type responds differently to different types of smoke. Because smoke detectors also respond to aerosols from non-fire sources, an understanding of their operating characteristics is helpful in their correct selection and placement to reduce the chances of false and nuisance alarms. Therefore, selection of a smoke detector should be based on the type of fire and fuel expected, as well as on environmental characteristics.

At some point, the smoke detector transmits an alarm signal either by sounding an internal alarm or by signaling a control panel. With digital and analog/digital systems, the detector sends information on the amount of smoke in the chamber back to the control panel, where a decision is made to perform some function, such as sounding an alarm. Such units are often called "smart" or "intelligent" devices. Because they send all information back to a control panel or processor and do not make alarm decisions, these units are often referred to as "sensors" rather than detectors. In the case of conventional detectors, a decision to alarm is made internally. The conventional detector then signals an alarm either by activating an internal audible or visual device or by signaling the control panel. Additional information on how conventional and digital smoke detectors signal a control panel is contained later in this supplement, in the subsection Wiring Methods.

Where required by an occupancy chapter of the *Life Safety Code*, household smoke detectors — often called single- or multiple-station smoke alarms —
These documents also do not contain any explicit requirements regarding detector sensitivity. Chapter 5 of NFPA 72 only requires that the detector be tested and listed for its intended use. It is the listing laboratory, acceptable to the authority having jurisdiction, that determines the range of acceptable smoke detector sensitivity for a given application.


The range of possible sensitivities for spot-type detectors is generally between 1.0 and 4.0 percent per foot (0.3 m) of obscuration due to gray smoke. This range provides the designer of a smoke detection system some choice with regard to sensitivity. The importance of this is explained later in this supplement, under the heading Selection and Placement. It is possible to obtain smoke detectors that are specially listed with higher sensitivities for use in special situations.

Ionization Detectors. Exhibit S2.3 shows an ionization smoke detector. Ionization smoke detectors have two parallel electrically charged plates separated by an air gap. A small, low-strength radioactive source causes the air between the plates to be ionized. Because of the voltage between the plates, the positive ions travel to the negative plate and the negative ions travel to the positive plate. This creates a small electrical current. As smoke particles enter the detector, they slow down the movement of the ionized air between the plates. The corresponding change in electrical current is measurable by the detector and is proportional to the number and size of the smoke particles between the plates. In the case of ionization

must be located and installed in accordance with NFPA 72, 2002 edition, Chapter 11. Chapter 5 of NFPA 72 governs the location and placement of required smoke detectors for protected premises systems. Unless otherwise noted, all requirements and recommendations for smoke detector spacing contained in Chapter 5 apply equally to ionization or photoelectric spot-type smoke detectors, to projected beam detectors, and to the sampling ports or heads of a sampling-type system.

For general area coverage with smoke detectors, Chapter 5 of NFPA 72 requires that spacing be based on manufacturer's recommendations. Chapter 5 also recommends an installed spacing of 30 ft (9 m) between detectors. This recommendation applies to smooth, flat ceilings, and is also in agreement with the recommendation of most manufacturers. Therefore, in many cases, the installed spacing is the manufacturer's recommended spacing, which is usually 30 ft (9 m), center to center. There is no listed or approved spacing of smoke detectors, as is provided for heat detectors. Also, there is no specific requirement for changing detector spacing depending on the sensitivity of the unit.

Chapter 5 of NFPA 72 requires detector spacing to be reduced for ceilings with beams or solid joists. Where smoke detectors are used, the beams or joists must be at least 4 in. (10 cm) deep before reductions are required. Spacing adjustment is also required when airflow in the space is greater than about 8 minutes per air change. The adjustment requirements for smoke detector spacing on beamed or joisted ceilings, sloped ceilings, and in the presence of high airflow are cumulative and very complex. NFPA 72 should be consulted and studied in detail to determine the ultimate installed spacing requirement.

Unlike its provisions for heat detectors, Chapter 5 does not contain specific spacing reductions for smoke detectors where ceiling height exceeds 10 ft (3 m). Instead, it advises following the manufacturers' recommendations and using good engineering judgment. Other factors that must be considered are discussed later, in the section Selection and Placement.

Spot-type smoke detector sensitivity is generally based on the percentage of light obscuration per foot required for the unit to signal an alarm. The alarm threshold can also be expressed in optical density per foot (or per meter), which can be converted to obscuration per foot.

The Life Safety Code does not require that detectors have any minimum or maximum sensitivity, only that they comply with the National Fire Alarm Code. These documents also do not contain any explicit

Exhibit S2.3 Ionization smoke detector.
smoke detectors, the strongest signal is obtained when there are a large number of small particles in the chamber.

**Photoelectric Detectors.** Exhibit S2.4 shows a photoelectric smoke detector. Spot-type photoelectric smoke detectors operate on the light-scattering principle. A small light source, usually an infrared LED, shines a beam into the detector chamber. A light-sensitive receiver is located so that it normally sees only a very small amount of light from the source reflected from the detector chamber. When smoke enters the detector chamber, additional light is scattered within the chamber, some of which reaches the photosensitive receiver and changes the detector signal. As with ionization detectors, the magnitude of the signal is related to the number and size of the smoke particles.

Many other factors also affect the signal from a light-scattering smoke detector. The color of the smoke affects the amount of light that is scattered. Dark smoke, such as that from some plastics and hydrocarbon fuels, absorbs more light than it reflects. Light-colored particles reflect a lot of light, so smaller quantities can produce strong signals. Particle shape also affects the amount of light reflected or refracted, as does the wavelength of the light source and the angle between the source and receiver. However, in the case of a particular scattering-type photoelectric detector design, the strongest signal is generally obtained when large, light-colored smoke particles are in the chamber.

**Projected Beam Detectors.** Projected beam smoke detectors, as illustrated in Exhibit S2.5, operate on the light obscuration principle. These detectors consist of a source that projects a light beam across a space to a receiver. As smoke enters the beam path, some of the light is absorbed and some is scattered, reducing the total amount reaching the receiver. The color and shape of the smoke particles are not as important as for spot-type photoelectric detectors. In the case of projected beam smoke detectors, it is the size and quantity of smoke particles in the path that have the greatest effect on the detector’s signal.

Projected beam smoke detectors respond to the total amount of light obscuration in their paths. When the percentage of light obscured reaches a given threshold, the unit sounds an alarm. Typically, the units are available with adjustable sensitivities between 20 and 70 percent total obscuration. If the light beam is suddenly and totally obscured, the unit should not alarm but should give a trouble signal after a short time period. In general, fires do not suddenly and totally obscure a light beam. Similarly, a very gradual loss of light is also probably not indicative of a fire but is more likely an accumulation of dust or a misalignment of the beam. This situation should also produce a trouble signal, not an alarm signal.

Very large, fast developing fires, such as a large spill of flammable liquid, can cause a rapid decrease in the signal received by a projected beam smoke detector. For this reason, the detector must have a setting that permits it to allow a fast blockage to cause an alarm signal rather than a trouble or supervisory signal. This setting should be used only where there is a real possibility of these types of fires.

When smoke detection is the objective, projected beam smoke detectors can have a measurable performance advantage over spot-type smoke detectors. Projected beam smoke detection can actually be more sensitive to real fires, yet less prone to nuisance alarms.

**Air-Sampling Detectors.** Sampling-type smoke detection devices are designed to draw air samples from the protected space to a separate detection chamber. The sampling portion might consist of a combination of air pumps, filters, and tubing, or piping fitted with
sampling heads or perforated to draw room air samples. The detection device might be self-contained or might be part of, or served by, a control panel.

Air-sampling detectors should not be confused with duct smoke detectors. Sampling-type detectors use positive ventilation methods to draw an air sample. Duct smoke detectors are usually only spot-type photoelectric or ionization detectors in special housings. Duct smoke detectors might use a sampling tube that penetrates the duct to allow natural pressure differences to draw air into the detector housing.

There are two principal types of air-sampling smoke detection systems. One type uses a cloud chamber to detect very small particles in a sample of air from the protected space. In a cloud chamber, humidity is added to the air sample, and the pressure is reduced to lower its temperature. This causes water to condense on small particles present in the sample. The resulting cloud is measured by an LED light source and a phototransistor light receiver. These cloud chamber units are very sensitive to very small (submicron) particles.

The second principal type of air-sampling smoke detection system uses a very sensitive photoelectric light-scattering detector. Unlike a spot-type, light-scattering smoke detector, this system uses a high-power strobe light or a laser beam rather than an infrared LED. Where combined with a sensitive light receiver, the unit can detect submicron-sized particles in very small concentrations. Other sampling-type smoke detectors might use other detection principles such as an ionization chamber.

Other Detection Principles

Radiant Energy Detectors. Radiant energy detectors are often called flame detectors. However, the broader name, radiant energy detectors, includes units designed to sense smoldering and glowing ember combustion.

The radiant energy emitted during combustion of a fuel falls predominantly into three categories, distinguished by the wavelength of the radiation:

1. Ultraviolet: wavelength smaller than visible radiation (smaller than about 0.35 microns)
2. Visible: wavelength larger than ultraviolet radiation but smaller than infrared radiation (between about 0.35 microns and 0.75 microns)
3. Infrared: wavelength larger than visible radiation (more than about 0.75 microns)

The two most common wavelengths detected by radiant energy detectors are the ultraviolet and infrared bandwidths. Except in very special applications, visible light comes from so many normal sources that it cannot be used effectively as a fire signature.

The application of radiant energy sensing detectors is beyond the scope of this supplement. The selection and use of flame and spark detectors is complex and requires thorough knowledge of fuel behavior, environmental conditions, and specific detector characteristics. Generally, these detectors are used in special applications such as in aircraft hangars and areas where flammable and combustible solids, liquids, and gases are handled, used, or conveyed. Subject to the approval of the authority having jurisdiction, these detectors can be used as part of an automatic fire detection system required by the Life Safety Code where specific detection, such as smoke, is not mentioned in the occupancy chapter.

Chapter 5 of NFPA 72 contains descriptions of these radiant energy detection principles. For more detailed information on these detectors and their applications, consult the Fire Protection Handbook, Fire Alarm Signaling Systems, and the manufacturers’ literature.

Other Fire Detectors. Chapter 5 of NFPA 72 recognizes that there are, or might someday be, detectors other than those already discussed, that are suitable for use as automatic fire detectors. The selection, application, and use of any detector are governed by their principle of operation, their testing and/or listing (if any), and their manufacturers’ recommendations.

Any fire detector listed or approved for its specific intended purpose is permitted to be used where the Life Safety Code requires automatic fire detection but does not specify the type. The authority having jurisdiction must approve the selection.

Monitoring Other Fire Protection Systems

Fire detection and alarm systems can be interconnected to receive signals from other fire prevention and protection systems. These systems might be required by parts of the Life Safety Code and include the following:

1. Sprinkler systems
2. Fire pumps
3. Other extinguishing systems (CO₂, water spray, dry chemical, wet chemical, foam)
4. Heating, ventilating, and air-conditioning systems
5. Smoke control systems

The signals received from these other systems or devices might be a fire alarm or a supervisory signal indicating the status of the system or device. Detailed
descriptions of these systems are not possible in this brief introduction to detection and alarm signaling. However, some information on sprinklers, the most common of these systems, is warranted.

Where an occupancy chapter of the Life Safety Code requires an automatic sprinkler system, the requirement indicates whether the system must be supervised. Requirements for automatic sprinkler system supervision are located in 9.7.2. Under Extinguishment Requirements, the occupancy chapter might also state that the system is required to be connected to the fire alarm system. Under Detection, Alarm, and Communications Systems of the same occupancy chapter, the subsection titled Initiation indicates whether alarm signals must be activated by the sprinkler system.

Where a supervised automatic sprinkler system is required, it must produce a distinct signal to indicate conditions that might impair the satisfactory operation of the sprinkler system. This requires monitoring of such features as the opening and closing of control valves, fire pump operation, water tank level and temperature, and both high and low air pressure on dry-pipe sprinkler systems. Chapter 9 also requires supervisory signals to terminate within the protected premises at a constantly attended location or in an approved remote receiving facility.

Chapter 9 of the Life Safety Code also requires waterflow alarm signals from required supervised sprinkler systems to be transmitted to an approved auxiliary, remote station, proprietary station, or central station facility. These systems are introduced later in this supplement in the section entitled Signaling. Where the occupancy chapter requires a sprinkler system to be monitored by and to produce an alarm on the protected premises system, NFPA 72 contains requirements for connection of the system.

NFPA 72 has specific definitions of alarm, trouble, and supervisory signals, at the local protected premises. Alarm signals indicate an emergency requiring immediate action. A supervisory signal indicates the need to initiate a specific action regarding some type of protective service or equipment, such as guard tour or extinguishing systems. For example, a closed-valve signal on a sprinkler system is a supervisory signal indicating the need to investigate the signal and take corrective action (that is, open the valve) when appropriate. A trouble signal indicates a fault or problem with a protective signaling system. Trouble signals occur because of faults in the protective signaling system, and supervisory signals are signals initiated in conjunction with other systems or services.

The three different signals must be distinct from one another. Trouble and supervisory signals at the protected premise are permitted to have the same audible signal, as long as they have separate and distinct visual signals. Therefore, the old practice of wiring a valve tamper switch to open the waterflow alarm circuit and cause a trouble signal is not acceptable. The valve tamper switch would break the circuit just as a broken wire would. Both would result in a trouble condition at the control panel. Correct and incorrect methods for monitoring supervisory devices are addressed in the section on wiring later in this supplement.

Selection and Placement

Within the context of the Life Safety Code, some degree of decision making is necessary concerning the type of detector to be used in a given situation. For instance, where the Code requires a supervised fire alarm system with initiation by smoke detection, it does not specify what type of smoke detection is permitted to be used. The Code intends only that life safety fire detection goals for this particular occupancy be met by smoke detection designed, installed, maintained, and tested in accordance with NFPA 72. The same is true for a required household fire alarm smoke detector in a dwelling unit. The opportunity to choose a smoke detection method allows design flexibility for performance and economy.

The majority of detectors used to meet the intent of this Code are spot-type ionization, spot-type photoelectric, or projected beam detectors. Air-sampling smoke detectors are very sensitive and cost more than systems using spot- and beam-type detectors. Their use is generally limited to clean, high-value areas such as computer rooms and industrial clean rooms for manufacturing semiconductors. They have also found use in telecommunications facilities and power plant control rooms. Because of their cost and sensitivity, these detectors are not a common choice for meeting requirements of most chapters of the Life Safety Code, despite the fact that they are allowed. Design considerations for these systems are complex and beyond the scope of this supplement.

The first step in selecting a smoke detector is to consider the type of fire likely to occur in the area. Photoelectric or projected beam detectors would provide a faster response if the fire is likely to smolder for some time because of the large particles produced during smoldering combustion. If the fire is most likely to be fast and hot with open flames, the larger quantity of small smoke particles will set off an ionization smoke detector more quickly than will either a photoelectric or projected beam detector.
The expected color of smoke should also be considered. Color is important to photoelectric light-scattering detectors but not to projected beam and ionization detectors. If black smoke is expected, projected beam or ionization detectors will give the fastest response. If the smoke is expected to be mostly large black particles, the ionization detector falls further down the list of choices. The projected beam detector would probably respond first, followed by either photoelectric or ionization.

Ambient environmental conditions must also be considered when selecting a smoke detection method. Smoke detectors cannot be used where the temperature is above or below the manufacturer's stated range. This range is usually 32°F to 120°F (0°C to 49°C), although lower and higher temperature units might be found.

Cooking odors are blamed for a large number of nuisance alarms. The odors that are produced by cooking contain a large number of small invisible particles. A smoke detector's response to cooking odors is not a false alarm; it is a response to a valid fire signature. An ionization smoke detector would probably trigger a nuisance alarm in response to cooking odors, whereas a photoelectric smoke detector would probably not activate the alarm unless the food was well burnt and producing visible smoke. Therefore, unless the detector can be located far enough from the kitchen to avoid odors, the better choice is a photoelectric detector.

Steam from showers and large sinks contains lots of small water drops and has much the same effect as cooking odors in causing nuisance alarms from ionization smoke detectors. The heavier the steam, the more likely it is to also cause photoelectric smoke detectors to alarm. However, the highly reflective nature of small water droplets in steam may cause photoelectric detectors to alarm even at low levels. Detectors can often be located to avoid these sources of false fire signatures.

Insects can set off either type of spot-type smoke detector. They are not likely to cause an alarm from a projected beam smoke detector because of the small amount of light they obscure. Detectors with good bug screens stop most insects, but some still manage to get into the detector chamber. Ionization smoke detectors are less prone to nuisance alarms from insects than spot-type photoelectric smoke detectors. Another solution that has been reportedly successful is to place an insecticide strip on or near the detector. The detector manufacturer should be consulted before taking this action. Some insecticides might produce enough fumes to set off ionization detectors or harm electronic components. An insecticide should never be sprayed in or near a functioning detector. It would probably set off the alarm, as would any aerosol spray, and it could harm the detector.

Cigarette smoke causes nuisance alarms from ionization and photoelectric smoke detectors. When the smoke dissipates to a light cloud, the ionization detector is likely to alarm first. When the smoke is heavy and thick, either type will alarm. Often, detectors can be placed to avoid such conditions. For instance, in elevator lobbies, smoke detectors should not be placed directly in front of the doors where people stand and where drafts from the shaft might bring dust into contact with the detector. In office areas, smoke detectors should not be placed directly over a smoker's desk or too close to a break room or cafeteria room, where smokers might congregate or where cooking might take place. Incidental cigarette smoke is not likely to set off projected beam smoke detectors. As a smoker passes near the beam, a cloud of smoke 3 ft to 10 ft (1 m to 3 m) wide might be produced, but it would not be dense enough to alarm the detector.

Detectors of the ionization or photoelectric type can be purchased with different sensitivities. Detector sensitivity is usually labeled on the detector and on its specification sheet. The sensitivity is typically between 1 percent and 4 percent per foot (0.3 m) obscuration. This is the amount of light obscuration measured immediately outside the detector when it alarms during tests with gray smoke. Comparing labels on a photoelectric and an ionization smoke detector usually indicates the ionization unit to be more sensitive. Typically, ionization smoke detectors have labeled sensitivities on the order of 1 percent to 2 percent per foot. Photoelectric detectors range from 1 percent to 4 percent per foot. This does not mean that ionization detectors are always more sensitive than photoelectric detectors, only that they might be more sensitive to fires that produce smoke similar to the gray smoke used in the test. A true comparison of detector sensitivity must include consideration of the type of smoke expected, as discussed in the previous paragraphs and in the section on fire signatures.

Sensitivity comparison is made more difficult by the fact that the light obscuration measurement used by the listing laboratories to rate sensitivity is not comparable to the factors that actually set off either spot detector type. For photoelectric detectors, it is the light scattered, not the light obscured, that is important. For ionization units, it is the quantity and size of the particle. The amount of light obscured across a given distance is only partly related to these factors. The published numbers are useful only as a relative comparison between detectors of a given type.
as they react to a given type of smoke. A photoelectric detector having an alarm threshold of 2 percent per foot obscuration is more sensitive than one with a threshold of 3 percent per foot. Similarly, an ionization detector with an alarm threshold of 1 percent per foot is more sensitive than one with a threshold of 2 percent per foot. However, one cannot say that a photoelectric detector with a 2 percent per foot obscuration threshold is as sensitive as an ionization detector with a 2 percent per foot threshold. It might be equally sensitive to the same gray smoke used by the testing laboratories to evaluate the units, but in a real fire, many factors — including smoke color and size — could cause one detector to respond before the other.

By nature of their design, projected beam smoke detectors are a good choice for large, open spaces. The source and the receiver of commercially available units might be placed as far as 300 ft (91 m) apart, with 30 ft (9 m) or more between adjacent beams. Therefore, there might be considerably fewer units to install. The sensitivity of projected beam smoke detectors is stated in total percent obscuration required to alarm the unit, not percent per foot, as is the case with spot-type detectors. The sensitivity is usually adjustable, between about 20 percent and 70 percent total obscuration, allowing adjustment for different distances between the source and the receiver.

Because projected beam detectors respond to the accumulated smoke in their path, they are sensitive to real fires while remaining insensitive to many environmental factors that would alarm a spot-type detector. For instance, insects in the light path are not likely to block 20 percent of the beam. Similarly, a cigarette smoker might create a cloud of 1 percent to 2 percent per foot smoke, which would be 5 ft or 10 ft (1.5 m or 3 m) in diameter. If this cloud were under a spot-type smoke detector, it would probably alarm unless a less sensitive unit were installed. However, the same cloud produces between 5 percent and 20 percent total obscuration of a beam projected through the cloud, which projected beam detectors can be set to disregard. Nevertheless, in a real fire scenario, a 20- to 30-ft (6- to 9-m) cloud of smoke — which is 1 percent to 2 percent per foot on average — is likely to be produced by the time a spot-type detector is activated and goes into alarm. A beam projected through this cloud would be obscured about 20 percent to 60 percent, which would set off a beam detector that had been calibrated in that range. The projected beam detector could be set for 30 percent total obscuration to respond sooner than a spot-type detector to a real fire, while still disregarding small sources of activation such as tobacco smokers, sinks, and kitchenettes.

Many other factors should be considered when selecting smoke detectors. For instance, in a room with moderate to high air movement, smoke from a fire that would normally set off a spot-type detector might be dissipated to form a thin haze. The fire must grow larger before there is enough smoke present to set off a spot-type detector. Use of either projected-beam or air-sampling detectors would overcome this delayed response. For more discussion of this and other factors affecting detector selection, consult NFPA 72, Chapter 5, as well as the National Fire Alarm Code Handbook, the Fire Protection Handbook, or Fire Alarm Signaling Systems. A review of manufacturers’ specification sheets and the standards used by testing laboratories for listing or approval can also provide some insight on detector selection.

The Code contains other choices concerning detector selection. In some cases heat detectors might be required or smoke detection simply cannot be used due to normal ambient conditions. In some locations, the authority having jurisdiction might require the area to be made suitable for smoke detectors. In other cases, it might be judged that heat detectors could be used and the life safety intent of the Code would still be met. These situations demand that a choice be made between the various types of heat detectors.

If the area has no friendly sources that produce rapid temperature changes, rate compensation or combination rate-of-rise/fixed-temperature heat detectors provide good results. If a fast-growing fire were to occur, these detectors would respond before a fixed-temperature heat detector. If a fire were slow growing, they would respond in about the same time as a fixed-temperature heat detector. Where rapid temperature changes are expected during normal conditions, fixed-temperature detectors should be chosen.

Detectors installed as household fire alarm equipment must be installed in accordance with NFPA 72, Chapter 11. This category includes single- and multiple-station self-contained smoke alarms and small systems installed to meet the requirements within the dwelling unit. (The distinction among single, multiple, and system detectors is explained in the section on wiring in this supplement.) Application of the Life Safety Code, combined with Chapter 11 of NFPA 72, usually results in the installation of smoke detectors on each level of a dwelling unit, outside of the bedrooms, and at the base of any stairs leading to upper levels. In new construction, detectors would also be placed in each bedroom.
However, where the smoke detectors also contain the alarm sounder to alert occupants, additional units might be needed to achieve audibility in all spaces of the dwelling unit. Additional detectors might also be warranted to provide longer escape times for some occupants or to provide faster response when complex floor plans are involved and smoke must travel a good distance to reach a required detector.

Where the Code requires an automatic fire alarm system initiated by smoke detection or heat detection, Chapter 5 of NFPA 72 governs the spacing and placement of the chosen detectors. The first step is to place detectors as close as possible to known hazards and as far away as possible from nuisance alarm sources. Any remaining space is then covered with evenly spaced detectors. This approach might result in a few more detectors than are required, but will provide better fire detection and reduced chances of false and nuisance alarms. For example, in a hall of a college dormitory, conditions might allow smoke detectors to be spaced 35 ft (10.7 m) on center. However, if such spacing results in a detector immediately outside a shower room, it might be best to use a different increment of spacing, such as 28 ft (8.5 m), and to put detectors no closer to the shower room door than 14 ft (4.3 m).

The maximum spacing between detectors or the maximum distance from any point on the ceiling to a detector is determined by the many factors previously discussed for each detector type. For heat detectors, the installer should begin with the listed or approved spacing, then make corrections for ceiling height, beams, joists, and slopes. Where using smoke detectors, the installer should start with the manufacturer’s recommended spacing, usually 30 ft (9 m), and make adjustments for ceiling height, beams, joists, slopes, and high airflow. It is important to note that the actual correction factors given in NFPA 72 for smoke detectors are different from the factors for heat detectors. NFPA 72 should be consulted for the exact correction factors to be used.

Once detector spacing has been determined, detectors must be located in accordance with other requirements of NFPA 72. Exhibit S2.6, reproduced from NFPA 72, shows that ceiling-mounted detectors must be installed at least 4 in. (10 cm) from walls. If the detector is to be wall-mounted, it should be installed at least 4 in. (10 cm), but no more than 12 in. (30 cm), from the top of the wall. The 4 in. × 4 in. (10 cm × 10 cm) space is called the dead air space. Detectors in that space will respond more slowly because smoke and heat from a small fire tend to circumvent the wall-ceiling intersection.

When all correction factors have been applied to determine a required spacing for detectors, area coverage begins by locating the first detectors at one-half that distance from a wall. Exhibit S2.7, reproduced from NFPA 72, demonstrates this concept. One part of the exhibit illustrates how spot-type detectors would be spaced, and the other half indicates how line-type detectors would be evenly located. In the diagram, S is the corrected, or installed, spacing. These examples assume that the corrected spacing results in a square, such as 30 ft × 30 ft (9 m × 9 m) or 25 ft × 25 ft (7.6 m × 7.6 m). In the case of installation between beams or joists, the corrected spacing would create a rectangle such as 15 ft × 30 ft (4.6 m × 9 m), the shorter distance being measured perpendicular to the joists or beams. Note in Exhibit S2.7 that no point on the ceiling can be farther from a detector than 0.7 times the installed spacing. This maximum distance applies to all points on a ceiling and is useful in laying out systems in irregularly shaped spaces. This concept is discussed in detail in NFPA 72.

If a ceiling has solid beams or joists, it must be decided whether the detector should be located on the bottom of the beams or joists or in the ceiling pocket. In the case of beamed ceilings, the detector could be located on the bottom of the beams or on the ceiling in the pocket, depending on the beam depth, beam spacing, and ceiling height. The reader should refer to NFPA 72 for specific requirements. Note that bar joists and trusses might not significantly impede the movement of smoke and heat. Unless the top cord of the bar joist or truss that is in direct contact with the ceiling is more than 4 in. (10 cm) deep, the
ceiling is considered smooth. In that case, the detectors must be mounted on the ceiling. Required detectors are not permitted to be mounted on the bottom of bar joists or trusses.

Detectors must also be located for ease of testing and maintenance. A smoke detector located over the open part of a stair tower probably cannot be reached very easily once scaffolding is removed. As a result, smoke detectors are often not tested or cleaned and might fail in a fire or cause false or nuisance alarms. Detectors should be located over a landing or where a ladder can be placed to reach them. There is no need to place the detector in the middle of the space. The space is considered to be adequately covered as long as all points on the ceiling are within the detector’s protection radius (0.7 times the installed spacing). Thus, in most stair towers, wall mounting would be sufficient to cover the space.

Construction dust is one of the largest causes of false and nuisance alarms from smoke detectors. When smoke detectors are installed before all construction work is complete, they collect dust in their chambers. The dust can cause immediate alarms, or it can bring the detector close to alarming. As a result, the slightest physical disturbance, such as air movement or people walking, might set it off. If dust has caused a detector to become more sensitive, even small amounts of cigarette smoke or other aerosols could set it off. Note that many analog, addressable smoke detectors have drift compensation algorithms to compensate for dirty chambers. Plaster and gypsum board dust are very difficult to clear from a detector without disassembly, cleaning, and subsequent recalibration by factory-trained service personnel.

Despite demands for a certificate of occupancy, early installation of detectors will only lead to future problems and must be resisted. NFPA 72 specifically states that smoke detectors are not permitted to be installed prior to the completion and cleanup of all other trade work. If acceptable to the authority having jurisdiction, however, the detectors might be installed while covered with bags or part of their original packaging. However, covering will render the smoke detectors unable to respond to smoke during a fire. The remainder of the system will be operational. Nevertheless, the life safety aspects of the system will have been compromised until the smoke detectors are uncovered.

In an open office area with a 20-ft (6-m) ceiling height, spot-type detectors might be used. However,
once the area is occupied, maneuvering a high ladder for the purpose of testing would be nearly impossible. This illustrates an application where a projected beam smoke detector would be preferred. The sender and receiver could be located on opposite walls where a ladder can be leaned to reach the units for cleaning and testing.

Many other factors affect the selection and placement of fire detectors. Temperature stratifications might prevent smoke from reaching the ceiling; airflow might speed the response of properly located detectors and slow the response of poorly located detectors; the height and width of fire and smoke doors might require additional smoke detectors for door release; machinery vibrations or radio frequency interference might result in the relocation of detectors to avoid false alarms. Complete familiarity with NFPA 72 is the best source of information for installing a reliable system. The reference list following this supplement contains other valuable references to assist designers, installers, inspectors, and owners in achieving reliable fire detection while minimizing the chance of false or nuisance alarms.

**POWER SOURCES AND SYSTEM WIRING METHODS**

**Household Fire Alarm Equipment**

Dwelling units are most often equipped with either single-station or multiple-station smoke alarms. In some cases, small systems designed as household fire alarm equipment, with detectors, a control panel, and some notification appliances, are used. Often, the control panel also serves as part of a security system.

Single-station smoke alarms are stand-alone units that detect smoke and provide occupant notification. Multiple-station units are actually single-station detectors that can be interconnected so that, if one is activated, all units sound an alarm. Most single- and multiple-station smoke alarms contain only an internal horn, although some contain flashing lights as well. Units are also available with internal relays that can be used to control other functions, such as door release, a nurse call signaling system, activation of a bed shaker to alert a hearing-impaired person, or operation of a light outside the dwelling unit.

For existing construction, the detectors may be permitted to be powered by battery or by commercial light and power (usually 120 V AC). Chapter 11 of NFPA 72 requires detectors used in new construction to have both primary AC power and secondary power by a battery. Alternatively, a detector with a non-removable, 10-year battery is permitted. In existing households, AC power is preferred. However, where AC is not practical, NFPA 72 allows the use of a monitored battery as the power source. Within the Life Safety Code, some occupancy chapters require AC power, even in existing facilities, where NFPA 72 would allow battery-operated units.

One reason AC-powered detectors are preferred is that the detector is less likely to be subject to tampering. Battery-powered (only) units are often disabled when the battery is “borrowed” for a toy or other device or removed due to false or nuisance alarms. Also, when batteries die they are often not replaced for some time, leaving part or all of the dwelling unit without smoke detection.

Some argue that battery power is superior because, during a power outage, people resort to candles for light and to fireplaces, stoves, or portable heaters for heat, all of which increase the probability of fire. However, the increased chance of fire may not offset the fact that, over time, loss of commercial power is less likely and shorter in duration than loss of battery power. NFPA 72 reflects the belief that the chance of fire during a power outage is smaller than the chance of fire occurring when a detector is rendered useless because it has no battery.

Single-station smoke alarms are now available with AC power and integral battery backup. These units are allowed, but not required, by both the Life Safety Code and NFPA 72 for existing construction, but they are required by both for new construction. Local codes, ordinances, or authorities can require their use.

NFPA 72, Chapter 11, requires that a switch not control AC power and that the circuit not have a ground fault interrupter — except where a ground fault interrupter serves all electrical circuits in the dwelling. Direct wiring to a power circuit is preferred. However, if a plug-in electrical cord is used, the standard requires some restraining method to make certain the unit is not accidentally unplugged. NFPA 72 permits AC power to come from either a dedicated circuit or an unswitched power or lighting circuit. Some experts prefer that AC-powered detectors be connected to an often-used light circuit, such as one feeding kitchen or hallway lights. Then, if a fault occurs, such as a blown fuse or circuit breaker, it is likely to receive immediate attention. If the detectors were connected to their own dedicated circuit or to one infrequently used, loss of power might go unnoticed until the units were tested. AC-powered units must also have a visual “power on” indicator.
Chapter 11 of NFPA 72 contains requirements for units that use batteries for primary power. Basically, these units must be designed so the battery will last for at least one year of normal use, including weekly testing. Also, they must provide an audible trouble signal when the battery is low, well before the unit fails to operate. The unit must be capable of sounding a trouble condition at least once a minute for seven days and still have enough battery power to operate the alarm sounder for 4 minutes. Because of this requirement, it is very important that only battery types recommended by the manufacturer be used. Additionally, the smoke detectors must visually indicate when the battery has been removed.

Where multiple-station units are used, they most often are connected to the same power circuit and also have a trip wire that interconnects them. When using multiple-station detectors, the manufacturer’s wiring diagrams and instructions should be followed closely. There is a limit on how many units should be interconnected. Some models allow only five or six detectors to be interconnected, while others allow up to thirty in a chain. However, Chapter 11 does not allow more than twelve multiple-station smoke alarms to be interconnected unless the interconnection is monitored for integrity. Detectors from different manufacturers cannot be interconnected. Different models from the same manufacturer might not be compatible for interconnection. Compatibility between different models allows both ionization and photoelectric detectors to be used on the same circuit where each is advantageous and also allows various sensitivities to be used in different areas of the dwelling unit.

The Life Safety Code and Chapter 11 of NFPA 72 both allow the use of component systems, rather than single- or multiple-station units, within a dwelling unit. The system must be listed or approved for use as household fire alarm equipment. NFPA 72 contains requirements, including supervision of detector circuits, for the performance of component systems used within the dwelling unit. The use of wireless radio as the signal transmission medium is permitted, provided each detector has its own transmitter and the unit automatically sends a test signal at least once every 24 hours. The installation of hard wiring for component systems is required to meet Article 760 of NFPA 70, National Electrical Code.®

NFPA 72 allows the use of combination systems, provided the fire detection and alarm portion of the system takes precedence over all other functions. Alarm signals for fire and any other function, such as burglary, must be distinctive.

NFPA 72 Protected Premises and Supervising Station Systems

Power. Systems intended to meet the requirements of NFPA 72 are required to have two power sources — primary power and secondary power. Primary power must come from a reliable source and is usually taken from a commercial light and power source, although NFPA 72 allows other sources to provide primary power such as engine-driven generators. Primary power must come through a dedicated branch circuit. Access to the circuit disconnecting means must be restricted and clearly marked “FIRE ALARM CIRCUIT.”

Secondary power is intended to operate all functions of the system in the event that primary power is lost. Most often, standby batteries provide secondary power. Engine-driven generators are also permitted to be used. All systems must be provided with secondary power capable of operating the system for 24 hours under normal loading conditions. Prior to the 2002 edition of NFPA 72, some systems required 24 hours and others required 60 hours of supervisory power. At the end of the normal supervisory period, each system must have 5 minutes of alarm power available, or if it’s an emergency voice/alarm communication system, 15 minutes of full load power.

NFPA 72 Circuit Classifications. In addition to power supply circuits, three principal types of circuits are used in fire protective signaling systems:

1. Initiating device circuits (IDCs)
2. Signaling line circuits (SLCs)
3. Notification appliance circuits (NACs)

An initiating device circuit (IDC) connects manual and automatic devices to a control panel or system. The main characteristic of an initiating device circuit is that the signal received at the control panel does not identify the device that operated. These circuits are also called initiating zones of the fire detection panel. Because the devices are not readily identified at the panel, the quantity of devices on a circuit and the area served by the circuit should be limited to make identification of the source a bit easier.

In addition, because the control panel cannot recognize the individual devices on the circuit, alarm devices cannot be mixed with supervisory devices — such as valve tamper switches — on the same circuit. Exhibit S2.8 shows one version of incorrect and correct methods for monitoring waterflow and valve tamper switches where using initiating device circuits.

A signaling line circuit (SLC) might connect ini-
Device Compatibility. Initiating devices and notification appliances must be compatible with the con-

\[ \text{Exhibit S2.8 Incorrect and correct wiring of valve tamper switch.} \]
control equipment to which they are connected. Where addressable, multiplex-type equipment is used, there is no doubt that the equipment must be compatible and must be designed specifically to work together. With notification appliances and conventional initiating devices, however, there is more flexibility in choice.

In the case of notification appliances, compatibility is primarily a function of voltage and power consumption. Therefore, designers, suppliers, and installers can match notification appliances from one source with control equipment from another source. However, the increased use of strobe lights and the requirement that they flash in synchronization have made it more difficult to mix and match strobes and panel power supplies. Changes may take place in the 2006 edition of NFPA 72 and in listing organization standards to create categories of strobe and power listings that will require more careful matching by the designer and installer.

For initiating devices, compatibility depends on whether the device requires operating power. Mechanical devices such as manual fire alarm boxes, most heat detectors, and waterflow switches do not require power to operate. When they alarm, they close a set of contacts, as a light switch does, to signal the control panel. There is no compatibility issue because these devices can be mixed and matched among various manufacturers.

If a device does require operating power, as a smoke detector does, compatibility depends on whether its source of operating power comes from the initiating device circuit (often called the detection zone) or from a separate, external power circuit. Where power comes from a circuit other than the one used to signal the control panel, there is no compatibility issue. As in the case of notification appliances, compatibility is then only a function of voltage and power consumption from the external power circuit. When the detector alarms, it closes a set of contacts to signal the control panel via the initiating device circuit in the same way a mechanical pull station does.

However, where a device such as a smoke detector obtains its operating power from the same circuit it uses to signal an alarm, compatibility is very important. These devices are often referred to as two-wire, zone-powered, or circuit-powered detectors. The electrical characteristics of the control panel and the detectors, including supervisory currents and alarm currents, must be matched carefully to ensure proper operation. Detector compatibility is a very complex issue. For more information on this subject, consult manufacturers’ data sheets, NFPA 72, Fire Alarm Signaling Systems, and the approval or test agency’s performance standards.

To check system compatibility, it is necessary to know the specific model of control panel as well as the model and quantity of the initiating device in question. Compatibility should be checked by consulting each manufacturer and the testing or approval agency acceptable to the authority having jurisdiction.

Addressable initiating devices must be compatible with the control equipment. They must speak the same language as control equipment and meet the network response characteristics required by NFPA 72. However, many devices, such as waterflow switches and projected beam smoke detectors will be conventional, contact type devices interfaced to the control unit through compatible monitor modules — also called signaling line circuit interfaces by NFPA 72.

Wiring Methods. Article 760 of NFPA 70, National Electrical Code®, covers the installation of wiring for fire alarm systems operating at 600 V or less. Article 760 allows two types of wiring methods — power-limited and non–power-limited. For a circuit to be designated as power-limited, it must meet certain voltage and power limitations. These are checked by the listing or approval agency. Where a circuit is designated as power-limited, the requirements for the wiring type and installation are less restrictive than if the circuit is non–power-limited.

In addition to defining power-limited and non–power-limited circuits, Article 760 provides detailed requirements for wiring methods. Included are requirements for wire gauges, insulation requirements, minimum requirements for stranded wires, overcurrent protection, circuit identification, and wiring raceways. Also included are restrictions on combining the use of power-limited and non–power-limited circuits and other nonfire circuits in the same raceway or enclosure.

The National Electrical Code should be consulted for details on wiring requirements. Additional discussion of Article 760 is contained in the National Electrical Code Handbook, which provides an explanation of the reasoning and intent behind specific code paragraphs.

**SIGNALING**

The subject of this section is output signaling, as opposed to the type of signaling that occurs between detectors and control equipment discussed in the section on wiring. The principal signaling functions of
a system are off-premises signaling to emergency forces and occupant notification.

Off-premises signaling may be transmitted to a supervising station that is part of a central station system, an auxiliary system, a remote station system, or a proprietary signaling system in accordance with NFPA 72. Where off-premises signaling is required or desirable, Chapter 8 of NFPA 72 should be consulted concerning installation and performance requirements for the system. That chapter contains requirements for the transmitter at the protected premises, the transmission method, and the receiving system. The standards allow only certain signaling methods that have shown themselves to be reliable. NFPA 72 does not recognize telephone tape dialers, for example. Similarly, digital communicators with only one phone line are not permitted, except in household fire alarm systems.

Each occupancy chapter of the Life Safety Code clearly states where occupant notification and/or emergency forces signaling is required. The chapter might also require specific occupant notification systems, such as emergency voice/alarm communication systems in high-rise hotels and dormitories. Each occupancy chapter should be carefully reviewed to determine which initiating devices are required to activate occupant notification signals and off-premises signaling. In most cases, all initiating devices operate as general alarm devices and activate all output functions. However, there are cases where detectors in specific areas of a building might not be required to sound evacuation signals. For example, duct smoke detectors may be permitted, or even required, to sound only a supervisory signal, not an alarm signal.

Where occupant notification is required, it must be distinct and clearly audible in all occupiable spaces. Chapter 7 of NFPA 72 contains criteria for the definition of Audible. The recommended noise level from an alarm system is at least 15 dBA above the 24-hour average ambient level or at least 5 dBA above any peak background noise that lasts 1 minute or more (dBA stands for decibels, A-weighted. This is a way of measuring sound pressure levels and adjusting for the way the human ear hears.) In areas used for sleeping, a minimum of 75 dBA is required by NFPA 72. This is an increase of 5 dB over previous editions, which required a minimum of 70 dBA.

There has been some concern that audible fire alarm signals may be insufficient to awaken some people, including young children. The 75-dBA requirement (and the previous 70 dBA requirement) is based on actual testing of a variety of ages. Drugs or alcohol did not impair the subjects. For some subjects, actual awakening at these levels was achieved in seconds, while others were not awakened for several minutes. It is expected that these levels are sufficient to awaken a very high percentage of the general population. However, if regular occurrence of drug or alcohol impairment, heavy sleepers, or persons not capable of self preservation are anticipated, then other signaling strategies may be warranted, beyond what the code requires.

The use of inexpensive meters (under $40) allows background levels in existing areas to be checked and systems to be installed appropriately. Ambient and fire alarm noise levels should be measured with all intervening doors closed and with common equipment such as air conditioners operating. For new construction, NFPA 72, Annex A, provides examples of ambient noise levels in a variety of occupancies.

Once background levels have been determined, design methods can be used to determine where audible notification appliances should be located. One such procedure is presented and discussed in The SFPE Handbook of Fire Protection Engineering. Calculations are not needed for existing construction. Portable appliances can be tried in a variety of locations before final mounting.

In most new construction, due to minimum insulation requirements and privacy laws, it is not possible to place alarm devices in common hallways and expect them to meet audibility requirements in adjacent spaces. Tests show that, in most cases, an audible device may be loud enough in only one or two immediately adjacent spaces. Therefore, a large number of units would be required in the common halls of occupancies such as apartments or dormitories. Cost estimates often indicate that it is less expensive to put smaller devices in each space, rather than to provide the required number of larger devices in common spaces.

NFPA 72 includes provisions allowing the use of narrow band noise analysis and signaling. By analyzing the frequency content of noise, it is often possible to design more efficient fire alarm signaling systems compared to those designed using dBA measurements. Often, the noise is concentrated in one or more octave bands. By using a signal in a different octave band, the alarm can be heard even though a dBA measurement might not “hear” the signal. For more information, consult the National Fire Alarm Code Handbook or the 19th edition of NFPA’s Fire Protection Handbook.

In addition to audible appliances, the Life Safety Code might require visual appliances for occupant
notification. Chapter 7 of NFPA 72 would then be consulted for the proper selection and placement of visual appliances to meet specific needs.

The signal produced by notification appliances must also convey the following information: FIRE EMERGENCY. This is where the requirement for distinct signals is applied. For instance, in a school, bells should not be used on a fire alarm system if bells are also used to signal class changes and recess. Similarly, in buildings equipped with earthquake warning systems, the fire signal needs to be distinct from an earthquake signal and recognizable by the occupants. NFPA 72 permits more than one signal to be used in a building, such as chimes in patient care areas of a hospital and horns elsewhere. However, both must be distinct and not used for any other purpose.

NFPA 72 has a requirement for a standard audible evacuation signal. The signal, referred to as a temporal coded three signal, can be produced on a variety of appliances such as bells, horns, speakers, and chimes. A coded three signal is recognized internationally as a distress signal. Thus, it would be the pattern of the signal, not the particular sound that would convey the information that there is a fire emergency.

Improvements and cost reductions in emergency voice alarm communication (EVAC) systems have made it economical to provide prerecorded and manual voice announcement systems in many applications. Most codes, including the Life Safety Code, require the use of voice signaling only in high-rise buildings, in large assembly occupancies, and in difficult to evacuate situations. Nevertheless, these systems can be used effectively in a variety of applications. Because the NAC circuits are connected to speakers driven by amplifiers, it is easier than it is with conventional direct current devices and less restrictive to add additional appliances when audibility is an issue. Also, speakers generally have adjustable power taps, permitting minor adjustment in audibility that is not possible with most conventional sounders. Finally, it is well known that a properly implemented voice announcement will result in faster and more complete evacuation of occupants.

Fire alarm systems that only use audible tones and/or flashing strobe lights impart only one bit of information: FIRE ALARM. It has long been recognized that environments having complex egress situations or high hazard potentials require occupant notification systems that provide more than one bit of information. To reduce the response time of the occupants and to effect the desired behavior, the message should contain several key elements. These include:

- Tell them what has happened and where.
- Tell them what they should do.
- Tell them why they should do it.

It is not possible to measure the audibility of a voice signal in the same way as tone signals. In addition, audibility is insufficient to ensure that the message is clear and understood. The intelligibility of the voice signal is measured in a different way that includes audibility, clarity, distortion, reverberation and several other important components. The National Fire Alarm Code Handbook includes a supplement describing voice intelligibility.

In a large space used for public meetings, conventions and trade shows, an EVAC system needs to be reliably intelligible, because it is intended to give information to a general public not familiar with the space. In large public spaces, occupants should not have to move any great distance to find a place where they can understand the message.

In a high-rise apartment building, it may not be necessary for the EVAC system to be intelligible in all parts of the apartment, even though it must be audible in all parts. It may be sufficient to provide a speaker in a common space to produce an adequate audible tone to awaken and alert the occupants. When the voice message follows, it may not be intelligible behind closed bedroom and bathroom doors. The occupants, in a familiar space, can move to a location where a repeating message can be intelligibly heard. The same signaling plan may work for office complexes — a person may have to open their office door to reliably understand the message.

While an EVAC system is the most common method of communicating information to occupants, it is not the only method. Research has shown that text and graphical messaging greatly enhance occupant movement during evacuation and relocation. The message delivery can be via large screens used in sports arenas or by small LCD display or CRT information kiosks located throughout a property.

Other types of output signaling that a fire alarm system might be required to provide include the following:

1. Fan and damper control
2. Heating, ventilating, and air-conditioning systems
3. Smoke control systems
4. Elevator control systems
5. Emergency lighting systems
6. Process control systems
SYSTEM INSPECTION, TESTING, AND MAINTENANCE

Surveys and general field experience demonstrate the importance of continued testing and maintenance of fire detection and signaling systems. Inspections are used to find changes in the building or environment that might affect a system. Testing identifies problems before they impair a system’s ability to perform during an emergency. Maintenance reduces false and nuisance alarms and keeps systems in service.

The Life Safety Code requires all fire detection and signaling equipment to be maintained and tested in accordance with the appropriate signaling standard. In the case of household fire alarm equipment, Chapter 11 of NFPA 72 is the governing standard. For other systems, Chapter 10 of NFPA 72 contains requirements for acceptance and periodic tests, visual inspections, and maintenance. Chapter 10 contains three important tables. The first lists the required frequency for visual inspections. The second table lists the methods for testing specific components, devices, and appliances. The third table lists the required frequency for actual testing of the specific components, devices, and appliances.

Whenever a system or device is to be tested, it is important to notify those who might hear or receive a signal from the system. Usually this means several days of advance notice to authorities and regular occupants of the area. In addition, when systems will be tested or worked on, the authority having jurisdiction must be notified, even for periodic tests that they might not witness. Other trades or specialists might require notice to participate in the tests. For instance, testing of smoke detectors used for elevator recall might require elevator technicians to be present, or HVAC mechanics or electricians may be required to reset air-moving equipment or dampers after the system has been tested. In addition, posting notices at entrances to the premises to alert people as they arrive is usually advisable. Notices should include phone numbers or brief procedures for reporting emergencies while the system is being tested or serviced.

The fire protection industry thinks of fire alarm testing as a positive thing, designed to uncover faults and increase reliability. However, a large segment of the public thinks of fire alarm testing negatively, as a nuisance and an interruption of their lives and work. Often, the public’s perception of testing is no different from that of false or nuisance alarms. This leads to the Cry Wolf Syndrome. If long, drawn out testing of alarm systems several times each year ensures an operable system but causes occupants to delay egress or even stay when the desired action is for them to leave, the actual increase in safety must be questioned.

When testing occupant notification systems, it is important to keep to a posted schedule and minimize the time of testing to prevent occupants from becoming desensitized to the signaling. This requires having sufficient personnel and equipment to do a thorough and fast test. Test programs should be designed to be thorough, but to minimize their impact on uninvolved occupants. The tester should consider recruiting key occupants to assist in qualitative examination of the notification system. Also, combining the audible and visible appliance testing with a fire drill for all occupants minimizes the effect of Cry Wolf Syndrome. The tester should also try to minimize the frequency and duration of the tests. For example, test only at 10:00 A.M. and again at 2:00 P.M. and for only 30 to 60 seconds.

Household Fire Alarm Equipment

The requirements for testing and maintenance of household fire alarm equipment are kept simple so that in most cases the homeowner can do the work. NFPA 72 requires that battery-operated units get new batteries in accordance with the manufacturers’ recommendations. In most cases, manufacturers recommend replacement of batteries at least once a year. Recent educational and awareness programs have promoted battery changing at the same time that clocks are changed from daylight savings time to standard time in the fall of each year. Scheduled battery replacement, rather than waiting for the signal that indicates the need for replacement, tends to increase confidence that the detector will work when needed. Facilities with large numbers of battery-operated detectors save time and labor by replacing all batteries at the same time, whether or not it is indicated.

NFPA 72 requires monthly testing of household fire alarm equipment. Where small systems with detectors and control panels are used in lieu of single- or multiple-station smoke alarms, NFPA 72 requires the owner to have the system tested by qualified technicians at least every 3 years.

All tests, inspections, and maintenance recommended by the manufacturer must be performed in accordance with its instructions. This emphasizes the importance of providing the owner, member of the household, or occupant with the manufacturer’s instruction booklet(s). Without the proper documentation, the individuals performing the test may not be aware of their responsibilities or the correct methods...
for testing and maintenance. NFPA 72 requires the installer or supplier to provide this and other information to the owner. In addition to the instructions, the owner must receive information on how to establish an evacuation plan and information on detector parts that require regular replacement, such as batteries. The owner must also receive written information on where to obtain repair and replacement service. It is important that users of household fire alarm equipment understand that the code-required minimum may give them only seconds to react and get out. In situations where a person might be impaired due to alcohol or drugs, or where elderly persons, young children or mobility-impaired persons need evacuation assistance, the warning given by code-required minimum coverage may be insufficient.

Each smoke detector for use in any application detailed in NFPA 72, Chapter 11 is required to have an integral test method. An aerosol, such as canned smoke, should be used to verify that the smoke detector is not blocked by excessive dust accumulation or by intentional blocking of the screen or ports. It is often impossible to tell by visual inspection alone if a detector has been blocked.

Cleaning of smoke detectors is necessary to prevent false and nuisance alarms and to ensure detector operation during a fire. NFPA 72 leaves the methods and frequency of cleaning up to each manufacturer. Most manufacturers recommend cleaning once or twice a year by vacuuming around the outside of the detector. Some detectors are now available that can be washed in a soap and water solution. Most manufacturers do not recommend disassembly of detectors for cleaning except by qualified technicians. If the detector is cleaned and properly maintained from the time it is new, the need for factory cleaning and calibration is almost eliminated.

Acceptance Testing

NFPA 72 requires 100 percent testing of the entire system upon completion of any installation or alteration. The test must include all devices and equipment and must test the system in all modes, including alarm, trouble, and supervisory. Satisfactory tests must be made in the presence of the authority having jurisdiction or a designated representative. NFPA 72 recognizes reacceptance tests on parts of systems affected by alterations or repairs.

A preliminary certificate of completion is required to be issued to the owner and, if requested, to the authority having jurisdiction prior to the final acceptance test. The preliminary certificate is issued after installation and wiring tests have been completed. A final version is to be issued and distributed after all operational acceptance tests have been completed. A sample copy of a certificate of completion is included in NFPA 72.

Following final acceptance of the system, the installer or supplier must provide the owner with an owner’s manual or manufacturer’s installation instruction, as well as final “as-built” drawings. During acceptance or reacceptance testing, the certificate of completion and as-built drawings must be verified for accuracy and completeness. If necessary, corrections should be made to the master documents, and any old copies should be replaced or updated.

Installation testing includes checking the entire system for stray voltages, ground faults, short circuits, and open circuits. Ground fault testing includes testing all conductors not intentionally connected to ground.

The loop resistance of initiating and notification appliance circuits must be measured and recorded. The measured value should be checked against the maximum allowable loop resistance indicated by the manufacturer of the control equipment. Signaling line circuits should also be tested in accordance with the manufacturer’s recommendations. This usually includes measurement of circuit capacitance as well as resistance.

System testing is done after all installation tests have been performed. After replacing any equipment removed during testing of the circuits, the control unit and all devices should be verified as being in the normal supervisory mode. Each circuit should be checked for proper supervision and integrity. This includes testing open circuit trouble indication as well as ground fault and short circuit fault indicators where provided. Where the style of circuit allows alarm receipt during specific faults, correct operation should be checked by testing devices electrically before and after the location of the test fault. It is useful during the testing to use a copy of the wiring style tables from NFPA 72 as a checklist.

Every initiating device and indicating appliance must be checked for correct alarm operation. This verifies correct operation of the device, the circuit, and the control equipment. For systems that respond differently and result in different outputs depending on the device or devices in alarm, a programming matrix should be prepared and checked. The matrix, or system description, should explain what occurs when each particular device or group of devices is operated. For instance, an alarm from any first floor detector might cause bells to ring, doors to release, and a connection to the fire department to be ac-
NFPA 72 requires acceptance testing records to be retained for 2 years. All equipment should be tested in accordance with the requirements of NFPA 72 and the manufacturers’ recommendations.

Periodic Testing

In addition to provisions for acceptance testing, NFPA 72 contains requirements for periodic tests and maintenance. Essentially, NFPA 72 requires all testing to be performed by qualified persons who understand the equipment. Ultimately, the owner of the system is responsible for ensuring that all required tests are done on time. Owners are permitted to rely on a written maintenance agreement with others, rather than use their own specialists. Delegation of responsibility for testing and maintenance must be in writing.

The required frequency for testing a device varies. Chapter 10 of NFPA 72 contains the required frequencies for all devices.

NFPA 72 requires the sensitivity of all smoke detectors to be checked within 1 year of the acceptance test, and every other year thereafter. During the years when sensitivity tests are not required, a pass/fail test using smoke or another unmeasured aerosol is still required. The intent of the sensitivity test is to ensure that the detector is within its listed and marked sensitivity range. Detectors that are more

Exhibit S2.9 Partial system input/output matrix.

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**System Outputs**

Occupant Notification & Information

| Floor | Device/Input | Qty | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
| 22    | Bsmmt smoke/heat detection | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 28    | G smoke/heat detection | 8  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 29    | 1st smoke/heat detection | 8  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 30    | 2nd smoke/heat detection | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 31    | 3rd smoke/heat detection | 4  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 32    | 4th smoke/heat detection | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 33    | 5th smoke/heat detection | 5  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 34    | M Level smoke/heat detection | 12 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 35    | 6th Connector smoke/heat detection | 2  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 36    | 7th Connector smoke/heat detection | 3  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 37    | S Level smoke/heat detection | 9  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 38    | Conn. Elev. Pent. smoke/heat detection | 0  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 39    | 6th smoke/heat detection | 9  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 40    | 7th smoke/heat detection | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 41    | 8th smoke/heat detection | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 42    | 9th smoke/heat detection | 4  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 43    | 10th smoke/heat detection | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 44    | 11th smoke/heat detection | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 45    | 12th smoke/heat detection | 7  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 46    | Penthouse 1 N smoke/heat detection | 0  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 47    | Penthouse 1 S smoke/heat detection | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Exhibit S2.9** Partial system input/output matrix.
The Mass Notification System (MNS) is a new category of communication and emergency management system addressed by NFPA 72. An MNS is used to provide information and instructions to people in a building, area, site, or other space using intelligible voice communications and possibly visible signals, text, graphics, tactile, or other communications methods.

In a broad context, an MNS is a communication and emergency management tool. In its simplest form, it may be used to manually alert or notify some or all occupants of a space that an emergency exists. Many fire alarm systems fit this description — they provide alerting but no additional information, and are intended to be used only for fire warning, leaving the recipient to take actions they deem appropriate or for which they have been trained or “programmed.” However, the title and definition of mass notification systems are meant to encompass greater possibilities for communication, information dissemination, and personnel management.

Depending on the situational needs, an MNS may be a simple alarm system, or it may be a highly secure command and control system suitable for use in a variety of situations including biological, poisonous gas, and nuclear terror threats; bombings; anti-personnel attacks; etc. Also, the system may be one-way or two-way. That is, it may be used only to give information to the target audience or area, or it may be designed to also receive and transmit information to a command center in the form of real-time sensor data or text, voice, or video communications from the scene.

Though not directly required by any current Life Safety Code requirements, mass notification systems may be used in many types of occupancies. It is expected that the inclusion of them as a category of system in NFPA 72 will result in their more widespread use in the future.

CONCLUSION

Fire alarm systems range from very simple units to large complex systems. This supplement has only briefly introduced the reader to the many requirements and good practices associated with their design, installation, testing, and use.

One of the most common failures associated with fire detection and alarm systems is the failure to provide fire protection. A fire detection and alarm system is not a fire protection system unless it does something to affect the fire, the property, or the people. For example, a complete fire detection system with smoke detectors and heat detectors in every room and space does little good if the system sounds a local alarm in the middle of the night when the building is not occupied and does not automatically communicate to the fire department, or if it does summon the fire department but the fire is too large for the arriving fire fighters to safely attack. Perhaps this system is protecting an historic library in a community with a part-paid fire company whose nearest apparatus is 5 miles distant — uphill. These examples illustrate a failure to engineer. The Life Safety Code and the National Fire Alarm Code address common occupancy and hazard conditions. Many requirements for fire detection and alarm are “pre-engineered” solutions.
for the expected conditions. However, where performance-based solutions are used, or in situations where owners have goals that go beyond simple code compliance, the designer may need to provide more than what the code requires.

The Life Safety Code and the National Fire Alarm Code contain a wealth of information for persons involved with any phase of a fire alarm system’s life. By drawing on the expertise of hundreds of professionals and specialists, users of these NFPA documents benefit from years of combined experience, which no single person or company could hope to attain.

REFERENCES

For additional information concerning the design, installation, testing, maintenance, and use of fire alarm systems, consult these references


NFPA 70, National Electrical Code®, 2005 edition, National Fire Protection Association, Quincy, MA.


In addition to the preceding publications listed and state and local authorities, the following organizations are sources for information on fire detection and signaling systems:

Automatic Fire Alarm Association, P.O. Box 951807, Lake Mary, FL 32795-1807. http://www.afaa.org

FM Global, 1301 Atwood Avenue, P.O. Box 7500, Johnston, RI 02919. http://www.fmglobal.com

National Fire Protection Association, 1 Battery March Park, Quincy, MA 02169-7471. http://www.nfpa.org


Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096. http://www.ul.com