

NFPA 72 National Fire Alarm Code[®]

1999 Edition



National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 72

National Fire Alarm Code®

1999 Edition

This edition of NFPA 72, *National Fire Alarm Code*®, was prepared by the Technical Committee on Fundamentals of Fire Alarm Systems, Household Fire Warning Equipment, Initiating Devices for Fire Alarm Systems, Notification Appliances for Fire Alarm Systems, Protected Premises Fire Alarm Systems, Public Fire Reporting Systems, Supervising Station Fire Alarm Systems, and Testing and Maintenance of Fire Alarm Systems; released by the Technical Correlating Committee on the National Fire Alarm Code; and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

This edition of NFPA 72 was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 72

NFPA's signaling standards date back to 1898. The 1993 edition of NFPA 72 was a consolidation of the 1989 edition of NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*; the 1990 edition of NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*; the 1990 edition of NFPA 72E, *Standard on Automatic Fire Detectors*; the 1989 edition of NFPA 72G, *Guide for the Installation, Maintenance, and Use of Notification Appliances for Protective Signaling Systems*; the 1988 edition of NFPA 72H, *Guide for Testing Procedures for Local, Auxiliary, Remote Station, and Proprietary Protective Signaling Systems*; and the 1989 edition of NFPA 74, *Standard for the Installation, Maintenance, and Use of Household Fire Warning Equipment*. Many of the requirements of these standards were identical or very similar. The recommendations that were taken from the guides (NFPA 72G and NFPA 72H) were changed to mandatory requirements.

The 1996 edition of NFPA 72 incorporated many changes of a technical nature. These changes related to issues such as the Americans with Disabilities Act, software testing, fire modeling, and communications.

The 1999 edition represents a major change in code content and organization. Vertical rules are not shown because of the extensive nature of the revisions. The chapters have been arranged to facilitate user friendliness and provide a logical structure. A new chapter on public fire reporting was added, and many technical revisions were made. Appendix B was streamlined to facilitate ease of use, many unenforceable terms were removed, and Chapter 3 was reorganized to facilitate a more logical approach.

Prior editions of this document have been translated into languages other than English, including Spanish.

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(Alt. to J. R. Gressel)
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(Alt. to D. G. Decker)
Manuelita E. David, Schirmer Engr Corp., CA [SE]
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Committee Scope: This Committee shall have primary responsibility for documents on common system fundamentals for signaling systems, including definitions, requirements for approvals, installation, service, power supplies, equipment locations, compatibility, and system interfaces.

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Rep. Automatic Fire Alarm Assn., Inc.

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(Chapter 2 and Appendix B)

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John E. Sleights, Factory Mutual Research Corp., MA [I]

Timothy M. Soverino, Nantucket Fire Dept., MA [U]

Rep. Int'l Municipal Signal Assn.

Jack H. Turner, Potter Electric Signal Co., MO [M]

Lawrence J. Wenzel, HSB Industrial Risk Insurers, CT [I]

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Ron Baugh, Sentrol, Inc., OR [M]

(Alt. to R. K. Mengel)

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(Alt. to W. P. Michna)

Jerry Cordasco, Siemens Cerberus Pyrotronics, NJ [M]

(Alt. to I. Ellner)

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(Vot. Alt.)

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(Alt. to O. E. Morphew)

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(Vot. Alt. to HSB Rep.)

J. Jeffrey Moore, HSB Industrial Risk Insurers, OH [I]

(Alt. to L. J. Wenzel)

John L. Parssinen, Underwriters Laboratories Inc., IL [RT]

(Alt. to P. E. Patty)

David L. Royse, Potter Electric Signal Co., MO [M]

(Alt. to J. H. Turner)

Walter F. Schuchard, Hingham, MA [SE]

(Alt. to J. B. Semple)

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Committee Scope: This Committee shall have primary responsibility for documents on the installation and operation of initiating devices for signaling systems, including automatic fire detection devices, sprinkler waterflow detectors, manually activated fire alarm stations, supervisory signaling initiating devices, and guard's tour stations.

Technical Committee on Notification Appliances for Fire Alarm Systems (NFA-NAS)

(Chapter 4)

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Ferdinand DeVoss, Underwriters Laboratories Inc., IL [RT]

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(Alt. to F. DeVoss)

Edward Thorp, System Sensor Division, IL [M]

(Alt. to R. Haus)

Scott Vandame, Schirmer Engr, Corp., VA [SE]

(Alt. to T. Carrie)

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(Chapter 3)

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Rep. California Automatic Fire Alarm Assn. Inc.

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Robert W. Elliott, Factory Mutual Research Corp., MA [I]

Kenneth L. Gentile, Code Consultants Inc., MO [SE]

Vic Humm, Vic Humm & Assoc., TN [SE]

Dennis P. Jenkins, Kemper Nat'l Insurance Cos., NC [I]

Larry Jesclard, Engineered Fire Systems, Inc., AK [M]

Rep. Fire Suppression Systems Assn.

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Jim R. Kern, HSB Professional Loss Control, TN [I]

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(Alt. to P. R. Barrett)

Paul M. Carroll, Central Signal Corp./Sentinel Alarm Co., MA [M]

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of this document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the proper configuration, performance, installation, and operation of public fire alarm reporting systems. The Committee scope shall be limited to systems that use parallel telephone, series telephone, coded, or code-voice networks which utilize wire and/or radio frequency (RF) technologies, to provide any combination of manual or auxiliary fire alarm service.

Reporting of alarms by voice over the public switched telephone network utilizing the Universal Emergency Number 911, or any other telephone number that can be dialed, is outside the scope of this Committee.

Technical Committee on Supervising Station Fire Alarm Systems (NFA-SSS)

(Chapter 5)

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the installation and operation of off-premises signaling systems, including the signal-receiving facility and the communications between the protected premises and the off-premises signal-receiving facility.

Technical Committee on Testing and Maintenance of Fire Alarm Systems (NFA-TMS)

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the proper testing and maintenance of signaling systems, their components, and the interface equipment.

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NFPA 72

National Fire Alarm Code®

1999 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

A reference in parentheses () at the end of a section or paragraph indicates that the material has been extracted from another NFPA document. The bold number in parentheses indicates the document number and is followed by the section number where the extracted material can be found in that document. The complete title and current edition of an extracted document can be found in the chapter on referenced publications.

Information on referenced publications can be found in Chapter 9 and Appendix C.

Chapter 1 Fundamentals of Fire Alarm Systems

1-1 Scope. NFPA 72 covers the application, installation, location, performance, and maintenance of fire alarm systems and their components.

1-2 Purpose.

1-2.1* The purpose of this code is to define the means of signal initiation, transmission, notification, and annunciation; the levels of performance; and the reliability of the various types of fire alarm systems. This code defines the features associated with these systems and also provides the information necessary to modify or upgrade an existing system to meet the requirements of a particular system classification. It is the intent of this code to establish the required levels of performance, extent of redundancy, and quality of installation but not to establish the methods by which these requirements are to be achieved.

1-2.2 Any reference or implied reference to a particular type of hardware is for the purpose of clarity and shall not be interpreted as an endorsement.

1-2.3 Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document.

Exception: Those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property.

1-3 General.

1-3.1 This code classifies fire alarm systems as follows:

- (1) Household fire warning systems
- (2) Protected premises fire alarm systems
- (3) Supervising station fire alarm systems
 - a. Auxiliary fire alarm systems
 1. Local energy type
 2. Parallel telephone type
 3. Shunt type
 - b. Remote supervising station fire alarm systems

- c. Proprietary supervising station systems
- d. Central station fire alarm systems
- e. Municipal fire alarm systems

1-3.2 A device or system having materials or forms that differ from those detailed in this code shall be permitted to be examined and tested according to the intent of the code and, if found equivalent, shall be approved.

1-3.3 The intent and meaning of the terms used in this code are, unless otherwise defined herein, the same as those of NFPA 70, *National Electrical Code*®.

1-4 Definitions. For the purposes of this code, the following terms are defined as follows.

Acknowledge. To confirm that a message or signal has been received, such as by the pressing of a button or the selection of a software command.

Active Multiplex System. A multiplexing system in which signaling devices such as transponders are employed to transmit status signals of each initiating device or initiating device circuit within a prescribed time interval so that the lack of receipt of such a signal can be interpreted as a trouble signal.

Addressable Device. A fire alarm system component with discrete identification that can have its status individually identified or that is used to individually control other functions.

Adverse Condition. Any condition occurring in a communications or transmission channel that interferes with the proper transmission or interpretation, or both, of status change signals at the supervising station. (*Refer to Trouble Signal.*)

Air Sampling-Type Detector. A detector that consists of a piping or tubing distribution network that runs from the detector to the area(s) to be protected. An aspiration fan in the detector housing draws air from the protected area back to the detector through air sampling ports, piping, or tubing. At the detector, the air is analyzed for fire products.

Alarm. A warning of fire danger.

Alarm Service. The service required following the receipt of an alarm signal.

Alarm Signal. A signal indicating an emergency that requires immediate action, such as a signal indicative of fire.

Alarm Verification Feature. A feature of automatic fire detection and alarm systems to reduce unwanted alarms wherein smoke detectors report alarm conditions for a minimum period of time, or confirm alarm conditions within a given time period after being reset, in order to be accepted as a valid alarm initiation signal.

Alert Tone. An attention-getting signal to alert occupants of the pending transmission of a voice message.

Analogue Initiating Device (Sensor). An initiating device that transmits a signal indicating varying degrees of condition as contrasted with a conventional initiating device, which can only indicate an on-off condition.

Annunciator. A unit containing one or more indicator lamps, alphanumeric displays, or other equivalent means in which each indication provides status information about a circuit, condition, or location.

Approved.* Acceptable to the authority having jurisdiction.

Audible Notification Appliance. A notification appliance that alerts by the sense of hearing.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

Automatic Extinguishing System Supervisory Device. A device that responds to abnormal conditions that could affect the proper operation of an automatic sprinkler system or other fire extinguishing system(s) or suppression system(s), including, but not limited to, control valves; pressure levels; liquid agent levels and temperatures; pump power and running; engine temperature and overspeed; and room temperature.

Automatic Fire Detector. A device designed to detect the presence of a fire signature and to initiate action. For the purpose of this code, automatic fire detectors are classified as follows: Automatic Fire Extinguishing or Suppression System Operation Detector, Fire-Gas Detector, Heat Detector, Other Fire Detectors, Radiant Energy-Sensing Fire Detector, Smoke Detector.

Automatic Fire Extinguishing or Suppression System Operation Detector. A device that automatically detects the operation of a fire extinguishing or suppression system by means appropriate to the system employed.

Auxiliary Box. A fire alarm box that can be operated from one or more remote actuating devices.

Auxiliary Fire Alarm System. A system connected to a municipal fire alarm system for transmitting an alarm of fire to the public fire service communications center. Fire alarms from an auxiliary fire alarm system are received at the public fire service communications center on the same equipment and by the same methods as alarms transmitted manually from municipal fire alarm boxes located on streets.

Auxiliary Fire Alarm System, Local Energy Type. An auxiliary system that employs a locally complete arrangement of parts, initiating devices, relays, power supply, and associated components to automatically trip a municipal transmitter or master box over electrical circuits that are electrically isolated from the municipal system circuits.

Auxiliary Fire Alarm System, Parallel Telephone Type. An auxiliary system connected by a municipally controlled individual circuit to the protected property to interconnect the initiating devices at the protected premises and the municipal fire alarm switchboard.

Auxiliary Fire Alarm System, Shunt Auxiliary Type. An auxiliary system electrically connected to an integral part of the municipal alarm system extending the municipal circuit into the protected premises to interconnect the initiating devices, which, when operated, open the municipal circuit shunted around the trip coil of the municipal transmitter or master box. The municipal transmitter or master box is thereupon energized to start transmission without any assistance from a local source of power.

Average Ambient Sound Level. The root mean square, A-weighted, sound pressure level measured over a 24-hour period.

Box Battery. The battery supplying power for an individual fire alarm box where radio signals are used for the transmission of box alarms.

Carrier. High-frequency energy that can be modulated by voice or signaling impulses.

Carrier System. A means of conveying a number of channels over a single path by modulating each channel on a different carrier frequency and demodulating at the receiving point to restore the signals to their original form.

Ceiling. The upper surface of a space, regardless of height. Areas with a suspended ceiling have two ceilings, one visible from the floor and one above the suspended ceiling.

Ceiling Height. The height from the continuous floor of a room to the continuous ceiling of a room or space.

Ceiling Surfaces, Beam Construction. Ceilings that have solid structural or solid nonstructural members projecting down from the ceiling surface more than 4 in. (100 mm) and spaced more than 3 ft (0.9 m), center to center.

Ceiling Surfaces, Girder. A support for beams or joists that runs at right angles to the beams or joists. If the top of the girder is within 4 in. (100 mm) of the ceiling, the girder is a factor in determining the number of detectors and is to be considered a beam. If the top of the girder is more than 4 in. (100 mm) from the ceiling, the girder is not a factor in detector location.

Ceiling Surfaces, Solid Joist Construction. Ceilings that have solid structural or solid nonstructural members projecting down from the ceiling surface for a distance of more than 4 in. (100 mm) and spaced at intervals of 3 ft (0.9 m) or less, center to center.

Central Station. A supervising station that is listed for central station service.

Central Station Fire Alarm System. A system or group of systems in which the operations of circuits and devices are transmitted automatically to, recorded in, maintained by, and supervised from a listed central station that has competent and experienced servers and operators who, upon receipt of a signal, take such action as required by this code. Such service is to be controlled and operated by a person, firm, or corporation whose business is the furnishing, maintaining, or monitoring of supervised fire alarm systems.

Central Station Service. The use of a system or a group of systems in which the operations of circuits and devices at a protected property are signaled to, recorded in, and supervised from a listed central station that has competent and experienced operators who, upon receipt of a signal, take such action as required by this code. Related activities at the protected property, such as equipment installation, inspection, testing, maintenance, and runner service, are the responsibility of the central station or a listed fire alarm service-local company. Central station service is controlled and operated by a person, firm, or corporation whose business is the furnishing of such contracted services or whose properties are the protected premises.

Certification. A systematic program that uses randomly selected follow-up inspections of the certified systems installed under the program that allows the listing organization to verify that a fire alarm system complies with all the requirements of this code. A system installed under such a program is identified by the issuance of a certificate and is designated as a certificated system.

Certification of Personnel.* A formal program of related instruction and testing as provided by a recognized organization or the authority having jurisdiction.

Channel. A path for voice or signal transmission that uses modulation of light or alternating current within a frequency band.

Circuit Interface. A circuit component that interfaces initiating devices or control circuits, or both; notification appli-

ances or circuits, or both; system control outputs; and other signaling line circuits to a signaling line circuit.

Cloud Chamber Smoke Detection. The principle of using an air sample drawn from the protected area into a high-humidity chamber combined with a lowering of chamber pressure to create an environment in which the resultant moisture in the air condenses on any smoke particles present, forming a cloud. The cloud density is measured by a photoelectric principle. The density signal is processed and used to convey an alarm condition when it meets preset criteria.

Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

Coded. An audible or visible signal that conveys several discrete bits or units of information. Notification signal examples are numbered strokes of an impact-type appliance and numbered flashes of a visible appliance.

Combination Detector. A device that either responds to more than one of the fire phenomenon or employs more than one operating principle to sense one of these phenomenon. Typical examples are a combination of a heat detector with a smoke detector or a combination rate-of-rise and fixed-temperature heat detector.

Combination Fire Alarm and Guard's Tour Box. A manually operated box for separately transmitting a fire alarm signal and a distinctive guard patrol tour supervisory signal.

Combination System.* A fire alarm system in which components are used, in whole or in part, in common with a non-fire signaling system.

Communications Channel. A circuit or path connecting a subsidiary station(s) to a supervising station(s) over which signals are carried.

Compatibility Listed. A specific listing process that applies only to two-wire devices, such as smoke detectors, that are designed to operate with certain control equipment.

Compatible Equipment. Equipment that interfaces mechanically or electrically as manufactured without field modification.

Contiguous Property. A single-owner or single-user protected premises on a continuous plot of ground, including any buildings thereon, that is not separated by a public thoroughfare, transportation right-of-way, property owned or used by others, or body of water not under the same ownership.

Control Unit. A system component that monitors inputs and controls outputs through various types of circuits.

Delinquency Signal. A signal indicating the need for action in connection with the supervision of guards or system attendants.

Derived Channel. A signaling line circuit that uses the local leg of the public switched network as an active multiplex channel while simultaneously allowing that leg's use for normal telephone communications.

Detector. A device suitable for connection to a circuit that has a sensor that responds to a physical stimulus such as heat or smoke.

Digital Alarm Communicator Receiver (DACR). A system component that accepts and displays signals from digital alarm communicator transmitters (DACTs) sent over the public switched telephone network.

Digital Alarm Communicator System (DACS). A system in which signals are transmitted from a digital alarm communicator transmitter (DACT) located at the protected premises through the public switched telephone network to a digital alarm communicator receiver (DACR).

Digital Alarm Communicator Transmitter (DACT). A system component at the protected premises to which initiating devices or groups of devices are connected. The DACT seizes the connected telephone line, dials a preselected number to connect to a DACR, and transmits signals indicating a status change of the initiating device.

Digital Alarm Radio Receiver (DARR). A system component composed of two subcomponents: one that receives and decodes radio signals, the other that annunciates the decoded data. These two subcomponents can be coresident at the central station or separated by means of a data transmission channel.

Digital Alarm Radio System (DARS). A system in which signals are transmitted from a digital alarm radio transmitter (DART) located at a protected premises through a radio channel to a digital alarm radio receiver (DARR).

Digital Alarm Radio Transmitter (DART). A system component that is connected to or an integral part of a digital alarm communicator transmitter (DACT) that is used to provide an alternate radio transmission channel.

Display. The visual representation of output data, other than printed copy.

Double Doorway.* A single opening that has no intervening wall space or door trim separating the two doors.

Double Dwelling Unit. A building consisting solely of two dwelling units. (*See Dwelling Unit.*)

Dual Control. The use of two primary trunk facilities over separate routes or different methods to control one communications channel.

Dwelling Unit. One or more rooms for the permanent use of one or more persons as a space for eating, living, and sleeping, with permanent provisions for cooking and sanitation. For the purposes of this code, *dwelling unit* includes one- and two-family attached and detached dwellings, apartments, and condominiums but does not include hotel and motel rooms and guest suites, dormitories, or sleeping rooms in nursing homes.

Electrical Conductivity Heat Detector. A line-type or spot-type sensing element in which resistance varies as a function of temperature.

Ember.* A particle of solid material that emits radiant energy due either to its temperature or the process of combustion on its surface. (*Refer to Spark.*)

Emergency Voice/Alarm Communications. Dedicated manual or automatic facilities for originating and distributing voice instructions, as well as alert and evacuation signals pertaining to a fire emergency, to the occupants of a building.

Evacuation.* The withdrawal of occupants from a building.

Evacuation Signal. Distinctive signal intended to be recognized by the occupants as requiring evacuation of the building.

Exit Plan. A plan for the emergency evacuation of the premises.

Field of View. The solid cone that extends out from the detector within which the effective sensitivity of the detector is at least 50 percent of its on-axis, listed, or approved sensitivity.

Fire Alarm Control Unit (Panel). A system component that receives inputs from automatic and manual fire alarm devices and might supply power to detection devices and to a transponder(s) or off-premises transmitter(s). The control unit might also provide transfer of power to the notification appliances and transfer of condition to relays or devices connected to the control unit. The fire alarm control unit can be a local fire alarm control unit or a master control unit.

Fire Alarm/Evacuation Signal Tone Generator. A device that produces a fire alarm/evacuation tone upon command.

Fire Alarm Signal. A signal initiated by a fire alarm-initiating device such as a manual fire alarm box, automatic fire detector, waterflow switch, or other device in which activation is indicative of the presence of a fire or fire signature.

Fire Alarm System. A system or portion of a combination system that consists of components and circuits arranged to monitor and annunciate the status of fire alarm or supervisory signal-initiating devices and to initiate the appropriate response to those signals.

Fire Command Center. The principal attended or unattended location where the status of the detection, alarm communications, and control systems is displayed and from which the system(s) can be manually controlled.

Fire-Gas Detector. A device that detects gases produced by a fire.

Fire Rating. The classification indicating in time (hours) the ability of a structure or component to withstand a standardized fire test. This classification does not necessarily reflect performance of rated components in an actual fire.

Fire Safety Function Control Device. The fire alarm system component that directly interfaces with the control system that controls the fire safety function.

Fire Safety Functions. Building and fire control functions that are intended to increase the level of life safety for occupants or to control the spread of the harmful effects of fire.

Fire Warden. A building staff member or a tenant trained to perform assigned duties in the event of a fire emergency.

Fixed-Temperature Detector.* A device that responds when its operating element becomes heated to a predetermined level.

Flame. A body or stream of gaseous material involved in the combustion process and emitting radiant energy at specific wavelength bands determined by the combustion chemistry of the fuel. In most cases, some portion of the emitted radiant energy is visible to the human eye.

Flame Detector.* A radiant energy-sensing fire detector that detects the radiant energy emitted by a flame. (*Refer to A-2-4.2.*)

Flame Detector Sensitivity. The distance along the optical axis of the detector at which the detector can detect a fire of specified size and fuel within a given time frame.

Gateway. A device that is used in the transmission of serial data (digital or analog) from the fire alarm control unit to other building system control units, equipment, or networks

and/or from other building system control units to the fire alarm control unit.

Guard's Tour Reporting Station. A device that is manually or automatically initiated to indicate the route being followed and the timing of a guard's tour.

Guard's Tour Supervisory Signal. A supervisory signal monitoring the performance of guard patrols.

Heat Alarm. A single or multiple station alarm responsive to heat.

Heat Detector. A fire detector that detects either abnormally high temperature or rate of temperature rise, or both.

Household Fire Alarm System. A system of devices that produces an alarm signal in the household for the purpose of notifying the occupants of the presence of a fire so that they will evacuate the premises.

Hunt Group. A group of associated telephone lines within which an incoming call is automatically routed to an idle (not busy) telephone line for completion.

Initiating Device. A system component that originates transmission of a change-of-state condition, such as in a smoke detector, manual fire alarm box, or supervisory switch.

Initiating Device Circuit. A circuit to which automatic or manual initiating devices are connected where the signal received does not identify the individual device operated.

Intermediate Fire Alarm or Fire Supervisory Control Unit. A control unit used to provide area fire alarm or area fire supervisory service that, where connected to the proprietary fire alarm system, becomes a part of that system.

Ionization Smoke Detection.* The principle of using a small amount of radioactive material to ionize the air between two differentially charged electrodes to sense the presence of smoke particles. Smoke particles entering the ionization volume decrease the conductance of the air by reducing ion mobility. The reduced conductance signal is processed and used to convey an alarm condition when it meets preset criteria.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Leg Facility. The portion of a communications channel that connects not more than one protected premises to a primary or secondary trunk facility. The leg facility includes the portion of the signal transmission circuit from its point of connection with a trunk facility to the point where it is terminated within the protected premises at one or more transponders.

Level Ceilings. Ceilings that are level or have a slope of less than or equal to 1 in 8.

Life Safety Network. A type of combination system that transmits fire safety control data through gateways to other building system control units.

Line-Type Detector. A device in which detection is continuous along a path. Typical examples are rate-of-rise pneumatic tubing detectors, projected beam smoke detectors, and heat-sensitive cable.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Loading Capacity. The maximum number of discrete elements of fire alarm systems permitted to be used in a particular configuration.

Loss of Power. The reduction of available voltage at the load below the point at which equipment can function as designed.

Low-Power Radio Transmitter. Any device that communicates with associated control/receiving equipment by low-power radio signals.

Maintenance. Repair service, including periodic inspections and tests, required to keep the fire alarm system and its component parts in an operative condition at all times, and the replacement of the system or its components when they become undependable or inoperable for any reason.

Manual Fire Alarm Box. A manually operated device used to initiate an alarm signal.

Master Box. A municipal fire alarm box that can also be operated by remote means.

Master Control Unit (Panel). A control unit that serves the protected premises or portion of the protected premises as a local control unit and accepts inputs from other fire alarm control units.

Multiple Dwelling Unit. A building containing three or more dwelling units. (*See Dwelling Unit.*)

Multiple Station Alarm. A single station alarm capable of being interconnected to one or more additional alarms so that the actuation of one causes the appropriate alarm signal to operate in all interconnected alarms.

Multiple Station Alarm Device. Two or more single station alarm devices that can be interconnected so that actuation of one causes all integral or separate audible alarms to operate; or one single station alarm device having connections to other detectors or to a manual fire alarm box.

Multiplexing. A signaling method characterized by simultaneous or sequential transmission, or both, and reception of multiple signals on a signaling line circuit, a transmission channel, or a communications channel, including means for positively identifying each signal.

Municipal Fire Alarm Box (Street Box). An enclosure housing a manually operated transmitter used to send an alarm to the public fire service communications center.

Municipal Fire Alarm System. A system of alarm-initiating devices, receiving equipment, and connecting circuits (other than a public telephone network) used to transmit alarms from street locations to the public fire service communications center.

Municipal Transmitter. A transmitter that can only be tripped remotely that is used to send an alarm to the public fire service communications center.

Noncoded Signal. An audible or visible signal conveying one discrete bit of information.

Noncontiguous Property. An owner- or user-protected premises where two or more protected premises, controlled by the same owner or user, are separated by a public thoroughfare, body of water, transportation right-of-way, or property owned or used by others.

Nonrequired System. A supplementary fire alarm system component or group of components that is installed at the option of the owner, and is not installed due to a building or fire code requirement.

Nonrestorable Initiating Device. A device in which the sensing element is designed to be destroyed in the process of operation.

Notification Appliance. A fire alarm system component such as a bell, horn, speaker, light, or text display that provides audible, tactile, or visible outputs, or any combination thereof.

Notification Appliance Circuit. A circuit or path directly connected to a notification appliance(s).

Notification Zone. An area covered by notification appliances that are activated simultaneously.

Nuisance Alarm. Any alarm caused by mechanical failure, malfunction, improper installation, or lack of proper maintenance, or any alarm activated by a cause that cannot be determined.

Off-Hook. To make connection with the public-switched telephone network in preparation for dialing a telephone number.

On-Hook. To disconnect from the public-switched telephone network.

Open Area Detection (Protection). Protection of an area such as a room or space with detectors to provide early warning of fire.

Operating Mode, Private. Audible or visible signaling only to those persons directly concerned with the implementation and direction of emergency action initiation and procedure in the area protected by the fire alarm system.

Operating Mode, Public. Audible or visible signaling to occupants or inhabitants of the area protected by the fire alarm system.

Operating System Software. The basic operating system software that can be altered only by the equipment manufacturer or its authorized representative. Operating system software is sometimes referred to as *firmware*, *BIOS*, or *executive program*.

Other Fire Detectors. Devices that detect a phenomenon other than heat, smoke, flame, or gases produced by a fire.

Ownership. Any property or building or its contents under legal control by the occupant, by contract, or by holding of a title or deed.

Paging System. A system intended to page one or more persons by such means as voice over loudspeaker, coded audible signals or visible signals, or lamp annunciators.

Parallel Telephone System. A telephone system in which an individually wired circuit is used for each fire alarm box.

Path (Pathways). Any conductor, optic fiber, radio carrier, or other means for transmitting fire alarm system information between two or more locations.

Permanent Visual Record (Recording). An immediately readable, not easily alterable, print, slash, or punch record of all occurrences of status change.

Photoelectric Light Obscuration Smoke Detection.* The principle of using a light source and a photosensitive sensor onto which the principal portion of the source emissions is focused. When smoke particles enter the light path, some of the light is scattered and some is absorbed, thereby reducing the light reaching the receiving sensor. The light reduction signal is processed and used to convey an alarm condition when it meets preset criteria.

Photoelectric Light-Scattering Smoke Detection.* The principle of using a light source and a photosensitive sensor arranged so that the rays from the light source do not normally fall onto the photosensitive sensor. When smoke particles enter the light path, some of the light is scattered by reflection and refraction onto the sensor. The light signal is processed and used to convey an alarm condition when it meets preset criteria.

Placarded. A means to signify that the fire alarm system of a particular facility is receiving central station service in accordance with this code by a listed central station or listed fire alarm service—local company that is part of a systematic follow-up program under the control of an independent third party listing organization.

Plant. One or more buildings under the same ownership or control on a single property.

Pneumatic Rate-of-Rise Tubing Heat Detector. A line-type detector comprising small-diameter tubing, usually copper, that is installed on the ceiling or high on the walls throughout the protected area. The tubing is terminated in a detector unit containing diaphragms and associated contacts set to actuate at a predetermined pressure. The system is sealed except for calibrated vents that compensate for normal changes in temperature.

Positive Alarm Sequence. An automatic sequence that results in an alarm signal, even when manually delayed for investigation, unless the system is reset.

Power Supply. A source of electrical operating power, including the circuits and terminations connecting it to the dependent system components.

Primary Battery (Dry Cell). A nonrechargeable battery requiring periodic replacement.

Primary Trunk Facility. That part of a transmission channel connecting all leg facilities to a supervising or subsidiary station.

Prime Contractor. The one company contractually responsible for providing central station services to a subscriber as required by this code. The prime contractor can be either a listed central station or a listed fire alarm service—local company.

Private Radio Signaling. A radio system under control of the proprietary supervising station.

Projected Beam-Type Detector. A type of photoelectric light obscuration smoke detector wherein the beam spans the protected area.

Proprietary Supervising Station. A location to which alarm or supervisory signaling devices on proprietary fire alarm sys-

tems are connected and where personnel are in attendance at all times to supervise operation and investigate signals.

Proprietary Supervising Station Fire Alarm System. An installation of fire alarm systems that serves contiguous and noncontiguous properties, under one ownership, from a proprietary supervising station located at the protected property, at which trained, competent personnel are in constant attendance. This includes the proprietary supervising station; power supplies; signal-initiating devices; initiating device circuits; signal notification appliances; equipment for the automatic, permanent visual recording of signals; and equipment for initiating the operation of emergency building control services.

Protected Premises. The physical location protected by a fire alarm system.

Protected Premises (Local) Control Unit (Panel). A control unit that serves the protected premises or a portion of the protected premises and indicates the alarm via notification appliances inside the protected premises.

Protected Premises (Local) Fire Alarm System. A protected premises system that sounds an alarm at the protected premises as the result of the manual operation of a fire alarm box or the operation of protection equipment or systems, such as water flowing in a sprinkler system, the discharge of carbon dioxide, the detection of smoke, or the detection of heat.

Public Fire Alarm Reporting System. A system of fire alarm initiating devices, receiving equipment, and connecting circuits used to transmit alarms from street locations to the communications center.

Public Fire Alarm Reporting System, Type A. A system in which an alarm from a fire alarm box is received and is retransmitted to fire stations either manually or automatically.

Public Fire Alarm Reporting System, Type B. A system in which an alarm from a fire alarm box is automatically transmitted to fire stations and, if used, is transmitted to supplementary alerting devices.

Public Fire Service Communications Center. The building or portion of the building used to house the central operating part of the fire alarm system; usually the place where the necessary testing, switching, receiving, transmitting, and power supply devices are located.

Public Switched Telephone Network. An assembly of communications facilities and central office equipment operated jointly by authorized common carriers that provides the general public with the ability to establish communications channels via discrete dialing codes.

Radiant Energy-Sensing Fire Detector. A device that detects radiant energy (such as ultraviolet, visible, or infrared) that is emitted as a product of combustion reaction and obeys the laws of optics.

Radio Alarm Repeater Station Receiver (RARSR). A system component that receives radio signals and resides at a repeater station that is located at a remote receiving location.

Radio Alarm Supervising Station Receiver (RASSR). A system component that receives data and annunciates that data at the supervising station.

Radio Alarm System (RAS). A system in which signals are transmitted from a radio alarm transmitter (RAT) located at a protected premises through a radio channel to two or more

radio alarm repeater station receivers (RARSR) and that are annunciated by a radio alarm supervising station receiver (RASSR) located at the central station.

Radio Alarm Transmitter (RAT). A system component at the protected premises to which initiating devices or groups of devices are connected that transmits signals indicating a status change of the initiating devices.

Radio Channel.* A band of frequencies of a width sufficient to allow its use for radio communications.

Rate Compensation Detector.* A device that responds when the temperature of the air surrounding the device reaches a predetermined level, regardless of the rate of temperature rise.

Rate-of-Rise Detector.* A device that responds when the temperature rises at a rate exceeding a predetermined value.

Rate-of-Rise Pneumatic Tubing Heat Detector. A line-type detector consisting of small-diameter tubing and a detector unit that actuates at a predetermined pressure. The system is sealed except for calibrated vents that compensate for changes in ambient temperature.

Record Drawings. Drawings (as-built) that document the location of all devices, appliances, wiring sequences, wiring methods, and connections of the components of the fire alarm system as installed.

Record of Completion. A document that acknowledges the features of installation, operation (performance), service, and equipment with representation by the property owner, system installer, system supplier, service organization, and the authority having jurisdiction.

Relocation. The movement of occupants from a fire zone to a safe area within the same building.

Remote Supervising Station Fire Alarm System. A system installed in accordance with this code to transmit alarm, supervisory, and trouble signals from one or more protected premises to a remote location where appropriate action is taken.

Repeater Station. The location of the equipment needed to relay signals between supervising stations, subsidiary stations, and protected premises.

Reset. A control function that attempts to return a system or device to its normal, non-alarm state.

Restorable Initiating Device. A device in which the sensing element is not ordinarily destroyed in the process of operation, whose restoration can be manual or automatic.

Runner. A person other than the required number of operators on duty at central, supervising, or runner stations (or otherwise in contact with these stations) available for prompt dispatching, when necessary, to the protected premises.

Runner Service. The service provided by a runner at the protected premises, including resetting and silencing of all equipment transmitting fire alarm or supervisory signals to an off-premises location.

Satellite Trunk. A circuit or path connecting a satellite to its central or proprietary supervising station.

Scanner. Equipment located at the telephone company wire center that monitors each local leg and relays status changes to the alarm center. Processors and associated equipment might also be included.

Secondary Trunk Facility. That part of a transmission channel connecting two or more, but fewer than all, leg facilities to a primary trunk facility.

Separate Sleeping Area. An area of the family living unit in which the bedrooms (or sleeping rooms) are located. Bedrooms (or sleeping rooms) separated by other use areas, such as kitchens or living rooms (but not bathrooms), are considered as separate sleeping areas.

Shall. Indicates a mandatory requirement.

Shapes of Ceilings. The shapes of ceilings can be classified as sloping or smooth.

Should. Indicates a recommendation or that which is advised but not required.

Signal. A status indication communicated by electrical or other means.

Signal Transmission Sequence. A DACT that obtains dial tone, dials the number(s) of the DACR, obtains verification that the DACR is ready to receive signals, transmits the signals, and receives acknowledgment that the DACR has accepted that signal before disconnecting (going on-hook).

Signaling Line Circuit. A circuit or path between any combination of circuit interfaces, control units, or transmitters over which multiple system input signals or output signals, or both, are carried.

Signaling Line Circuit Interface. A system component that connects a signaling line circuit to any combination of initiating devices, initiating device circuits, notification appliances, notification appliance circuits, system control outputs, and other signaling line circuits.

Single Dwelling Unit. A building consisting solely of one dwelling unit. (*See Dwelling Unit.*)

Single Station Alarm. A detector comprising an assembly that incorporates a sensor, control components, and an alarm notification appliance in one unit operated from a power source either located in the unit or obtained at the point of installation.

Single Station Alarm Device. An assembly that incorporates the detector, the control equipment, and the alarm-sounding device in one unit operated from a power supply either in the unit or obtained at the point of installation.

Site-Specific Software. Software that defines the specific operation and configuration of a particular system. Typically, it defines the type and quantity of hardware modules, customized labels, and specific operating features of a system.

Sloping Ceiling. A ceiling that has a slope of more than 1 in 8.

Sloping Peaked-Type Ceiling.* A ceiling in which the ceiling slopes in two directions from the highest point. Curved or domed ceilings can be considered peaked with the slope figured as the slope of the chord from highest to lowest point.

Sloping Shed-Type Ceiling.* A ceiling in which the high point is at one side with the slope extending toward the opposite side.

Smoke Alarm. A single or multiple station alarm responsive to smoke.

Smoke Detector. A device that detects visible or invisible particles of combustion.

Smooth Ceiling.* A ceiling surface uninterrupted by continuous projections, such as solid joists, beams, or ducts, extending more than 4 in. (100 mm) below the ceiling surface.

Spacing. A horizontally measured dimension related to the allowable coverage of fire detectors.

Spark.* A moving ember.

Spark/Ember Detector. A radiant energy-sensing fire detector that is designed to detect sparks or embers, or both. These devices are normally intended to operate in dark environments and in the infrared part of the spectrum.

Spark/Ember Detector Sensitivity. The number of watts (or the fraction of a watt) of radiant power from a point source radiator, applied as a unit step signal at the wavelength of maximum detector sensitivity, necessary to produce an alarm signal from the detector within the specified response time.

Spot-Type Detector. A device in which the detecting element is concentrated at a particular location. Typical examples are bimetallic detectors, fusible alloy detectors, certain pneumatic rate-of-rise detectors, certain smoke detectors, and thermoelectric detectors.

Story. The portion of a building included between the upper surface of a floor and the upper surface of the floor or roof next above.

Stratification. The phenomenon where the upward movement of smoke and gases ceases due to the loss of buoyancy.

Subscriber. The recipient of a contractual supervising station signal service(s). In case of multiple, noncontiguous properties having single ownership, the term refers to each protected premises or its local management.

Subsidiary Station. A subsidiary station is a normally untended location that is remote from the supervising station and is linked by a communications channel(s) to the supervising station. Interconnection of signals on one or more transmission channels from protected premises with a communications channel(s) to the supervising station is performed at this location.

Supervising Station. A facility that receives signals and at which personnel are in attendance at all times to respond to these signals.

Supervisory Service. The service required to monitor performance of guard tours and the operative condition of fixed suppression systems or other systems for the protection of life and property.

Supervisory Signal. A signal indicating the need for action in connection with the supervision of guard tours, the fire suppression systems or equipment, or the maintenance features of related systems.

Supervisory Signal Initiating Device. An initiating device such as a valve supervisory switch, water level indicator, or low air pressure switch on a dry-pipe sprinkler system in which the change of state signals an off-normal condition and its restoration to normal of a fire protection or life safety system; or a need for action in connection with guard tours, fire suppression systems or equipment, or maintenance features of related systems.

Supplementary. As used in this code, supplementary refers to equipment or operations not required by this code and designated as such by the authority having jurisdiction.

Switched Telephone Network. An assembly of communications facilities and central office equipment operated jointly by authorized service providers that provides the general public with the ability to establish transmission channels via discrete dialing.

System Unit. The active subassemblies at the central station used for signal receiving, processing, display, or recording of status change signals; a failure of one of these subassemblies causes the loss of a number of alarm signals by that unit.

Tactile Notification Appliance. A notification appliance that alerts by the sense of touch or vibration.

Textual Audible Notification Appliance. A notification appliance that conveys a stream of audible information. An example of a textual audible notification appliance is a speaker that reproduces a voice message.

Textual Visible Notification Appliance. A notification appliance that conveys a stream of visible information that displays an alphanumeric or pictorial message. Textual visible notification appliances provide temporary text, permanent text, or symbols. Textual visible notification appliances include, but are not limited to, annunciators, monitors, CRTs, displays, and printers.

Transmission Channel. A circuit or path connecting transmitters to supervising stations or subsidiary stations on which signals are carried.

Transmitter. A system component that provides an interface between signaling line circuits, initiating device circuits, or control units and the transmission channel.

Transponder. A multiplex alarm transmission system functional assembly located at the protected premises.

Trouble Signal. A signal initiated by the fire alarm system or device indicative of a fault in a monitored circuit or component.

Visible Notification Appliance. A notification appliance that alerts by the sense of sight.

Voice Intelligibility.* Audible voice information that is distinguishable and understandable.

WATS (Wide Area Telephone Service). Telephone company service allowing reduced costs for certain telephone call arrangements. In-WATS or 800-number service calls can be placed from anywhere in the continental United States to the called party at no cost to the calling party. Out-WATS is a service whereby, for a flat-rate charge, dependent on the total duration of all such calls, a subscriber can make an unlimited number of calls within a prescribed area from a particular telephone terminal without the registration of individual call charges.

Wavelength.* The distance between the peaks of a sinusoidal wave. All radiant energy can be described as a wave having a wavelength. Wavelength serves as the unit of measure for distinguishing between different parts of the spectrum. Wavelengths are measured in microns (μM), nanometers (nm), or angstroms (\AA).

Wireless Control Panel. A component that transmits/receives and processes wireless signals.

Wireless Protection System. A system or a part of a system that can transmit and receive signals without the aid of wire. It can consist of either a wireless control panel or a wireless repeater.

Wireless Repeater. A component used to relay signals between wireless receivers or wireless control panels, or both.

Zone. A defined area within the protected premises. A zone can define an area from which a signal can be received, an area to which a signal can be sent, or an area in which a form of control can be executed.

1-5 Fundamentals.

1-5.1 Common System Fundamentals. The provisions of Chapter 1 shall apply to Chapters 2 through 7.

1-5.1.1 General. The provisions of Chapter 1 shall cover the basic functions of a complete fire alarm system. These systems shall be primarily intended to provide notification of fire alarm, supervisory, and trouble conditions; to alert the occupants; to summon appropriate aid; and to control fire safety functions.

1-5.1.2 Equipment. Equipment constructed and installed in conformity with this code shall be listed for the purpose for which it is used.

1-5.1.3* System Design. Fire alarm system plans and specifications shall be developed in accordance with this code by persons who are experienced in the proper design, application, installation, and testing of fire alarm systems. The system designer shall be identified on the system design documents. Evidence of qualifications shall be provided when requested by the authority having jurisdiction.

1-5.1.4 System Installation. Installation personnel shall be supervised by persons who are qualified and experienced in the installation, inspection, and testing of fire alarm systems. Examples of qualified personnel shall include, but not be limited to, the following:

- (1) Factory trained and certified personnel
- (2) National Institute of Certification in Engineering Technologies (NICET) fire alarm level II certified personnel
- (3) Personnel licensed or certified by state or local authority

1-5.2 Power Supplies.

1-5.2.1 Scope. The provisions of this section apply to power supplies used for fire alarm systems.

1-5.2.2 Code Conformance. All power supplies shall be installed in conformity with the requirements of NFPA 70, *National Electrical Code*, for such equipment and with the requirements indicated in this subsection.

1-5.2.3* Power Sources. Fire alarm systems shall be provided with at least two independent and reliable power supplies, one primary and one secondary (standby), each of which shall be of adequate capacity for the application.

Exception No. 1: Where the primary power is supplied by a dedicated branch circuit of an emergency system in accordance with NFPA 70, National Electrical Code, Article 700, or a legally required standby system in accordance with NFPA 70, National Electrical Code, Article 701, a secondary supply shall not be required.

Exception No. 2: Where the primary power is supplied by a dedicated branch circuit of an optional standby system in accordance with NFPA 70, National Electrical Code, Article 702, which also meets the performance requirements of Article 700 or Article 701, a secondary supply shall not be required.

Where dc voltages are employed, they shall be limited to no more than 350 volts above earth ground.

1-5.2.4 Primary Supply. The primary supply shall have a high degree of reliability, shall have adequate capacity for the intended service, and shall consist of one of the following:

- (1) Light and power service arranged in accordance with 1-5.2.5
- (2) Where a person specifically trained in its operation is on duty at all times, an engine-driven generator or equivalent arranged in accordance with 1-5.2.10

1-5.2.5 Light and Power Service.

1-5.2.5.1 A light and power service employed to operate the system under normal conditions shall have a high degree of reliability and capacity for the intended service. This service shall consist of one of the following:

(a) *Two-Wire Supplies.* A two-wire supply circuit shall be permitted to be used for either the primary operating power supply or the trouble signal power supply of the signaling system.

(b) *Three-Wire Supplies.* A three-wire ac or dc supply circuit having a continuous unfused neutral conductor, or a polyphase ac supply circuit having a continuous unfused neutral conductor where interruption of one phase does not prevent operation of the other phase, shall be permitted to be used with one side or phase for the primary operating power supply and the other side or phase for the trouble signal power supply of the fire alarm system.

1-5.2.5.2 Connections to the light and power service shall be on a dedicated branch circuit(s). The circuit(s) and connections shall be mechanically protected. Circuit disconnecting means shall have a red marking, shall be accessible only to authorized personnel, and shall be identified as FIRE ALARM CIRCUIT CONTROL. The location of the circuit disconnecting means shall be permanently identified at the fire alarm control unit.

1-5.2.5.3 Overcurrent Protection. An overcurrent protective device of suitable current-carrying capacity and capable of interrupting the maximum short-circuit current to which it may be subject shall be provided in each ungrounded conductor. The overcurrent protective device shall be enclosed in a locked or sealed cabinet located immediately adjacent to the point of connection to the light and power conductors.

1-5.2.5.4 Circuit breakers or engine stops shall not be installed in such a manner as to cut off the power for lighting or for operating elevators.

1-5.2.6 Secondary Supply Capacity and Sources. The secondary supply shall automatically supply the energy to the system within 30 seconds, and without loss of signals, wherever the primary supply is incapable of providing the minimum voltage required for proper operation. The secondary (standby) power supply shall supply energy to the system in the event of total failure of the primary (main) power supply or when the primary voltage drops to a level insufficient to maintain functionality of the control equipment and system components. Under maximum quiescent load (system functioning in a non-alarm condition), the secondary supply shall have sufficient capacity to operate a protected premises, central station, or proprietary system for 24 hours, or an auxiliary or remote station system for 60 hours; and, at the end of that period, shall be capable of operating all alarm notification appliances used for evacuation or to direct aid to the location of an emergency for 5 minutes. The secondary power supply for emergency voice/alarm communications service shall be capable of operating the system under maximum quiescent

load for 24 hours and then shall be capable of operating the system during a fire or other emergency condition for a period of 2 hours. Fifteen minutes of evacuation alarm operation at maximum connected load shall be considered the equivalent of 2 hours of emergency operation.

For a combination system, the secondary supply capacity required above shall include the load of any non-fire related equipment, functions, or features which are not automatically disconnected upon transfer of operating power to the secondary supply.

The secondary supply shall consist of one of the following:

- (a) A storage battery arranged in accordance with 1-5.2.9.
- (b) An automatic starting, engine-driven generator arranged in accordance with 1-5.2.10 and storage batteries with 4 hours of capacity arranged in accordance with 1-5.2.9.
- (c) Multiple engine-driven generators, one of which is arranged for automatic starting, arranged in accordance with 1-5.2.10, and capable of supplying the energy required herein, with the largest generator out of service. The second generator shall be permitted to be started by pushbutton.

Operation on secondary power shall not affect the required performance of a fire alarm system. The system shall produce the same alarm, supervisory, and trouble signals and indications (excluding the ac power indicator) when operating from the standby power source as are produced when the unit is operating from the primary power source.

1-5.2.7 Continuity of Power Supplies.

(a) Where signals could be lost on transfer of power between the primary and secondary sources, rechargeable batteries of sufficient capacity to operate the system under maximum normal load for 15 minutes shall assume the load in such a manner that no signals are lost where either of the following conditions exists:

- (1) Secondary power is supplied in accordance with 1-5.2.6(a) or 1-5.2.6(b), and the transfer is made manually
- (2) Secondary power is supplied in accordance with 1-5.2.6(c)
- (b) Where signals will not be lost due to transfer of power between the primary and secondary sources, one of the following arrangements shall be made:
 - (1) The transfer shall be automatic.
 - (2) Special provisions shall be made to allow manual transfer within 30 seconds of loss of power.
 - (3) The transfer shall be arranged in accordance with 1-5.2.6(a).

(c) *Where a computer system of any kind or size is used to receive or process signals, an uninterruptible power supply (UPS) with sufficient capacity to operate the system for at least 15 minutes, or until the secondary supply is capable of supplying the UPS input power requirements, shall be required where either of the following conditions apply:

- (1) The status of signals previously received will be lost upon loss of power.
- (2) The computer system cannot be restored to full operation within 30 seconds of loss of power.

(d) *A positive means for disconnecting the input and output of the UPS system while maintaining continuity of power supply to the load shall be provided.

1-5.2.8 Power Supply for Remotely Located Control Equipment.

1-5.2.8.1 Additional power supplies, where provided for control units, circuit interfaces, or other equipment essential to

system operation, located remote from the main control unit, shall be comprised of a primary and secondary power supply that shall meet the same requirements as those of 1-5.2.1 through 1-5.2.8 and 1-5.8.6.

1-5.2.8.2 Power supervisory devices shall be arranged so as not to impair the receipt of fire alarm or supervisory signals.

1-5.2.9* Storage Batteries.

1-5.2.9.1 **Location.** Storage batteries shall be located so that the fire alarm equipment, including overcurrent devices, are not adversely affected by battery gases and shall conform to the requirements of NFPA 70, *National Electrical Code*, Article 480. Cells shall be suitably insulated against grounds and crosses and shall be mounted securely in such a manner so as not to be subject to mechanical injury. Racks shall be suitably protected against deterioration. If not located in or adjacent to the fire alarm control panel, the batteries and their charger location shall be permanently identified at the fire alarm control unit.

1-5.2.9.2 Battery Charging.

1-5.2.9.2.1 Adequate facilities shall be provided to automatically maintain the battery fully charged under all conditions of normal operation and, in addition, to recharge batteries within 48 hours after fully charged batteries have been subject to a single discharge cycle as specified in 1-5.2.5.3. Upon attaining a fully charged condition, the charge rate shall not be so excessive as to result in battery damage.

1-5.2.9.2.2 Supervising stations shall maintain spare parts or units available, which shall be used to restore failed charging capacity prior to the consumption of one-half of the capacity of the batteries for the supervising station equipment.

1-5.2.9.2.3* Batteries shall be either trickle- or float-charged.

1-5.2.9.2.4 A rectifier employed as a battery charging supply source shall be of adequate capacity. A rectifier employed as a charging means shall be energized by an isolating transformer.

1-5.2.9.3 **Overcurrent Protection.** The batteries shall be protected against excessive load current by overcurrent devices having a rating not less than 150 percent and not more than 250 percent of the maximum operating load in the alarm condition. The batteries shall be protected from excessive charging current by overcurrent devices or by automatic current-limiting design of the charging source.

1-5.2.9.4 **Metering.** The charging equipment shall provide either integral meters or readily accessible terminal facilities for the connection of portable meters by which the battery voltage and charging current can be determined.

1-5.2.9.5 **Charger Supervision.** Supervision means appropriate for the batteries and charger employed shall be provided to detect a failure of battery charging and initiate a trouble signal in accordance with 1-5.4.6.

1-5.2.10 Engine-Driven Generator.

1-5.2.10.1 **Installation.** The installation of engine-driven generators shall conform to the provisions of NFPA 110, *Standard for Emergency and Standby Power Systems*.

Exception: Where restricted by the provisions of 1-5.2.

1-5.2.10.2 **Capacity.** The unit shall be of a capacity that is sufficient to operate the system under the maximum normal load

conditions in addition to all other demands placed upon the unit, such as those of emergency lighting.

1-5.2.10.3 Fuel.

1-5.2.10.3.1 Fuel shall be stored in outside underground tanks wherever possible, and gravity feed shall not be used. If gasoline-driven generators are used, fuel shall be supplied from a frequently replenished “working” tank, or other means provided, to ensure that the gasoline is always fresh because gasoline deteriorates with age.

1-5.2.10.3.2 Sufficient fuel shall be available in storage for 6 months of testing plus the capacity specified in 1-5.2.5. For public fire alarm reporting systems, the requirements of Chapter 6 shall apply.

Exception No. 1: If a reliable source of supply is available at any time on a 2-hour notice, sufficient fuel shall be in storage for 12 hours of operation at full load.

Exception No. 2: Fuel systems using natural or manufactured gas supplied through reliable utility mains shall not be required to have fuel storage tanks unless located in seismic risk zone 3 or greater as defined in ANSI A-58.1, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures.

1-5.2.10.4 Battery and Charger. A separate storage battery and separate automatic charger shall be provided for starting the engine-driven generator and shall not be used for any other purpose.

1-5.3 Compatibility. All fire detection devices that receive their power from the initiating device circuit or signaling line circuit of a fire alarm control unit shall be listed for use with the control unit.

1-5.4 System Functions.

1-5.4.1 Protected Premises Fire Safety Functions.

1-5.4.1.1 Fire safety functions shall be permitted to be performed automatically. The performance of automatic fire safety functions shall not interfere with power for lighting or for operating elevators. The performance of automatic fire safety functions shall not preclude the combination of fire alarm services with other services requiring monitoring of operations.

1-5.4.1.2* The time delay between the activation of an initiating device and the automatic activation of a local fire safety function shall not exceed 20 seconds.

Effective on January 1, 2002, the time delay between the activation of an initiating device and the automatic activation of a local fire safety function shall not exceed 10 seconds.

1-5.4.2 Alarm Signals.

1-5.4.2.1* Coded Alarm Signals. A coded alarm signal shall consist of not less than three complete rounds of the number transmitted. Each round shall consist of not less than three impulses.

1-5.4.2.2* Actuation of alarm notification appliances or emergency voice communications and annunciation at the protected premises shall occur within 20 seconds after the activation of an initiating device.

Effective on January 1, 2002, actuation of alarm notification appliances or emergency voice communications and annunciation at the protected premises shall occur within 10 seconds after the activation of an initiating device.

1-5.4.3 Supervisory Signals.

1-5.4.3.1 Coded Supervisory Signal. A coded supervisory signal shall be permitted to consist of two rounds of the number transmitted to indicate a supervisory off-normal condition, and one round of the number transmitted to indicate the restoration of the supervisory condition to normal.

1-5.4.3.2 Combined Coded Alarm and Supervisory Signal Circuits.

1-5.4.3.2.1 Where both coded sprinkler supervisory signals and coded fire or waterflow alarm signals are transmitted over the same signaling line circuit, provision shall be made either to obtain alarm signal precedence or sufficient repetition of the alarm signal to prevent the loss of an alarm signal.

1-5.4.3.2.2 Visible and audible supervisory signals and visible indication of their restoration to normal shall be indicated within 90 seconds at the following locations:

- (1) Control unit (central equipment) for local fire alarm systems
- (2) Building fire command center for emergency voice/alarm communications systems
- (3) Supervising station location for systems installed in compliance with Chapter 5

1-5.4.4 Distinctive Signals. Fire alarms, supervisory signals, and trouble signals shall be distinctively and descriptively annunciated.

1-5.4.5 Fire Safety Function Status Indicators.

1-5.4.5.1 All controls provided specifically for the purpose of manually overriding any automatic fire safety function shall provide visible indication of the status of the associated control circuits.

1-5.4.5.2* Where status indicators are provided for emergency equipment or fire safety functions, they shall be arranged to reflect the actual status of the associated equipment or function.

1-5.4.6 Trouble Signals. Trouble signals and their restoration to normal shall be indicated within 200 seconds at the locations identified in 1-5.4.6.1 or 1-5.4.6.2. Trouble signals required to indicate at the protected premises shall be indicated by distinctive audible signals. These audible trouble signals shall be distinctive from alarm signals. If an intermittent signal is used, it shall sound at least once every 10 seconds, with a minimum duration of $\frac{1}{2}$ second. An audible trouble signal shall be permitted to be common to several supervised circuits. The trouble signal(s) shall be located in an area where it is likely to be heard.

1-5.4.6.1 Visible and audible trouble signals and visible indication of their restoration to normal shall be indicated at the following locations:

- (1) Control unit (central equipment) for protected premises fire alarm systems
- (2) Building fire command center for emergency voice/alarm communications service
- (3) Central station or remote station location for systems installed in compliance with Chapter 5

1-5.4.6.2 Trouble signals and their restoration to normal shall be visibly and audibly indicated at the proprietary supervising station for systems installed in compliance with Chapter 5.

1-5.4.6.3 Audible Trouble Signal Silencing Means.

1-5.4.6.3.1 A means for silencing the trouble notification appliance(s) shall be permitted only if it is key-operated, located within a locked enclosure, or arranged to provide equivalent protection against unauthorized use. Such a means shall be permitted only if it transfers the trouble indication to a suitably identified lamp or other acceptable visible indicator. The visible indication shall persist until the trouble condition has been corrected. The audible trouble signal shall sound when the silencing means is in its silence position and no trouble exists.

1-5.4.6.3.2 If an audible trouble notification appliance is also used to indicate a supervisory condition, as permitted in 1-5.4.7(b), a trouble signal silencing switch shall not prevent subsequent sounding of supervisory signals.

1-5.4.6.3.3* An audible trouble signal that has been silenced at the protected premises shall automatically re-sound every 24 hours or less until fault conditions are restored to normal. The audible trouble signal shall sound until it is manually silenced or acknowledged. The re-sounded trouble signal shall also be automatically retransmitted to any supervising station to which the original trouble signal was transmitted.

1-5.4.6.3.4* If permitted by the authority having jurisdiction, the requirement for a 24-hour re-sound of an audible trouble signal shall be permitted to occur only at a supervising station that meets the requirements of Chapter 5 and not at the protected premises.

1-5.4.7 Distinctive Signals. Audible alarm notification appliances for a fire alarm system shall produce signals that are distinctive from other similar appliances used for other purposes in the same area. The distinction among signals shall be as follows:

(a) Fire alarm signals shall be distinctive in sound from other signals. Their sound shall not be used for any other purpose. The requirements of 3-8.4.1.2.1 shall apply.

(b) *Supervisory signals shall be distinctive in sound from other signals. Their sound shall not be used for any other purpose.

Exception: A supervisory signal sound shall be permitted to be used to indicate a trouble condition. If the same sound is used for both supervisory signals and trouble signals, the distinction between signals shall be by other appropriate means such as visible annunciation.

(c) Fire alarm, supervisory, and trouble signals shall take precedence, in that respective order of priority, over all other signals.

Exception: Signals from hold-up alarms or other life-threatening signals shall be permitted to take precedence over supervisory and trouble signals if acceptable to the authority having jurisdiction.

1-5.4.8 Alarm Signal Deactivation. A means for turning off activated alarm notification appliances shall be permitted only where it is key-operated, located within a locked cabinet, or arranged to provide equivalent protection against unauthorized use. Such means shall be permitted only if a visible zone alarm indication or the equivalent has been provided as specified in 1-5.7.1, and subsequent actuation of initiating devices on other initiating device circuits or subsequent actuation of addressable initiating devices on signaling line circuits cause the notification appliances to reactivate. A means that is left in the "off" position when there is no alarm shall operate an audi-

ble trouble signal until the means is restored to normal. If automatically turning off the alarm notification appliances is permitted by the authority having jurisdiction, the alarm shall not be turned off in less than 5 minutes.

Exception No. 1: If otherwise permitted by the authority having jurisdiction, the 5-minute requirement shall not apply.

Exception No. 2: If permitted by the authority having jurisdiction, subsequent actuation of another addressable initiating device of the same type in the same room or space shall not be required to cause the notification appliance(s) to reactivate.

1-5.4.9 Supervisory Signal Silencing. A means for silencing a supervisory signal notification appliance(s) shall be permitted only if it is key-operated, located within a locked enclosure, or arranged to provide equivalent protection against unauthorized use. Such a means shall be permitted only if it transfers the supervisory indication to a lamp or other visible indicator and subsequent supervisory signals in other zones cause the supervisory notification appliance(s) to re-sound. A means that is left in the "silence" position where there is no supervisory off-normal signal shall operate a visible signal silence indicator and cause the trouble signal to sound until the silencing means is restored to normal position.

1-5.4.10* Presignal Feature. If permitted by the authority having jurisdiction, systems shall be permitted to have a feature that allows initial fire alarm signals to sound only in department offices, control rooms, fire brigade stations, or other constantly attended central locations and for which human action is subsequently required to activate a general alarm, or a feature that allows the control equipment to delay the general alarm by more than 1 minute after the start of the alarm processing. If there is a connection to a remote location, the transmission of the alarm signal to the supervising station shall activate upon the initial alarm signal.

1-5.4.11 Positive Alarm Sequence.

1-5.4.11.1 Systems that have positive alarm features complying with 1-5.4.11 shall be permitted if approved by the authority having jurisdiction.

1-5.4.11.1.1 The signal from an automatic fire detection device selected for positive alarm sequence operation shall be acknowledged at the control unit by trained personnel within 15 seconds of annunciation in order to initiate the alarm investigation phase. If the signal is not acknowledged within 15 seconds, all building and remote signals shall be activated immediately and automatically.

1-5.4.11.1.2 Trained personnel shall have up to 180 seconds during the alarm investigation phase to evaluate the fire condition and reset the system. If the system is not reset during this investigation phase, all building and remote signals shall be activated immediately and automatically.

1-5.4.11.2 If a second automatic fire detector selected for positive alarm sequence is actuated during the alarm investigation phase, all normal building and remote signals shall be activated immediately and automatically.

1-5.4.11.3 If any other initiating device is actuated, all building and remote signals shall be activated immediately and automatically.

1-5.4.11.4* The system shall provide means for bypassing the positive alarm sequence.

1-5.5 Performance and Limitations.

1-5.5.1 Voltage, Temperature, and Humidity Variation. Equipment shall be designed so that it is capable of performing its intended functions under the following conditions:

- (1) *At 85 percent and at 110 percent of the nameplate primary (main) and secondary (standby) input voltage(s)
- (2) At ambient temperatures of 32°F (0°C) and 120°F (49°C)
- (3) At a relative humidity of 85 percent and an ambient temperature of 86°F (30°C)

1-5.5.2 Installation and Design.

1-5.5.2.1* All systems shall be installed in accordance with the specifications and standards approved by the authority having jurisdiction.

1-5.5.2.2 Devices and appliances shall be located and mounted so that accidental operation or failure is not caused by vibration or jarring.

1-5.5.2.3 All apparatus requiring rewinding or resetting to maintain normal operation shall be restored to normal as promptly as possible after each alarm and kept in normal condition for operation.

1-5.5.2.4 Equipment shall be installed in locations where conditions do not exceed the voltage, temperature, and humidity limits specified in 1-5.5.1.

Exception: Equipment specifically listed for use in locations where conditions can exceed the upper and lower limits specified in 1-5.5.1.

1-5.5.3 To reduce the possibility of damage by induced transients, circuits and equipment shall be properly protected in accordance with the requirements of NFPA 70, *National Electrical Code*, Article 800.

1-5.5.4* Wiring. The installation of all wiring, cable, and equipment shall be in accordance with NFPA 70, *National Electrical Code*, and specifically with Articles 760, 770, and 800, where applicable. Optical fiber cables shall be protected against mechanical injury in accordance with Article 760.

1-5.5.5 Grounding. All systems shall test free of grounds.

Exception: Parts of circuits or equipment that are intentionally and permanently grounded to provide ground-fault detection, noise suppression, emergency ground signaling, and circuit protection grounding.

1-5.5.6 Initiating Devices.

1-5.5.6.1 Initiating devices of the manual or automatic type shall be selected and installed so as to minimize nuisance alarms.

1-5.5.6.2 Fire alarm boxes of the manually operated type shall comply with 3-8.3.2.1.

1-5.6* Protection of Fire Alarm Control Unit(s). In areas that are not continuously occupied, automatic smoke detection shall be provided at the location of each fire alarm control unit(s) to provide notification of fire at that location.

Exception: Where ambient conditions prohibit installation of automatic smoke detection, automatic heat detection shall be permitted.

1-5.7 Zoning and Annunciation.

1-5.7.1 Visible Zone Alarm Indication. If required, the location of an operated initiating device shall be visibly indicated by building, floor, fire zone, or other approved subdivision by annunciation, printout, or other approved means. The visible

indication shall not be canceled by the operation of an audible alarm silencing means.

1-5.7.1.1 The primary purpose of fire alarm system annunciation is to enable responding personnel to identify the location of a fire quickly and accurately and to indicate the status of emergency equipment or fire safety functions that might affect the safety of occupants in a fire situation. All required annunciation means shall be readily accessible to responding personnel and shall be located as required by the authority having jurisdiction to facilitate an efficient response to the fire situation.

1-5.7.1.2* Zone of Origin. Fire alarm systems serving two or more zones shall identify the zone of origin of the alarm initiation by annunciation or coded signal.

1-5.7.1.3 Visual annunciators shall be capable of displaying all zones in alarm. If all zones in alarm are not displayed simultaneously, there shall be visual indication that other zones are in alarm.

1-5.7.2 Alarm annunciation at the fire command center shall be by means of audible and visible indicators.

1-5.7.3 For the purpose of alarm annunciation, each floor of the building shall be considered as a separate zone. If a floor is subdivided by fire or smoke barriers and the fire plan for the protected premises allows relocation of occupants from the zone of origin to another zone on the same floor, each zone on the floor shall be annunciated separately for purposes of alarm location.

1-5.7.4 If the system serves more than one building, each building shall be indicated separately.

1-5.8 Monitoring Integrity of Installation Conductors and Other Signaling Channels.

1-5.8.1* All means of interconnecting equipment, devices, and appliances and wiring connections shall be monitored for the integrity of the interconnecting conductors or equivalent path so that the occurrence of a single open or a single ground-fault condition in the installation conductors or other signaling channels and their restoration to normal shall be automatically indicated within 200 seconds.

Exception No. 1: Styles of initiating device circuits, signaling line circuits, and notification appliance circuits tabulated in Table 3-5, Table 3-6, and Table 3-7 that do not have an "X" under "Trouble" for the abnormal condition indicated.

Exception No. 2: Shorts between conductors, other than as required by 1-5.8.5, 1-5.8.6, and 1-5.8.7.1 and Table 3-5, Table 3-6, and Table 3-7, shall not be subject to this requirement.

Exception No. 3: A noninterfering shunt circuit, provided that a fault circuit condition on the shunt circuit wiring results only in the loss of the noninterfering feature of operation.

Exception No. 4: Connections to and between supplementary system components, provided that single open, ground, or short-circuit conditions of the supplementary equipment or interconnecting means, or both, do not affect the required operation of the fire alarm system.

Exception No. 5: The circuit of an alarm notification appliance installed in the same room with the central control equipment, provided that the notification appliance circuit conductors are installed in conduit or are equivalently protected against mechanical injury.

Exception No. 6: A trouble signal circuit.

Exception No. 7: Interconnection between listed equipment within a common enclosure.*

Exception No. 8: Interconnection between enclosures containing control equipment located within 20 ft (6 m) of each other where the conductors are installed in conduit or equivalently protected against mechanical injury.

Exception No. 9: Conductors for ground detection where a single ground does not prevent the required normal operation of the system.

Exception No. 10: Central station circuits serving notification appliances within a central station.

Exception No. 11: Pneumatic rate-of-rise systems of the continuous line type in which the wiring terminals of such devices are connected in multiple across electrically supervised circuits.

Exception No. 12: Interconnecting wiring of a stationary computer and the computer's keyboard, video monitor, mouse-type device, or touch screen, so long as the interconnecting wiring does not exceed 8 ft (2.4 m) in length; is a listed computer/data processing cable as permitted by NFPA 70, National Electrical Code; and failure of cable does not cause the failure of the required system functions not initiated from the keyboard, mouse, or touch screen.

Exception No. 13: Communications and transmission channels extending from a supervising station to a subsidiary station(s) or protected premises, or both, which are compliant with the requirements of Chapter 5 and electrically isolated from the fire alarm system (or circuits) by a transmitter(s), are not required to monitor the integrity of installation conductors for a ground-fault condition, provided that a single ground condition does not affect the required operation of the fire alarm system.

1-5.8.2 Interconnection means shall be arranged so that a single break or single ground fault does not cause an alarm signal.

1-5.8.3 Unacknowledged alarm signals shall not be interrupted if a fault on an initiating device circuit or a signaling line circuit occurs while there is an alarm condition on that circuit.

Exception: Circuits used to interconnect fire alarm control panels.

1-5.8.4 An open, ground, or short-circuit fault on the installation conductors of one alarm notification appliance circuit shall not affect the operation of any other alarm notification circuit.

1-5.8.5 The occurrence of a wire-to-wire short-circuit fault on any alarm notification appliance circuit shall result in a trouble signal at the protected premises.

Exception No. 1: A circuit employed to produce a supplementary local alarm signal, provided that the occurrence of a short circuit on the circuit in no way affects the required operation of the fire alarm system.

Exception No. 2: The circuit of an alarm notification appliance installed in the same room with the central control equipment, provided that the notification appliance circuit conductors are installed in conduit or are equivalently protected against mechanical injury.

Exception No. 3: Central station circuits serving notification appliances within a central station.

1-5.8.6 Monitoring Integrity of Emergency Voice/Alarm Communications Systems.

1-5.8.6.1* Monitoring Integrity of Speaker Amplifier and Tone-Generating Equipment. If speakers are used to produce audible fire alarm signals, the following shall apply:

- (1) Failure of any audio amplifier shall result in an audible trouble signal.
- (2) Failure of any tone-generating equipment shall result in an audible trouble signal.

Exception: Tone-generating and amplifying equipment enclosed as integral parts and serving only a single, listed loudspeaker shall not be required to be monitored.

1-5.8.6.2 Where a two-way telephone communications circuit is provided, its installation wires shall be monitored for a short-circuit fault that would cause the telephone communications circuit to become inoperative.

1-5.8.7 Monitoring Integrity of Power Supplies.

1-5.8.7.1 All primary and secondary power supplies shall be monitored for the presence of voltage at the point of connection to the system. Failure of either supply shall result in a trouble signal in accordance with 1-5.4.6. The trouble signal also shall be visually and audibly indicated at the protected premises. Where the DACT is powered from a protected premises fire alarm system control unit, power failure indication shall be in accordance with this paragraph.

Exception No. 1: A power supply for supplementary equipment.

Exception No. 2: The neutral of a three-, four-, or five-wire ac or dc supply source.

Exception No. 3: In a central station, the main power supply, provided the fault condition is otherwise indicated so as to be obvious to the operator on duty.

Exception No. 4: The output of an engine-driven generator that is part of the secondary power supply, provided the generator is tested weekly in accordance with Chapter 7.

1-5.8.7.2* Power supply sources and electrical supervision for digital alarm communications systems shall be in accordance with 1-5.2 and 1-5.8.1.

1-5.8.7.3 The primary power failure trouble signal for the DACT shall not be transmitted until the actual battery capacity is depleted by at least 25 percent, but not by more than 50 percent.

1-6 Documentation.

1-6.1 Approval and Acceptance.

1-6.1.1 The authority having jurisdiction shall be notified prior to installation or alteration of equipment or wiring. At its request, complete information regarding the system or system alterations, including specifications, wiring diagrams, battery calculation, and floor plans shall be submitted for approval.

1-6.1.2 Before requesting final approval of the installation, if required by the authority having jurisdiction, the installing contractor shall furnish a written statement stating that the system has been installed in accordance with approved plans and tested in accordance with the manufacturer's specifications and the appropriate NFPA requirements.

1-6.1.3* The record of completion form, Figure 1-6.2.1, shall be permitted to be a part of the written statement required in 1-6.1.2. When more than one contractor has been responsible for the installation, each contractor shall complete the portions of the form for which that contractor had responsibility.

1-6.2 Completion Documents.

1-6.2.1* A record of completion (*Figure 1-6.2.1*) shall be prepared for each system. Parts 1, 2, and 4 through 10 shall be completed after the system is installed and the installation wiring has been checked. Part 3 shall be completed after the operational acceptance tests have been completed. A preliminary copy of the record of completion shall be given to the system owner and, if requested, to other authorities having jurisdiction after completion of the installation wiring tests. A final copy shall be provided after completion of the operational acceptance tests.

1-6.2.1.1 All fire alarm systems that are modified after the initial installation shall have the original record of completion revised to show all changes from the original information and shall include a revision date.

Figure 1-6.2.1 Record of completion.

FIRE ALARM SYSTEM RECORD OF COMPLETION

Name of protected property: _____

Address: _____

Representative of protected property (name/phone): _____

Authority having jurisdiction: _____

Address/telephone number: _____

1. Type(s) of System or Service

_____ NFPA 72, Chapter 3 — Local

If alarm is transmitted to location(s) off premises, list where received: _____

_____ NFPA 72, Chapter 3 — Emergency Voice/Alarm Service

Quantity of voice/alarm channels: _____ Single: _____ Multiple: _____

Quantity of speakers installed: _____ Quantity of speaker zones: _____

Quantity of telephones or telephone jacks included in system: _____

_____ NFPA 72, Chapter 6 — Auxillary

Indicate type of connection:

_____ Local energy _____ Shunt _____ Parallel telephone

Location of telephone number for receipt of signals: _____

_____ NFPA 72, Chapter 5 — Remote Station

Alarm: _____

Supervisory: _____

_____ NFPA 72, Chapter 5 — Proprietary

If alarms are retransmitted to public fire service communications centers or others, indicate location and telephone numbers of the organization receiving alarm: _____

Indicate how alarm is retransmitted: _____

_____ NFPA 72, Chapter 5 — Central Station

Prime contractor: _____

Central station location: _____

Means of transmission of signals from the protected premises to the central station:

_____ McCulloh _____ Multiplex _____ One-way radio

_____ Digital alarm communicator _____ Two-way radio _____ Others

Means of transmission of alarms to the public fire service communications center:

(a) _____

(b) _____

System location: _____

(NFPA Record of Completion 1 of 4)

Figure 1-6.2.1 (Continued)

	Organization name/phone	Representative name/phone
Installer	_____	_____
Supplier	_____	_____
Service organization	_____	_____
Location of record (as-built) drawings: _____		
Location of owners manuals: _____		
Location of test reports: _____		
A contract, dated _____, for test and inspection in accordance with NFPA standard(s)		
No(s). _____, dated _____, is in effect.		

2. Record of System Installation

(Fill out after installation is complete and wiring checked for opens, shorts, ground faults, and improper branching, but prior to conducting operational acceptance tests.)

This system has been installed in accordance with the NFPA standards as shown below, was inspected by _____ on _____, includes the devices shown below, and has been in service since _____.

___ NFPA 72, Chapters 1 2 3 4 5 6 7 (circle all that apply)

___ NFPA 70, *National Electrical Code*, Article 760

___ Manufacturer's instructions

___ Other (specify): _____

Signed: _____ Date: _____

Organization: _____

3. Record of System Operation

All operational features and functions of this system were tested by _____ on _____, and found to be operating properly in accordance with the requirements of:

___ NFPA 72, Chapters 1 2 3 4 5 6 7 (circle all that apply)

___ NFPA 70, *National Electrical Code*, Article 760

___ Manufacturer's instructions

___ Other (specify): _____

Signed: _____ Date: _____

Organization: _____

4. Alarm-Initiating Devices and Circuits

Quantity and class of initiating device circuits (see NFPA 72, Table 3-5) Quantity: _____ Style: _____ Class: _____

MANUAL

(a) _____ Manual stations _____ Noncoded, activating _____ Transmitters _____ Coded

(b) _____ Combination manual fire alarm and guard's tour coded stations

AUTOMATIC

Coverage: Complete: _____ Partial: _____

(a) _____ Smoke detectors _____ Ion _____ Photo

(b) _____ Duct detectors _____ Ion _____ Photo

(c) _____ Heat detectors _____ FT _____ RR _____ FT/RR _____ RC

Figure 1-6.2.1 (Continued)

- (d) _____ Sprinkler waterflow switches: _____ Transmitters _____ Noncoded, activating _____ Coded
- (e) _____ Other (list): _____

5. Supervisory Signal-Initiating Devices and Circuits (use blanks to indicate quantity of devices)

GUARD'S TOUR

- (a) _____ Coded stations
- (b) _____ Noncoded stations, activating _____ transmitters
- (c) _____ Compulsory guard tour system comprised of _____ transmitter stations and _____ intermediate stations

Note: Combination devices are recorded under 4(b) and 5(a).

SPRINKLER SYSTEM

- (a) _____ Coded valve supervisory signaling attachments
Value supervisory switches, activating _____ transmitters
- (b) _____ Building temperature points
- (c) _____ Site water temperature points
- (d) _____ Site water supply level points

Electric fire pump:

- (e) _____ Fire pump power
- (f) _____ Fire pump running
- (g) _____ Phase reversal

Engine-driven fire pump:

- (h) _____ Selector in auto position
- (i) _____ Engine or control panel trouble
- (j) _____ Fire pump running

Engine-driven generator:

- (k) _____ Selector in auto position
- (l) _____ Control panel trouble
- (m) _____ Transfer switches
- (n) _____ Engine running

Other supervisory function(s) (specify): _____

6. Alarm Notification Appliances and Circuits

Quantity and class (see NFPA 72, Table 3-7) of notification appliance circuits connected to the system:

Types and quantities of notification appliances installed: Quantity: _____ Style: _____ Class: _____

- (a) _____ Bells _____ Inch
- (b) _____ Speakers
- (c) _____ Horns
- (d) _____ Chimes
- (e) _____ Other: _____

1-6.2.2 Every system shall include the following documentation, which shall be delivered to the owner or the owner's representative upon final acceptance of the system:

- (1) *An owner's manual and installation instructions covering all system equipment
- (2) Record drawings

1-6.2.3 Central Station Fire Alarm Systems. It shall be conspicuously indicated by the prime contractor (*see Chapter 4*) that the fire alarm system providing service at a protected premises complies with all applicable requirements of this code by providing a means of verification as specified in either 1-6.2.3.1 or 1-6.2.3.2.

1-6.2.3.1 The installation shall be certificated.

1-6.2.3.1.1 Central station fire alarm systems providing service that complies with all requirements of this code shall be certificated by the organization that has listed the prime contractor, and a document attesting to this certification shall be located on or near the fire alarm system control unit or, where no control unit exists, on or near a fire alarm system component.

1-6.2.3.1.2 A central repository of issued certification documents, accessible to the authority having jurisdiction, shall be maintained by the organization that has listed the central station.

1-6.2.3.2 The installation shall be placarded.

1-6.2.3.2.1 Central station fire alarm systems providing service that complies with all requirements of this code shall be conspicuously marked by the prime contractor to indicate compliance. The marking shall be by means of one or more securely affixed placards.

1-6.2.3.2.2 The placard(s) shall be 20 in.² (130 cm²) or larger, shall be located on or near the fire alarm system control unit or, where no control unit exists, on or near a fire alarm system component, and shall identify the central station and, where applicable, the prime contractor by name and telephone number.

1-6.3 Records. A complete, unalterable record of the tests and operations of each system shall be kept until the next test and for 1 year thereafter. The record shall be available for examination and, if required, reported to the authority having jurisdiction. Archiving of records by any means shall be permitted if hard copies of the records can be provided promptly when requested.

Exception: If off-premises monitoring is provided, records of all signals, tests, and operations recorded at the supervising station shall be maintained for not less than 1 year.

Chapter 2 Initiating Devices

2-1 Introduction.

2-1.1 Scope. Chapter 2 shall cover minimum requirements for performance, selection, use, and location of automatic fire detection devices, sprinkler waterflow detectors, manually activated fire alarm stations, and supervisory signal initiating devices, including guard tour reporting used to ensure timely warning for the purposes of life safety and the protection of a building, space, structure, area, or object.

Detector requirements in dwelling units shall be determined in accordance with Chapter 8.

2-1.2 Purpose.

2-1.2.1 The material in Chapter 2 shall be intended for use by persons knowledgeable in the application of fire detection and fire alarm systems and services.

2-1.2.2 Automatic and manual initiating devices shall contribute to life safety, fire protection, and property conservation only if used in conjunction with other equipment. The interconnection of these devices with control equipment configurations and power supplies, or with output systems responding to external actuation, shall be detailed elsewhere in this code or in other NFPA codes and standards.

2-1.3 Installation and Required Location of Initiating Devices.

2-1.3.1 Where subject to mechanical damage, an initiating device shall be protected. A mechanical guard used to protect a smoke or heat detector shall be listed for use with the detector being used.

2-1.3.2 In all cases, initiating devices shall be supported independently of their attachment to the circuit conductors.

2-1.3.3 Initiating devices shall be installed in all areas where required by other NFPA codes and standards or the authority having jurisdiction. Each installed initiating device shall be accessible for periodic maintenance and testing.

2-1.3.4* Connection to the Fire Alarm System. Duplicate terminals, leads, or connectors that provide for the connection of installation wiring, shall be provided on each initiating device for the express purpose of connecting into the fire alarm system to monitor the integrity of the signaling and power wiring.

Exception: Initiating devices connected to a system that provides the required monitoring.

2-1.4 Requirements for Smoke and Heat Detectors.

2-1.4.1 Detectors shall not be recessed into the mounting surface in any manner.

Exception: If tested and listed for such recessed mounting.

2-1.4.2* Detector Coverage.

2-1.4.2.1 Total (Complete) Coverage. If required, total coverage shall include all rooms, halls, storage areas, basements, attics, lofts, spaces above suspended ceilings, and other subdivisions and accessible spaces; and the inside of all closets, elevator shafts, enclosed stairways, dumbwaiter shafts, and chutes. Inaccessible areas shall not be required to be protected by detectors.

Exception No. 1: If inaccessible areas contain combustible material, they shall be made accessible and shall be protected by a detector(s).

Exception No. 2: Detectors shall not be required in combustible blind spaces if any of the following conditions exist:

(a) *Where the ceiling is attached directly to the underside of the supporting beams of a combustible roof or floor deck*

(b) *Where the concealed space is entirely filled with a noncombustible insulation (In solid joist construction, the insulation shall be required to fill only the space from the ceiling to the bottom edge of the joist of the roof or floor deck.)*

(c) *Where there are small, concealed spaces over rooms, provided any space in question does not exceed 50 ft² (4.6 m²) in area*

(d) In spaces formed by sets of facing studs or solid joists in walls, floors, or ceilings where the distance between the facing studs or solid joists is less than 6 in. (150 mm)

Exception No. 3: Detectors shall not be required below open grid ceilings if all of the following conditions exist:

(a) Openings of the grid are $1/4$ in. (6.4 mm) or larger in the least dimension.

(b) Thickness of the material does not exceed the least dimension.

(c) Openings constitute at least 70 percent of the area of the ceiling material.

Exception No. 4: Concealed, accessible spaces above suspended ceilings that are used as a return air plenum meeting the requirements of NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, where equipped with smoke detection at each connection from the plenum to the central air-handling system.

Exception No. 5: Detectors shall not be required underneath open loading docks or platforms and their covers and for accessible under-floor spaces if all of the following conditions exist:

(a) Space is not accessible for storage purposes or entrance of unauthorized persons and is protected against the accumulation of wind-borne debris.

(b) Space contains no equipment such as steam pipes, electric wiring, shafting, or conveyors.

(c) Floor over the space is tight.

(d) No flammable liquids are processed, handled, or stored on the floor above.

2-1.4.2.2* Partial Coverage. If required, partial detection systems shall be provided in all common areas and work spaces, such as corridors, lobbies, storage rooms, equipment rooms, and other tenantless spaces in those environments suitable for proper detector operation in accordance with this code.

2-1.4.2.3* Selective Coverage. Where codes, standards, laws, or authorities having jurisdiction require the protection of selected areas only, the specified areas shall be protected in accordance with this code.

2-1.4.2.4* Supplementary (Nonrequired) Coverage. Where installed, detection that is not required by an applicable law, code, or standard, whether total (complete), partial, or selective coverage, shall conform to the requirements of this code.

Exception: Spacing requirements of Chapter 2.

2-1.4.3 Where nonrequired detection devices are installed for a specific hazard, additional nonrequired detection devices shall not be required to be installed throughout an entire room or building.

2-2 Heat-Sensing Fire Detectors. Heat-sensing fire detectors shall be installed in all areas where required by other NFPA codes and standards or by the authority having jurisdiction.

2-2.1 Temperature Classification.

2-2.1.1 Color Coding.

2-2.1.1.1 Heat-sensing fire detectors of the fixed-temperature or rate-compensated, spot-type shall be classified as to the temperature of operation and marked with a color code in accordance with Table 2-2.1.1.1.

Exception: Heat-sensing fire detectors where the alarm threshold is field adjustable and that are marked with the temperature range.

2-2.1.1.2 If the overall color of a heat-sensing fire detector is the same as the color code marking required for that detector, one of the following arrangements, applied in a contrasting color and visible after installation, shall be employed:

- (1) Ring on the surface of the detector
- (2) Temperature rating in numerals at least $3/8$ in. (9.5 mm) high

2-2.1.2* A heat-sensing fire detector integrally mounted on a smoke detector shall be listed or approved for not less than 50-ft (15-m) spacing.

2-2.1.3* Heat-sensing fire detectors shall be marked with their operating temperature and thermal response coefficient as determined by the organization listing the device. The requirement for the marking of the thermal response coefficient shall have an effective date of July 1, 2002.

Table 2-2.1.1.1 Temperature Classification for Heat-Sensing Fire Detectors

Temperature Classification	Temperature Rating Range		Maximum Ceiling Temperature		Color Code
	°F	°C	°F	°C	
Low*	100 – 134	39 – 57	20 below	11 below	Uncolored
Ordinary	135 – 174	58 – 79	100	38	Uncolored
Intermediate	175 – 249	80 – 121	150	66	White
High	250 – 324	122 – 162	225	107	Blue
Extra high	325 – 399	163 – 204	300	149	Red
Very extra high	400 – 499	205 – 259	375	191	Green
Ultra high	500 – 575	260 – 302	475	246	Orange

*Intended only for installation in controlled ambient areas. Units shall be marked to indicate maximum ambient installation temperature.

2-2.2 Location.

2-2.2.1* Spot-type heat-sensing fire detectors shall be located on the ceiling not less than 4 in. (100 mm) from the sidewall or on the sidewalls between 4 in. and 12 in. (100 mm and 300 mm) from the ceiling.

Exception No. 1: In the case of solid joist construction, detectors shall be mounted at the bottom of the joists.

Exception No. 2: In the case of beam construction where beams are less than 12 in. (300 mm) in depth and less than 8 ft (2.4 m) on center, detectors shall be permitted to be installed on the bottom of beams.

2-2.2.2 Line-type heat detectors shall be located on the ceiling or on the sidewalls not more than 20 in. (500 mm) from the ceiling.

Exception No. 1: In the case of solid joist construction, detectors shall be mounted at the bottom of the joists.

Exception No. 2: In the case of beam construction where beams are less than 12 in. (300 mm) in depth and less than 8 ft (2.4 m) on center, detectors shall be permitted to be installed on the bottom of beams.

Exception No. 3: If a line-type detector is used in an application other than open area protection, the manufacturer's installation instructions shall be followed.

2-2.3* Temperature. Detectors having fixed-temperature or rate-compensated elements shall be selected in accordance with Table 2-2.1.1.1 for the maximum expected ambient ceiling temperature that can be expected.

The temperature rating of the detector shall be at least 20°F (11°C) above the maximum expected temperature at the ceiling.

2-2.4* Spacing.

2-2.4.1* Smooth Ceiling Spacing.

2-2.4.1.1 One of the following requirements shall apply:

- (1) The distance between detectors shall not exceed their listed spacing, and there shall be detectors within a distance of one-half the listed spacing, measured at a right angle, from all walls or partitions extending to within 18 in. (460 mm) of the ceiling.
- (2) All points on the ceiling shall have a detector within a distance equal to 0.7 times the listed spacing (0.7S). This is useful in calculating locations in corridors or irregular areas.

2-2.4.1.2* Irregular Areas. For irregularly shaped areas, the spacing between detectors shall be permitted to be greater than the listed spacing, provided the maximum spacing from a detector to the farthest point of a sidewall or corner within its zone of protection is not greater than 0.7 times the listed spacing.

2-2.4.2 Solid Joist Construction. The spacing of heat detectors, where measured at right angles to the solid joists, shall not exceed 50 percent of the smooth ceiling spacing permitted under 2-2.4.1.1 and 2-2.4.1.2.

2-2.4.3* Beam Construction. A ceiling shall be treated as a smooth ceiling if the beams project no more than 4 in. (100 mm) below the ceiling. If the beams project more than 4 in. (100 mm) below the ceiling, the spacing of spot-type heat detectors at right angles to the direction of beam travel shall be not more than two-thirds of the smooth ceiling spacing permitted under 2-2.4.1.1 and 2-2.4.1.2. If the

beams project more than 18 in. (460 mm) below the ceiling and are more than 8 ft (2.4 m) on center, each bay formed by the beams shall be treated as a separate area.

2-2.4.4 Sloping Ceilings.

2-2.4.4.1* Peaked. A row of detectors shall first be spaced and located at or within 3 ft (0.9 m) of the peak of the ceiling, measured horizontally. The number and spacing of additional detectors, if any, shall be based on the horizontal projection of the ceiling in accordance with the type of ceiling construction.

2-2.4.4.2* Shed. Sloping ceilings having a rise greater than 1 ft in 8 ft (1 m in 8 m) shall have a row of detectors located on the ceiling within 3 ft (0.9 m) of the high side of the ceiling measured horizontally, spaced in accordance with the type of ceiling construction. The remaining detectors, if any, shall be located in the remaining area on the basis of the horizontal projection of the ceiling.

2-2.4.4.3 For a roof slope of less than 30 degrees, all detectors shall be spaced using the height at the peak. For a roof slope of greater than 30 degrees, the average slope height shall be used for all detectors other than those located in the peak.

2-2.4.5 High Ceilings.

2-2.4.5.1* On ceilings 10 ft to 30 ft (3 m to 9.1 m) high, heat detector linear spacing shall be reduced in accordance with Table 2-2.4.5.1 prior to any additional reductions for beams, joists, or slope, where applicable.

Exception: Table 2-2.4.5.1 shall not apply to the following detectors, which rely on the integration effect:

- (a) Line-type electrical conductivity detectors (see A-1-4)
- (b) Pneumatic rate-of-rise tubing (see A-1-4)

In these cases, the manufacturer's recommendations shall be followed for appropriate alarm point and spacing.

Table 2-2.4.5.1 Heat Detector Spacing Reduction Based on Ceiling Height

Ceiling Height Above		Up to and Including		Multiply Listed Spacing by
ft	m	ft	m	
0	0	10	3.05	1.00
10	3.05	12	3.66	0.91
12	3.66	14	4.27	0.84
14	4.27	16	4.88	0.77
16	4.88	18	5.49	0.71
18	5.49	20	6.10	0.64
20	6.10	22	6.71	0.58
22	6.71	24	7.32	0.52
24	7.32	26	7.93	0.46
26	7.93	28	8.54	0.40
28	8.54	30	9.14	0.34

2-2.4.5.2* The minimum spacing of heat detectors shall not be required to be less than 0.4 times the height of the ceiling.

2-2.4.6 Appendix B shall be permitted to be used as one alternative design method for determining detector spacing.

2-3 Smoke-Sensing Fire Detectors.

2-3.1 General.

2-3.1.1* The purpose of Section 2-3 shall be to provide information to assist in design and installation of reliable early warning smoke detection systems for protection of life and property.

2-3.1.2 Section 2-3 shall cover general area application of smoke detectors in ordinary indoor locations.

2-3.1.3 For information on use of smoke detectors for control of smoke spread, the requirements of Section 2-10 shall apply.

2-3.1.4 For additional guidance in the application of smoke detectors for flaming fires of various sizes and growth rates in areas of various ceiling heights, refer to Appendix B.

2-3.2* Smoke detectors shall be installed in all areas where required by applicable laws, codes, or standards.

2-3.3* Sensitivity.

2-3.3.1 Smoke detectors shall be marked with their nominal production sensitivity (percent per foot obscuration), as required by the listing. The production tolerance around the nominal sensitivity also shall be indicated.

2-3.3.2 Smoke detectors that have provision for field adjustment of sensitivity shall have an adjustment range of not less than 0.6 percent per foot obscuration. If the means of adjustment is on the detector, a method shall be provided to restore the detector to its factory calibration. Detectors that have provision for program-controlled adjustment of sensitivity shall be permitted to be marked with their programmable sensitivity range only.

2-3.4 Location and Spacing.

2-3.4.1* General.

2-3.4.1.1 The location and spacing of smoke detectors shall result from an evaluation based on the guidelines detailed in this code and on engineering judgment. Some of the conditions that shall be included in the evaluation are the following:

- (1) Ceiling shape and surface
- (2) Ceiling height
- (3) Configuration of contents in the area to be protected
- (4) Burning characteristics of the combustible materials present
- (5) Ventilation
- (6) Ambient environment

2-3.4.1.2 If the intent is to protect against a specific hazard, the detector(s) shall be permitted to be installed closer to the hazard in a position where the detector can intercept the smoke.

2-3.4.2 Air Sampling-Type Smoke Detector. Each sampling port of an air sampling-type smoke detector shall be treated as a spot-type detector for the purpose of location and spacing. Maximum air sample transport time from the farthest sampling point shall not exceed 120 seconds.

2-3.4.3* Spot-Type Smoke Detectors.

2-3.4.3.1 Spot-type smoke detectors shall be located on the ceiling not less than 4 in. (100 mm) from a sidewall to the near edge or, if on a sidewall, between 4 in. and 12 in. (100 mm and 300 mm) down from the ceiling to the top of the detector. (Refer to Figure A-2-2.2.1.)

2-3.4.3.2* To minimize dust contamination, smoke detectors, where installed under raised floors, shall be mounted only in an orientation for which they have been listed.

2-3.4.4 Projected Beam-Type Smoke Detectors. Projected beam-type smoke detectors shall be located with their projected beams parallel to the ceiling and in accordance with the manufacturer's documented instructions. The effects of stratification shall be evaluated when locating the detectors.

Exception: Beams shall be permitted to be installed vertically or at any angle needed to afford protection of the hazard involved (for example, vertical beams through the open shaft area of a stairwell where there is a clear vertical space inside the handrails).

2-3.4.4.1 The beam length shall not exceed the maximum permitted by the equipment listing.

2-3.4.4.2 If mirrors are used with projected beams, the mirrors shall be installed in accordance with the manufacturer's documented instructions.

2-3.4.5 Smooth Ceiling Spacing.

2-3.4.5.1 Spot-Type Detectors.

2-3.4.5.1.1 On smooth ceilings, spacing of 30 ft (9.1 m) shall be permitted to be used as a guide. In all cases, the manufacturer's documented instructions shall be followed. Other spacing shall be permitted to be used depending on ceiling height, different conditions, or response requirements. For the detection of flaming fires, the guidelines in Appendix B shall be permitted to be used.

2-3.4.5.1.2* For smooth ceilings, all points on the ceiling shall have a detector within a distance equal to 0.7 times the selected spacing.

2-3.4.5.2* Projected Beam-Type Detectors. For location and spacing of projected beam-type detectors, the manufacturer's documented installation instructions shall be followed.

2-3.4.6* Solid Joist and Beam Construction. Solid joists over 1 ft (0.3 m) in depth shall be treated as beams for smoke detector spacing purposes.

2-3.4.6.1* Flat Ceilings. For ceiling heights of 12 ft (3.66 m) or lower, and beam or solid joist depths of 1 ft (0.3 m) or less, smooth ceiling spaces running in the direction parallel to the run of the beams or solid joists shall be used and one-half the smooth ceiling spacing shall be in the direction perpendicular to the run of the beams or solid joists. For beams over 1 ft (0.3 m) in depth, spot-type detectors shall be permitted to be located either on the ceiling or on the bottom of the beams.

For beam depths exceeding 1 ft (0.3 m) or for ceiling heights exceeding 12 ft (3.66 m), spot-type detectors shall be located on the ceiling in every beam pocket.

For solid joists, the detectors shall be located on the bottom of the joists.

2-3.4.6.2* Sloped Ceilings. For beamed ceilings with beams running parallel to (up) the slope, the spacing for flat beamed

ceilings shall be used. The ceiling height shall be taken as the average height over the slope. For slopes greater than 10 degrees, the detectors located at one-half the spacing from the low end shall not be required. Spacings shall be measured along a horizontal projection of the ceilings.

For beamed ceilings with beams running perpendicular to (across) the slope, the spacing for flat beamed ceilings shall be used. The ceiling height shall be taken as the average height over the slope.

For solid joists, the detectors shall be located on the bottom of the joists.

2-3.4.6.3 A projected beam-type smoke detector shall be equivalent to a row of spot-type smoke detectors for flat and sloped ceiling applications.

2-3.4.7* Peaked. Detectors shall first be spaced and located within 3 ft (0.9 m) of the peak, measured horizontally. The number and spacing of additional detectors, if any, shall be based on the horizontal projection of the ceiling.

2-3.4.8* Shed. Detectors shall first be spaced and located within 3 ft (0.9 m) of the high side of the ceiling, measured horizontally. The number and spacing of additional detectors, if any, shall be based on the horizontal projection of the ceiling.

2-3.4.9 Raised Floors and Suspended Ceilings. Spaces beneath raised floors and above suspended ceilings shall be treated as separate rooms for smoke detector spacing purposes. Detectors installed beneath raised floors or above suspended ceilings, or both, including raised floors and suspended ceilings used for environmental air, shall not be used in lieu of providing detection within the room.

2-3.4.9.1 Raised Floors. Detectors installed beneath raised floors shall be spaced in accordance with 2-3.4.1, 2-3.4.1.2, and 2-3.4.3.2. If the area beneath the raised floor is also used for environmental air, detector spacing shall also conform to 2-3.5.1 and 2-3.5.2.

2-3.4.9.2 Suspended Ceilings. Detector spacing above suspended ceilings shall conform to the requirements of 2-3.4 for the ceiling configuration. If detectors are installed in ceilings used for environmental air, detector spacing shall also conform to 2-3.5.1 and 2-3.5.2.

2-3.4.10 Partitions. Where partitions extend upward to within 18 in. (460 mm) of the ceiling, they shall not influence the spacing. Where the partition extends to within less than 18 in. (460 mm) of the ceiling, the effect of smoke travel shall be evaluated in the reduction of spacing.

2-3.5 Heating, Ventilating, and Air-Conditioning (HVAC).

2-3.5.1* In spaces served by air-handling systems, detectors shall not be located where airflow prevents operation of the detectors.

2-3.5.2 Plenums.

2-3.5.2.1 In under-floor spaces and above-ceiling spaces that are used as HVAC plenums, detectors shall be listed for the anticipated environment as required by 2-3.6.1.1. Detector spacings and locations shall be selected based on anticipated airflow patterns and fire type.

2-3.5.2.2* Detectors placed in environmental air ducts or plenums shall not be used as a substitute for open area detectors. If detectors are used for the control of smoke spread, the

requirements of Section 2-10 shall apply. If open area protection is required, 2-3.4 shall apply.

2-3.6 Special Considerations.

2-3.6.1 The selection and placement of smoke detectors shall take into account both the performance characteristics of the detector and the areas into which the detectors are to be installed to prevent nuisance alarms or improper operation after installation. Paragraphs 2-3.6.1.1 through 2-3.6.1.3 shall apply.

2-3.6.1.1* Smoke detectors shall not be installed if any of the following ambient conditions exist:

- (1) Temperature below 32°F (0°C)
- (2) Temperature above 100°F (38°C)
- (3) Relative humidity above 93 percent
- (4) Air velocity greater than 300 ft/min (1.5 m/sec)

Exception: Detectors specifically designed for use in ambient conditions beyond the limits of 2-3.6.1.1(1) through (4) and listed for the temperature, humidity, and air velocity conditions expected.

2-3.6.1.2* The location of smoke detectors shall be based on an evaluation of potential ambient sources of smoke, moisture, dust, or fumes, and electrical or mechanical influences to minimize nuisance alarms.

2-3.6.1.3 Detectors shall not be installed until after the construction cleanup of all trades is complete and final.

Exception: Where required by the authority having jurisdiction for protection during construction. Detectors that have been installed during construction and found to have a sensitivity outside the listed and marked sensitivity range shall be cleaned or replaced in accordance with Chapter 7 at completion of construction.

2-3.6.1.4* Stratification. The effect of stratification below the ceiling shall be taken into account. The guidelines in Appendix B shall be permitted to be used.

2-3.6.2 Spot-Type Detectors.

2-3.6.2.1 Smoke detectors that have a fixed temperature element as part of the unit shall be selected in accordance with Table 2-2.1.1.1 for the maximum ceiling temperature expected in service.

2-3.6.2.2* Holes in the back of a detector shall be covered by a gasket, sealant, or equivalent means, and the detector shall be mounted so that airflow from inside or around the housing does not prevent the entry of smoke during a fire or test condition.

2-3.6.3 Projected Beam-Type Detectors.

2-3.6.3.1 Projected beam-type detectors and mirrors shall be mounted on stable surfaces to prevent false or erratic operation due to movement. The beam shall be designed so that small angular movements of the light source or receiver do not prevent operation due to smoke and do not cause nuisance alarms.

2-3.6.3.2* The light path of projected beam-type detectors shall be kept clear of opaque obstacles at all times.

2-3.6.4 Air Sampling-Type Detectors.

2-3.6.4.1* Sampling pipe networks shall be designed on the basis of and shall be supported by sound fluid dynamic principles to ensure required performance. Network design details shall include calculations showing the flow characteristics of the pipe network and each sample port.

2-3.6.4.2* Air-sampling detectors shall give a trouble signal if the airflow is outside the manufacturer's specified range. The sampling ports and in-line filter, if used, shall be kept clear in accordance with the manufacturer's documented instructions.

2-3.6.4.3 Air-sampling network piping and fittings shall be airtight and permanently fixed. Sampling system piping shall be conspicuously identified as SMOKE DETECTOR SAMPLING TUBE. DO NOT DISTURB, as follows:

- (1) At changes in direction or branches of piping
- (2) At each side of penetrations of walls, floors, or other barriers
- (3) At intervals on piping that provide visibility within the space, but no greater than 20 ft (6 m)

2-3.6.5* High Rack Storage. Where smoke detectors are installed to actuate a suppression system, NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

2-3.6.6 High Air-Movement Areas.

2-3.6.6.1 General. The purpose and scope of 2-3.6.6 shall be to provide location and spacing guidance for smoke detectors intended for early warning of fire in high air-movement areas.

Exception: Detectors provided for the control of smoke spread are covered by the requirements of Section 2-10.

2-3.6.6.2 Location. Smoke detectors shall not be located directly in the airstream of supply registers.

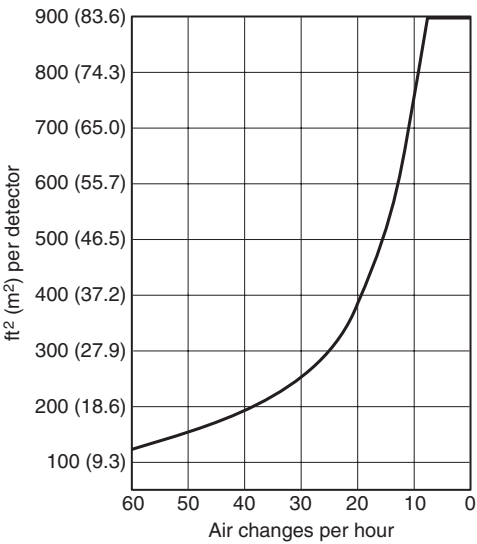
2-3.6.6.3* Spacing. Smoke detector spacing shall be in accordance with Table 2-3.6.6.3 and Figure 2-3.6.6.3.

Exception: Air-sampling or projected beam smoke detectors installed in accordance with the manufacturer's documented instructions.

Table 2-3.6.6.3 Smoke Detector Spacing Based on Air Movement

Minimum per Air Change	Air Changes per Hour	Spacing per Detector	
		ft ²	m ²
1	60	125	11.61
2	30	250	23.23
3	20	375	34.84
4	15	500	46.45
5	12	625	58.06
6	10	750	69.68
7	8.6	875	81.29
8	7.5	900	83.61
9	6.7	900	83.61
10	6	900	83.61

Figure 2-3.6.6.3 High air-movement areas (not to be used for under-floor or above-ceiling spaces).



2-4 Radiant Energy-Sensing Fire Detectors.

2-4.1* General. The purpose and scope of Section 2-4 shall be to provide standards for the selection, location, and spacing of fire detectors that sense the radiant energy produced by burning substances. These detectors are categorized as flame detectors and spark/ember detectors.

2-4.2* Fire Characteristics and Detector Selection.

2-4.2.1* The type and quantity of radiant energy-sensing fire detectors shall be determined based on the performance characteristics of the detector and an analysis of the hazard, including the burning characteristics of the fuel, the fire growth rate, the environment, the ambient conditions, and the capabilities of the extinguishing media and equipment.

2-4.2.2* The selection of the radiant energy-sensing detectors shall be based on the following:

- (1) Matching of the spectral response of the detector to the spectral emissions of the fire or fires to be detected
- (2) Minimizing the possibility of spurious nuisance alarms from non-fire sources inherent to the hazard area

2-4.3 Spacing Considerations.

2-4.3.1 General Rules.

2-4.3.1.1* Radiant energy-sensing fire detectors shall be employed consistent with the listing or approval and the inverse square law, which defines the fire size versus distance curve for the detector.

2-4.3.1.2 Detector quantity shall be based on the detectors being positioned so that no point requiring detection in the hazard area is obstructed or outside the field of view of at least one detector.

2-4.3.2 Spacing Considerations for Flame Detectors.

2-4.3.2.1* The location and spacing of detectors shall be the result of an engineering evaluation that includes the following:

- (1) Size of the fire that is to be detected
- (2) Fuel involved

- (3) Sensitivity of the detector
- (4) Field of view of the detector
- (5) Distance between the fire and the detector
- (6) Radiant energy absorption of the atmosphere
- (7) Presence of extraneous sources of radiant emissions
- (8) Purpose of the detection system
- (9) Response time required

2-4.3.2.2 The system design shall specify the size of the flaming fire of given fuel that is to be detected.

2-4.3.2.3* In applications where the fire to be detected could occur in an area not on the optical axis of the detector, the distance shall be reduced or detectors added to compensate for the angular displacement of the fire in accordance with the manufacturer's documented instructions.

2-4.3.2.4* In applications in which the fire to be detected is of a fuel that differs from the test fuel used in the process of listing or approval, the distance between the detector and the fire shall be adjusted consistent with the fuel specificity of the detector as established by the manufacturer.

2-4.3.2.5 Because flame detectors are line-of-sight devices, special care shall be taken to ensure that their ability to respond to the required area of fire in the zone that is to be protected is not compromised by the presence of intervening structural members or other opaque objects or materials.

2-4.3.2.6* Provisions shall be made to sustain detector window clarity in applications where airborne particulates and aerosols coat the detector window between maintenance intervals and affect sensitivity.

2-4.3.3 Spacing Considerations for Spark/Ember Detectors.

2-4.3.3.1* The location and spacing of detectors shall be the result of an engineering evaluation that includes the following:

- (1) Size of the spark or ember that is to be detected
- (2) Fuel involved
- (3) Sensitivity of the detector
- (4) Field of view of the detector
- (5) Distance between the fire and the detector
- (6) Radiant energy absorption of the atmosphere
- (7) Presence of extraneous sources of radiant emissions
- (8) Purpose of the detection systems
- (9) Response time required

2-4.3.3.2* The system design shall specify the size of the spark or ember of the given fuel that the detection system is to detect.

2-4.3.3.3 Spark detectors shall be positioned so that all points within the cross section of the conveyance duct, conveyor, or chute where the detectors are located are within the field of view (as defined in Section 1-4) of at least one detector.

2-4.3.3.4* The location and spacing of the detectors shall be adjusted using the inverse square law, modified for the atmospheric absorption and the absorption of nonburning fuel suspended in the air in accordance with the manufacturer's documented instructions.

2-4.3.3.5* In applications where the sparks to be detected could occur in an area not on the optical axis of the detector, the distance shall be reduced or detectors added to compensate for the angular displacement of the fire in accordance with the manufacturer's documented instructions.

2-4.3.3.6* Provisions shall be made to sustain the detector window clarity in applications where airborne particulates and aerosols coat the detector window and affect sensitivity.

2-4.4 Other Considerations.

2-4.4.1 Radiant energy-sensing detectors shall be protected either by way of design or installation to ensure that optical performance is not compromised.

2-4.4.2 If necessary, radiant energy-sensing detectors shall be shielded or otherwise arranged to prevent action from unwanted radiant energy.

2-4.4.3 Where used in outdoor applications, radiant energy-sensing detectors shall be shielded or otherwise arranged in a fashion to prevent diminishing sensitivity by conditions such as rain or snow and yet allow a clear field of vision of the hazard area.

2-4.4.4 A radiant energy-sensing fire detector shall not be installed in a location where the ambient conditions are known to exceed the extremes for which the detector has been listed.

2-5 Other Fire Detectors.

2-5.1 Detectors that operate on principles different from those covered by Sections 2-2, 2-3, and 2-4 shall be classified as *other fire detectors*. Such detectors shall be installed in all areas where they are required either by other NFPA codes and standards or by the authority having jurisdiction.

2-5.2 "Other fire detectors" shall operate where subjected to the abnormal concentration of combustion effects that occur during a fire, such as water vapor, ionized molecules, or other phenomena for which they are designed. Detection depends on the size and intensity of fire to provide the necessary quantity of required products and related thermal lift, circulation, or diffusion for operation.

2-5.3* Room sizes and contours, airflow patterns, obstructions, and other characteristics of the protected hazard shall be taken into account.

2-5.4 Location and Spacing.

2-5.4.1 The location and spacing of detectors shall be based on the principle of operation and an engineering survey of the conditions anticipated in service. The manufacturer's technical bulletin shall be consulted for recommended detector uses and locations.

2-5.4.2 Detectors shall not be spaced beyond their listed or approved maximums. Closer spacing shall be used where the structural or other characteristics of the protected hazard warrant.

2-5.4.3 The location and sensitivity of the detectors shall be the result of an engineering evaluation that includes the following:

- (1) Structural features, size, and shape of the rooms and bays
- (2) Occupancy and uses of the area
- (3) Ceiling height
- (4) Ceiling shape, surface, and obstructions
- (5) Ventilation
- (6) Ambient environment
- (7) Burning characteristics of the combustible materials present
- (8) Configuration of the contents in the area to be protected

2-6 Sprinkler Waterflow Alarm-Initiating Devices.

2-6.1 The provisions of Section 2-6 shall apply to devices that initiate an alarm indicating a flow of water in a sprinkler system.

2-6.2* Initiation of the alarm signal shall occur within 90 seconds of waterflow at the alarm-initiating device when flow occurs that is equal to or greater than that from a single sprinkler of the smallest orifice size installed in the system. Movement of water due to waste, surges, or variable pressure shall not be indicated.

2-6.3 Piping between the sprinkler system and a pressure actuated alarm-initiating device shall be galvanized or of nonferrous metal or other approved corrosion-resistant material of not less than $\frac{3}{8}$ in. (9.5 mm) nominal pipe size.

2-7* Detection of the Operation of Other Automatic Extinguishing Systems. The operation of fire extinguishing systems or suppression systems shall initiate an alarm signal by alarm-initiating devices installed in accordance with their individual listings.

2-8 Manually Actuated Alarm-Initiating Devices. Manual fire alarm boxes shall be used only for fire alarm-initiating purposes. However, combination manual fire alarm boxes and guard's signaling stations shall be permitted.

2-8.1 Mounting. Each manual fire alarm box shall be securely mounted. The operable part of each manual fire alarm box shall be not less than $3\frac{1}{2}$ ft (1.1 m) and not more than $4\frac{1}{2}$ ft (1.37 m) above floor level.

2-8.2 Location and Spacing.

2-8.2.1 Manual fire alarm boxes shall be located throughout the protected area so that they are unobstructed and accessible.

2-8.2.2 Manual fire alarm boxes shall be located within 5 ft (1.5 m) of the exit doorway opening at each exit on each floor.

2-8.2.3 Manual fire alarm boxes shall be mounted on both sides of group openings over 40 ft (12.2 m) in width. Manual fire alarm boxes shall be mounted within 5 ft (1.5 m) of each side of the opening.

2-8.2.4* Additional manual fire alarm boxes shall be provided so that the travel distance to the nearest fire alarm box will not be in excess of 200 ft (61 m) measured horizontally on the same floor.

2-8.3* A coded manual fire alarm box shall produce at least three repetitions of the coded signal, with each repetition to consist of at least three impulses.

2-9 Supervisory Signal-Initiating Devices.

2-9.1 Control Valve Supervisory Signal-Initiating Device.

2-9.1.1 Two separate and distinct signals shall be initiated: one indicating movement of the valve from its normal position and the other indicating restoration of the valve to its normal position. The off-normal signal shall be initiated during the first two revolutions of the hand wheel or during one-fifth of the travel distance of the valve control apparatus from its normal position. The off-normal signal shall not be restored at any valve position except normal.

2-9.1.2 An initiating device for supervising the position of a control valve shall not interfere with the operation of the valve, obstruct the view of its indicator, or prevent access for valve maintenance.

2-9.2 Pressure Supervisory Signal-Initiating Device. Two separate and distinct signals shall be initiated: one indicating that the required pressure has increased or decreased and the other indicating restoration of the pressure to its normal value. The following requirements shall apply to pressure supervisory signal-initiating devices:

(a) A pressure tank supervisory signal-initiating device for a pressurized limited water supply, such as a pressure tank, shall indicate both high- and low-pressure conditions. A signal shall be initiated when the required pressure increases or decreases by 10 psi (70 kPa).

(b) A pressure supervisory signal-initiating device for a dry-pipe sprinkler system shall indicate both high- and low-pressure conditions. A signal shall be initiated when the pressure increases or decreases by 10 psi (70 kPa).

(c) A steam pressure supervisory signal-initiating device shall indicate a low-pressure condition. A signal shall be initiated prior to the pressure falling below 110 percent of the minimum operating pressure of the steam-operated equipment supplied.

(d) An initiating device for supervising the pressure of sources other than those specified in 2-9.2(a) through (c) shall be provided as required by the authority having jurisdiction.

2-9.3 Water Level Supervisory Signal-Initiating Device. Two separate and distinct signals shall be initiated: one indicating that the required water level has been lowered or raised and the other indicating restoration.

2-9.3.1 A pressure tank signal-initiating device shall indicate both high- and low-water level conditions. A signal shall be initiated when the water level falls 3 in. (76 mm) or rises 3 in. (76 mm).

2-9.3.2 A supervisory signal-initiating device for other than pressure tanks shall initiate a low-water level signal when the water level falls 12 in. (300 mm).

2-9.4 Water Temperature Supervisory Signal-Initiating Device. A temperature supervisory device for a water storage container exposed to freezing conditions shall initiate two separate and distinctive signals. One signal shall indicate a decrease in water temperature to 40°F (4.4°C) and the other shall indicate its restoration to above 40°F (4.4°C).

2-9.5 Room Temperature Supervisory Signal-Initiating Device. A room temperature supervisory device shall indicate a decrease in room temperature to 40°F (4.4°C) and its restoration to above 40°F (4.4°C).

2-10* Smoke Detectors for Control of Smoke Spread.

2-10.1* Smoke detectors installed and used to prevent smoke spread by initiating control of fans, dampers, doors, and other equipment shall be classified in the following manner:

- (1) Area detectors that are installed in the related smoke compartments
- (2) Detectors that are installed in the air duct systems

2-10.2* Detectors that are installed in the air duct system per 2-10.1(2) shall not be used as a substitute for open area protection. If open area protection is required, 2-3.4 shall apply.

2-10.3* Purposes.

2-10.3.1 To prevent the recirculation of dangerous quantities of smoke, a detector approved for air duct use shall be installed on the supply side of air-handling systems as required

by NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, and 2-10.4.2.1.

2-10.3.2 If smoke detectors are used to initiate selectively the operation of equipment to control smoke spread, the requirements of 2-10.4.2.2 shall apply.

2-10.3.3 If detectors are used to initiate the operation of smoke doors, the requirements of 2-10.6 shall apply.

2-10.3.4 If duct detectors are used to initiate the operation of smoke dampers within ducts, the requirements of 2-10.5 shall apply.

2-10.4 Application.

2-10.4.1 Area Detectors within Smoke Compartments. Area smoke detectors within smoke compartments shall be permitted to be used to control the spread of smoke by initiating appropriate operation of doors, dampers, and other equipment.

2-10.4.2* Smoke Detection for the Air Duct System.

2-10.4.2.1 Supply Air System. Where the detection of smoke in the supply air system is required by other NFPA standards, a detector(s) listed for the air velocity present and that is located in the supply air duct downstream of both the fan and the filters shall be installed.

Exception: Additional smoke detectors shall not be required to be installed in ducts where the air duct system passes through other smoke compartments not served by the duct.

2-10.4.2.2* Return Air System. If the detection of smoke in the return air system is required by other NFPA standards, a detector(s) listed for the air velocity present shall be located where the air leaves each smoke compartment, or in the duct system before the air enters the return air system common to more than one smoke compartment.

Exception No. 1: Where total coverage smoke detection is installed in all areas of the smoke compartment served by the return air system, installation of air duct detectors in the return air system shall not be required, provided their function is accomplished by the design of the area detection system.

Exception No. 2: Additional smoke detectors shall not be required to be installed in ducts where the air duct system passes through other smoke compartments not served by the duct.

2-10.5 Location and Installation of Detectors in Air Duct Systems.

2-10.5.1 Detectors shall be listed for the purpose for which they are being used.

2-10.5.2* Air duct detectors shall be installed in such a way as to obtain a representative sample of the airstream. This installation shall be permitted to be achieved by any of the following methods:

- (1) Rigid mounting within the duct
- (2) Rigid mounting to the wall of the duct with the sensing element protruding into the duct
- (3) Installation outside the duct with rigidly mounted sampling tubes protruding into the duct
- (4) Installation through the duct with projected light beam

2-10.5.3 Detectors shall be accessible for cleaning and shall be mounted in accordance with the manufacturer's instructions. Access doors or panels shall be provided in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

2-10.5.4 The location of all detectors in air duct systems shall be permanently and clearly identified and recorded.

2-10.5.5 Detectors mounted outside of a duct that employs sampling tubes for transporting smoke from inside the duct to the detector shall be designed and installed to allow verification of airflow from the duct to the detector.

2-10.5.6 Detectors shall be listed for operation over the complete range of air velocities, temperature, and humidity expected at the detector when the air-handling system is operating.

2-10.5.7 All penetrations of a return air duct in the vicinity of detectors installed on or in an air duct shall be sealed to prevent entrance of outside air and possible dilution or redirection of smoke within the duct.

2-10.5.8 Where in-duct smoke detectors are installed in concealed locations more than 10 ft (3 m) above the finished floor or in arrangements where the detector's alarm indicator is not visible to responding personnel, the detectors shall be provided with remote alarm indicators. Remote alarm indicators shall be installed in an accessible location and shall be clearly labeled to indicate both their function and the air-handling unit(s) associated with each detector (for example, In-Duct Smoke Detector Alarm).

Exception: Where the specific detector in alarm is indicated at the control unit.

2-10.6 Smoke Detectors for Door Release Service.

2-10.6.1 Smoke detectors that are part of an open area protection system covering the room, corridor, or enclosed space on each side of the smoke door and that are located and spaced as required by 2-3.4 shall be permitted to accomplish smoke door release service.

2-10.6.2 Smoke detectors that are used exclusively for smoke door release service shall be located and spaced as required by 2-10.6.

2-10.6.3 When smoke door release is accomplished directly from the smoke detector(s), the detector(s) shall be listed for releasing service.

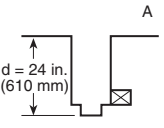
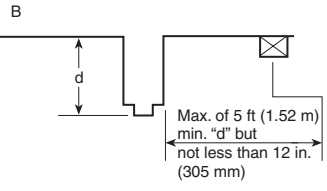
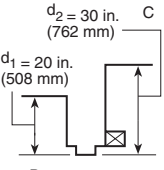
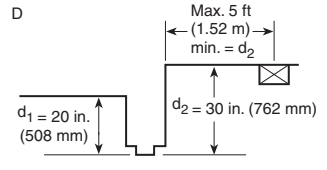
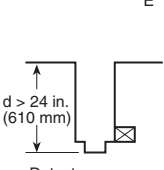
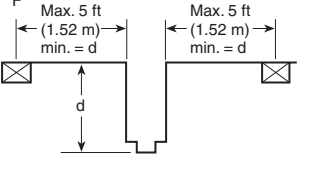
2-10.6.4 Smoke detectors shall be of the photoelectric, ionization, or other approved type.

2-10.6.5 Number of Detectors Required.

2-10.6.5.1 If doors are to be closed in response to smoke flowing in either direction, the requirements of 2-10.6.5.1.1 through 2-10.6.5.1.3 shall apply.

2-10.6.5.1.1 If the depth of wall section above the door is 24 in. (610 mm) or less, one ceiling-mounted detector shall be required on one side of the doorway only. Figure 2-10.6.5.1.1, parts B and D, shall apply.

Figure 2-10.6.5.1.1 Detector location requirements for wall sections.

Depth of wall section above door	Door frame mounted	Ceiling mounted
"d"	Smoke detector listed for frame mounting or as part of closer assembly	Smoke detector ceiling mounted
0-24 in. on both sides of doorway	 Detector or detector closer mounted on either side	 One detector mounted on either side
Over 24 in. on one side only	 Detector or detector closer mounted on higher side	 One detector mounted on higher side
Over 24 in. on both sides	 Detector or detector closer mounted on either side	 Two detectors required
Over 60 in. (1524 mm)	G Might require additional detectors	

2-10.6.5.1.2* If the depth of wall section above the door is greater than 24 in. (610 mm), two ceiling-mounted detectors shall be required, one on each side of the doorway. Figure 2-10.6.5.1.1, part F, shall apply.

2-10.6.5.1.3 If a detector is specifically listed for door frame mounting or if a listed combination or integral detector-door closer assembly is used, only one detector shall be required if installed in the manner recommended by the manufacturer.

2-10.6.5.2 If door release is intended to prevent smoke transmission from one space to another in one direction only, one detector located in the space to which smoke is to be confined shall be required, regardless of the depth of wall section above the door. Alternatively, a smoke detector conforming with 2-10.6.5.1.3 shall be permitted to be used.

2-10.6.5.3 If there are multiple doorways, additional ceiling-mounted detectors shall be required as specified in 2-10.6.5.3.1 through 2-10.6.5.3.3.

2-10.6.5.3.1 If the separation between doorways exceeds 24 in. (610 mm), each doorway shall be treated separately. Figure 2-10.6.5.3.1, part E, shall apply.

2-10.6.5.3.2 Each group of three doorway openings shall be treated separately. Figure 2-10.6.5.3.2 shall apply.

2-10.6.5.3.3 Each group of doorway openings that exceeds 20 ft (6.1 m) in width measured at its overall extremes shall be treated separately. Figure 2-10.6.5.3.3 shall apply.

2-10.6.5.4 If there are multiple doorways and listed door frame-mounted detectors or if listed combination or integral detector-door closer assemblies are used, there shall be one detector for each single or double doorway.

Figure 2-10.6.5.3.1 Detector location requirements for single and double doors.

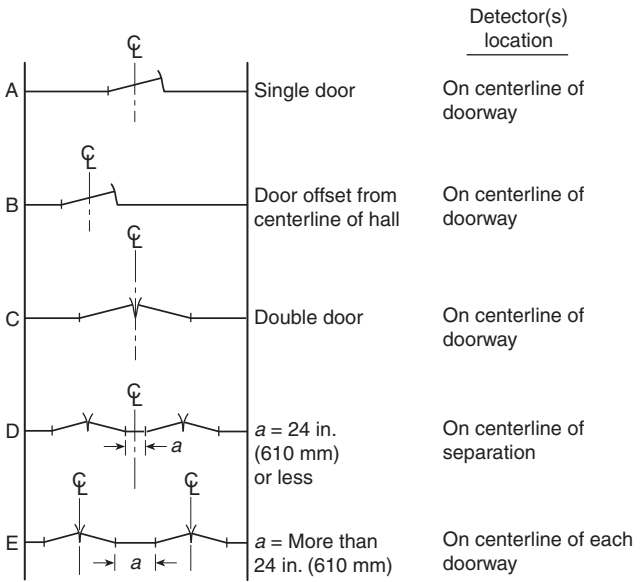


Figure 2-10.6.5.3.2 Detector location requirements for group doorways.

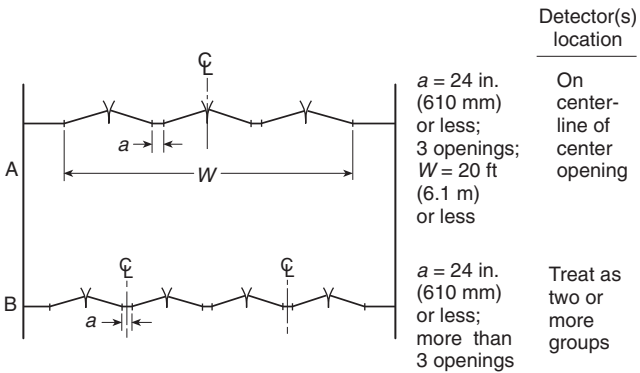
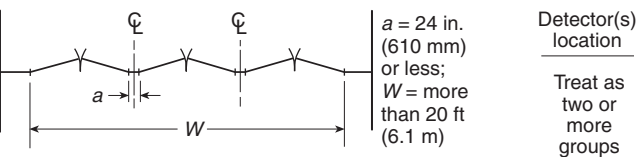


Figure 2-10.6.5.3.3 Detector location requirements for group doorways over 20 ft (6.1 m) in width.



2-10.6.6 Location.

2-10.6.6.1 If ceiling-mounted smoke detectors are to be installed on a smooth ceiling for a single or double doorway, they shall be located as follows (*Figure 2-10.6.5.3.1 shall apply.*):

- (1) On the centerline of the doorway
- (2) No more than 5 ft (1.5 m) measured along the ceiling and perpendicular to the doorway (*Figure 2-10.6.5.1.1 shall apply.*)
- (3) No closer than shown in Figure 2-10.6.5.1.1, parts B, D, and F

2-10.6.6.2 If ceiling-mounted detectors are to be installed in conditions other than those outlined in 2-10.6.6.1, an engineering evaluation shall be made.

Chapter 3 Protected Premises Fire Alarm Systems

3-1 Scope. Chapter 3 shall provide requirements for the application, installation, and performance of fire alarm systems, including fire alarm and supervisory signals, within protected premises.

3-2 General. The systems covered in Chapter 3 shall be used for the protection of life by automatically indicating the necessity for evacuation of the building or fire area, and for the protection of property through the automatic notification of responsible persons and for the automatic activation of fire safety functions. The requirements of Chapters 1, 2, 4, and 5 shall also apply, unless they are in conflict with this chapter.

3-2.1 Testing. All protected premises fire alarm systems shall be maintained and tested in accordance with Chapter 7.

3-2.2 Signal Annunciation. Protected premises fire alarm systems shall be arranged to annunciate alarm, supervisory, and trouble signals in accordance with 1-5.7.

3-2.3 Software and Firmware Control.

3-2.3.1 All software and firmware provided with a fire alarm system shall be listed for use with the fire alarm control unit.

3-2.3.2 A record of installed software and firmware version numbers shall be maintained at the location of the fire alarm control unit.

3-2.3.3* All software and firmware shall be protected from unauthorized changes.

3-2.3.4 All changes shall be tested in accordance with 7-1.6.2.

3-2.4 Nonrequired Systems.

3-2.4.1 Nonrequired protected premises systems shall meet the requirements of this code.

3-2.4.2 Nonrequired systems shall meet performance standards approved by the authority having jurisdiction.

3-3 Applications. Protected premises fire alarm systems shall include one or more of the following features:

- (1) Manual alarm signal initiation
- (2) Automatic alarm signal initiation
- (3) Monitoring of abnormal conditions in fire suppression systems
- (4) Activation of fire suppression systems
- (5) Activation of fire safety functions
- (6) Activation of alarm notification appliances
- (7) Emergency voice/alarm communications

- (8) Guard's tour supervisory service
- (9) Process monitoring supervisory systems
- (10) Activation of off-premises signals
- (11) Combination systems
- (12) Integrated systems

3-4 System Performance and Integrity.

3-4.1 Purpose. Section 3-4 shall provide information to be used in the design and installation of protected premises fire alarm systems for the protection of life and property.

3-4.2* Circuit Designations. Initiating device, notification appliance, and signaling line circuits shall be designated by class or style, or both, depending on the circuit's capability to continue to operate during specified fault conditions.

3-4.2.1 Class. Initiating device, notification appliance, and signaling line circuits shall be permitted to be designated as either Class A or Class B, depending on the capability of the circuit to transmit alarm and trouble signals during nonsimultaneous single circuit fault conditions as specified by the following:

- (1) Circuits capable of transmitting an alarm signal during a single open or a nonsimultaneous single ground fault on a circuit conductor shall be designated as Class A.
- (2) Circuits incapable of transmitting an alarm beyond the location of the fault conditions specified in 3-4.2.1(a) shall be designated as Class B.

Faults on both Class A and Class B circuits shall result in a trouble condition on the system in accordance with the requirements of 1-5.8.

3-4.2.2 Style.

3-4.2.2.1 Initiating device, notification appliance, and signaling line circuits shall be permitted to be designated by style so as to describe requirements in addition to the requirements shown for Class A or Class B according to the following:

- (1) An initiating device circuit shall be permitted to be designated as either Style A, B, C, D, or E, depending on its ability to meet the alarm and trouble performance requirements shown in Table 3-5, during a single open, single ground, wire-to-wire short, and loss-of-carrier fault condition.
- (2) A notification appliance circuit shall be permitted to be designated as either Style W, X, Y, or Z, depending on its ability to meet the alarm and trouble performance requirements shown in Table 3-7, during a single open, single ground, and wire-to-wire short fault condition.
- (3) A signaling line circuit shall be permitted to be designated as either Style 0.5, 1, 2, 3, 3.5, 4, 4.5, 5, 6, or 7, depending on its ability to meet the alarm and trouble performance requirements shown in Table 3-6, during a single open, single ground, wire-to-wire short, simultaneous wire-to-wire short and open, simultaneous wire-to-wire short and ground, simultaneous open and ground, and loss-of-carrier fault conditions.

3-4.2.2.2* All styles of Class A circuits using physical conductors (for example, metallic, optical fiber) shall be installed such that the outgoing and return conductors, exiting from and returning to the control unit, respectively, are routed separately. The outgoing and return (redundant) circuit conductors shall not be run in the same cable assembly (that is, multiconductor cable), enclosure, or raceway.

Exception: The outgoing and return (redundant) circuit conductors shall be permitted to be run in the same cable assembly, enclosure, or raceway under any of the following conditions:

(a) For a distance not to exceed 10 ft (3 m) where the outgoing and return conductors enter or exit the initiating device, notification appliance, or control unit enclosures.

(b) Where the vertically run conductors are contained in a 2-hour rated cable assembly or enclosed (installed) in a 2-hour rated enclosure.

(c) Where looped conduit/raceway systems are provided, single conduit/raceway drops to individual devices or appliances shall be permitted.

(d) Where looped conduit/raceway systems are provided, single conduit/raceway drops to multiple devices or appliances installed within a single room not exceeding 1000 ft² (92.9 m²) in area shall be permitted.

3-4.3 Signaling Paths.

3-4.3.1 The class or style of signaling paths (circuits) shall be determined from an evaluation based on the path performance detailed in this code and on engineering judgment.

3-4.3.2 When determining the integrity and reliability of the interconnecting signaling paths (circuits) installed within the protected premises, the following influences shall be considered:

- (1) Transmission media used
- (2) Length of the circuit conductors
- (3) Total building area covered by and the quantity of initiating devices and notification appliances connected to a single circuit
- (4) Effect of a fault in the fire alarm system on the objectives stated in Section 3-2
- (5) Nature of the hazard present within the protected premises
- (6) Functional requirements of the system necessary to provide the level of protection required for the system
- (7) Size and nature of the population of the protected premises

3-4.3.3 Results of the evaluation required by 3-4.3.1 shall be included with the documentation required by Section 1-6.

3-5* Performance of Initiating Device Circuits (IDC). The assignment of class designations or style designations, or both, to initiating device circuits shall be based on their performance capabilities under abnormal (fault) conditions in accordance with the requirements of Table 3-5.

3-6* Performance of Signaling Line Circuits (SLC). The assignment of class designations or style designations, or both, to signaling line circuits shall be based on their performance capabilities under abnormal (fault) conditions in accordance with the requirements of Table 3-6.

Table 3-5 Performance of Initiating Device Circuits (IDC)

Class	B			B			B			A			A		
Style	A			B			C			D			Eα		
	Alarm	Trouble	Alarm receipt capability during abnormal condition	Alarm	Trouble	Alarm receipt capability during abnormal condition	Alarm	Trouble	Alarm receipt capability during abnormal condition	Alarm	Trouble	Alarm receipt capability during abnormal condition	Alarm	Trouble	Alarm receipt capability during abnormal condition
Abnormal condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Single open	—	X	—	—	X	—	—	X	—	—	X	X	—	X	X
Single ground	—	X	—	—	X	R	—	X	R	—	X	R	—	X	R
Wire-to-wire short	X	—	—	X	—	—	—	X	—	X	—	—	—	X	—
Loss of carrier (if used)/ channel interface	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—

R = Required capacity

X = Indication required at protected premises and as required by Chapter 5

α = Style exceeds minimum requirements of Class A

Table 3-6 Performance of Signaling Line Circuits (SLC)

Class	B			B			A			B			B			B			B			A			A			A		
Style	0.5			1			2 α			3			3.5			4			4.5			5 α			6 α			7 α		
	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions	Alarm	Trouble	Alarm receipt capability during abnormal conditions
Abnormal condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Single open	—	X	—	—	X	—	—	X	R	—	X	—	—	X	—	—	X	—	—	X	R	—	X	R	—	X	R	—	X	R
Single ground	—	X	—	—	X	R	—	X	R	—	X	R	—	X	—	—	X	R	—	X	—	—	X	R	—	X	R	—	X	R
Wire-to-wire short	—	—	—	—	—	—	—	—	M	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	R
Wire-to-wire short & open	—	—	—	—	—	—	—	—	M	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—
Wire-to-wire short & ground	—	—	—	—	—	—	—	X	M	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—
Open and ground	—	—	—	—	—	—	—	X	R	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	X	—	X	R
Loss of carrier (if used)/channel interface	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—	—	X	—

M = May be capable of alarm with wire-to-wire short

R = Required capability

X = Indication required at protected premises and as required by Chapter 5

 α = Style exceeds minimum requirements for Class A

3-7 Performance of Notification Appliance Circuits (NAC). The assignment of class designations or style designations, or both, to notification appliance circuits shall be based on their performance capabilities under abnormal (fault) conditions in accordance with the requirements of Table 3-7.

Table 3-7 Notification Appliance Circuits (NAC)

Class	B		B		B		A	
Style	W		X		Y		Z	
Abnormal condition	Trouble indication at protected premises	Alarm capability during abnormal conditions	Trouble indication at protected premises	Alarm capability during abnormal conditions	Trouble indication at protected premises	Alarm capability during abnormal conditions	Trouble indication at protected premises	Alarm capability during abnormal conditions
	1	2	3	4	5	6	7	8
Single open	X	—	X	X	X	—	X	X
Single ground	X	—	X	—	X	X	X	X
Wire-to-wire short	X	—	X	—	X	—	X	—

X = Indication required at protected premises

3-8 System Requirements.

3-8.1* Fire Alarm Control Units. Fire alarm systems shall be permitted to be either integrated systems combining all detection, notification, and auxiliary functions in a single system or a combination of component subsystems. Fire alarm system components shall be permitted to share control equipment or shall be able to operate as stand alone subsystems, but, in any case, they shall be arranged to function as a single system. All component subsystems shall be capable of simultaneous, full load operation without degradation of the required, overall system performance.

3-8.1.1 The method of interconnection of control units shall meet the monitoring requirements of 1-5.8 and NFPA 70, *National Electrical Code*®, Article 760, and shall be achieved by the following recognized means:

- (1) Electrical contacts listed for the connected load
- (2) Listed digital data interfaces (such as serial communications ports and gateways)
- (3) Other listed methods

3-8.1.2 If approved by the authority having jurisdiction, interconnected control units providing localized detection, evacuation signaling, and auxiliary functions shall be permitted to be monitored by a fire alarm system as initiating devices.

3-8.1.2.1 Each interconnected control unit shall be separately monitored for alarm, trouble, and supervisory conditions.

3-8.1.2.2 Interconnected control unit alarm signals shall be permitted to be monitored by zone or by combined common signals.

3-8.1.3 Protected premises fire alarm control units shall be capable of being reset or silenced only from the control unit at the protected premises.

Exception: Where otherwise specifically permitted by the authority having jurisdiction.

3-8.1.4 Protected Premises Fire Alarm Systems Interconnected with Dwelling Unit Fire Warning Equipment.

3-8.1.4.1 A protected premises fire alarm system shall be permitted to be interconnected to dwelling unit fire warning equipment only for the purposes of transmitting an alarm from the protected premises fire alarm system to the dwelling unit fire warning system.

3-8.1.4.2 If interconnected, an alarm condition at the protected premises fire alarm system shall cause the alarm notification appliance(s) within the family living unit of the dwelling unit fire warning system to become energized. The notification appliances shall remain energized until the protected premises fire alarm system is silenced or reset.

3-8.1.4.3 The interconnection circuit or path from the protected premises fire alarm system to the dwelling unit fire warning system shall be monitored for integrity by the protected premises fire alarm system in accordance with 1-5.8.

3-8.1.4.4 An alarm condition occurring at the dwelling unit fire warning system or the operation of any test switches provided as part of the dwelling unit fire warning equipment shall not cause an alarm condition at the protected premises fire alarm system.

3-8.2 Combination Systems.

3-8.2.1* Fire alarm systems shall be permitted to share components, equipment, circuitry, and installation wiring with non-fire alarm systems.

3-8.2.2 If common wiring is used for combination systems, the equipment for non-fire alarm systems shall be permitted to be connected to the common wiring of the system. Short circuits, open circuits, or grounds in this equipment or between this equipment and the fire alarm system wiring shall not interfere with the monitoring for integrity of the fire alarm system or prevent alarm, supervisory, or fire safety control signal transmissions.

3-8.2.3 To maintain the integrity of fire alarm system functions, the provision for removal, replacement, failure, or maintenance procedure on any supplementary hardware, software, or circuit(s) shall not impair the required operation of the fire alarm system.

Exception: Where the hardware, software, or circuit(s) is listed for fire alarm use.

3-8.2.4 Speakers used as alarm notification appliances on fire alarm systems shall not be used for nonemergency purposes.

*Exception No. 1:** If the fire command center is constantly attended by a trained operator, selective paging shall be permitted as approved by the authority having jurisdiction.

*Exception No. 2:** If all of the following conditions are met:

(a) *The speakers and associated audio equipment are installed or located with safeguards to prevent tampering or misadjustment of those components essential to intended operation for fire.*

(b) *The monitoring integrity requirements of 1-5.8 and 3-8.4.1.3.2 shall continue to be met while the system is used for nonemergency purposes.*

(c) *It is permitted by the authority having jurisdiction.*

3-8.2.5 In combination systems, fire alarm signals shall be distinctive, clearly recognizable, and take precedence over any other signal even when a non-fire alarm signal is initiated first.

3-8.2.6 If the authority having jurisdiction determines that the information being displayed or annunciated on a combination system is excessive and is causing confusion and delayed response to a fire emergency, the authority having jurisdiction shall be permitted to require that the display or annunciation of information for the fire alarm system be separate from and have priority over information for the non-fire alarm systems.

3-8.3 Fire Alarm System Inputs.

3-8.3.1 General.

3-8.3.1.1 Fire alarm boxes, automatic alarm-initiating devices, and waterflow initiating devices shall be listed for the intended application, installed in accordance with Chapter 2, and tested in accordance with Chapter 7.

3-8.3.1.2 For fire alarm systems employing automatic fire detectors or waterflow detection devices, at least one fire alarm box shall be provided to initiate a fire alarm signal. This fire alarm box shall be located where required by the authority having jurisdiction.

Exception: Fire alarm systems dedicated to elevator recall control and supervisory service as permitted in 3-9.3.1.

3-8.3.1.3 Supervisory devices shall be installed in accordance with Chapter 2.

3-8.3.2 Alarm Signal Initiation.

3-8.3.2.1 Manual Fire Alarm Signal Initiation. Manual fire alarm signal initiation shall comply with the requirements of Section 2-8. If signals from fire alarm boxes and other fire alarm initiating devices within a building are transmitted over the same signaling line circuit, there shall be no interference with fire alarm box signals when both types of initiating devices are operated at the same time. Provision of the shunt noninterfering method of operation shall be permitted for this performance.

3-8.3.2.2 Automatic Fire Alarm Signal Initiation. Automatic fire alarm-signal initiation devices that have integral trouble signal contacts shall be connected to the initiating device circuit so that a trouble condition within a device does not impair alarm transmission from any other initiating device.

Exception: Where the trouble condition is caused by electrical disconnection of the device or by removing the initiating device from its plug-in base.

3-8.3.2.3 Detection Devices.

3-8.3.2.3.1* Systems equipped with alarm verification features shall be permitted, under the following conditions:

(a) The alarm verification feature is not initially enabled unless conditions or occupant activities that are expected to

cause nuisance alarms are anticipated in the area that is protected by the smoke detectors. Enabling of the alarm verification feature shall be protected by password or limited access.

(b) A smoke detector that is continuously subjected to a smoke concentration above alarm threshold does not delay the system functions of 1-5.4 by more than 1 minute.

(c) Actuation of an alarm initiating device other than a smoke detector causes the system functions of 1-5.4 without additional delay.

(d) When the alarm verification feature is enabled, disabled, or changed, the comments section of the Record of Completion (Figure 1-6.2.1, item 10) shall be used to record the status or change to system operation.

3-8.3.2.3.2 Automatic Drift Compensation. If automatic drift compensation of sensitivity for a fire detector is provided, the control unit shall identify the affected detector when the limit of compensation is reached.

3-8.3.2.3.3 Systems that require the operation of two automatic detectors to initiate the alarm response shall be permitted as follows:

- (1) The systems shall not be prohibited by the authority having jurisdiction.
- (2) There shall be at least two automatic detectors in each protected space.
- (3) The alarm verification feature shall not be used.

3-8.3.2.3.3.1 For systems that require the operation of two automatic detectors to initiate fire safety functions or to activate fire extinguishing or suppression systems, the detectors shall be installed at the spacing determined in accordance with Chapter 2.

3-8.3.2.3.3.2 For systems that require the operation of two automatic detectors to activate public mode notification, the detectors shall be installed at a linear spacing not more than 0.7 times the linear spacing determined in accordance with Chapter 2.

3-8.3.2.4 Waterflow Alarm Signal Initiation.

3-8.3.2.4.1 A dry-pipe or preaction sprinkler system that is supplied with water by a connection beyond the alarm-initiating device of a wet-pipe system shall be equipped with a separate waterflow alarm-initiating pressure switch or other approved means to initiate a waterflow alarm.

3-8.3.2.4.2 The number of waterflow switches permitted to be connected to a single initiating device circuit shall not exceed five.

3-8.3.2.5 Signal Initiation from Automatic Fire Suppression System Other than Waterflow.

3-8.3.2.5.1 The operation of an automatic fire suppression system installed within the protected premises shall cause an alarm signal at the protected premises fire alarm control unit.

3-8.3.2.5.2 The integrity of each fire suppression system actuating device and its circuit shall be supervised in accordance with 1-5.8.1 and with other applicable NFPA standards.

3-8.3.3 Supervisory Signal Initiation.

3-8.3.3.1 General. The provisions of 3-8.3.3 shall apply to the monitoring of sprinkler systems, other fire suppression systems, and other systems for the protection of life and property for the initiation of a supervisory signal indicating

an off-normal condition that could adversely affect the performance of the system.

3-8.3.3.1.1 The number of supervisory devices permitted to be connected to a single initiating device circuit shall not exceed 20.

3-8.3.3.1.2* Provisions shall be made for supervising the conditions that are essential for the operation of sprinkler and other fire suppression systems.

Exception: Those conditions related to water mains, tanks, cisterns, reservoirs, and other water supplies controlled by a municipality or a public utility.

3-8.3.3.1.3* Signals shall distinctively indicate the particular function (e.g., valve position, temperature, or pressure) of the system that is off-normal and also indicate its restoration to normal.

3-8.3.3.2 Pump Supervision. Automatic fire pumps and special service pumps shall be supervised in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and the authority having jurisdiction.

3-8.3.3.2.1 Supervision of electric power supplying the pump shall be made on the line side of the motor starter. All phases and phase reversal shall be supervised.

3-8.3.3.2.2 If both sprinkler supervisory signals and pump running signals are transmitted over the same path, the pump running signal shall have priority.

Exception: Where the path is so arranged such that simultaneous signals are not lost.

3-8.3.3.3 Automatic Fire Suppression System Panel Supervision.

3-8.3.3.3.1 A supervisory signal shall indicate the off-normal condition and its restoration to normal as required by the system employed.

3-8.3.3.3.2* If a valve is installed in the connection between an alarm-initiating device intended to signal activation of a fire suppression system and the fire suppression system, the valve shall be supervised in accordance with the requirements of Chapter 2.

3-8.3.4 Trouble Signal Initiation.

3-8.3.4.1 Automatic fire suppression system alarm-initiating devices and supervisory signal-initiating devices and their circuits shall be designed and installed so that they cannot be subject to tampering, opening, or removal without initiating a signal. This provision shall include junction boxes installed outside of buildings to facilitate access to the initiating device circuit.

Exception No. 1: Covers of junction boxes inside of buildings.

Exception No. 2: Tamperproof screws or other equivalent mechanical means shall be permitted for preventing access to junction boxes installed outside buildings.

3-8.3.4.2 The integrity of each fire suppression system actuating device and its circuit shall be supervised in accordance with 1-5.8.1 and with other applicable NFPA standards.

3-8.4 Fire Alarm System Outputs.

3-8.4.1 Occupant Notification. Fire alarm systems provided for evacuation or relocation of occupants shall have one or more notification appliances listed for the purpose on each floor of the building and so located such that they have the

characteristics described in Chapter 4 for public mode or private mode, as required.

Notification zones shall be consistent with the emergency response or evacuation plan for the protected premises. The boundaries of notification zones shall be coincident with building outer walls, building fire or smoke compartment boundaries, floor separations, or other fire safety subdivisions.

3-8.4.1.1 Survivability.

3-8.4.1.1.1 Paragraph 3-8.4.1.1 applies only to systems used for partial evacuation or relocation of occupants.

3-8.4.1.1.2 A single notification appliance circuit shall not serve more than one notification zone.

3-8.4.1.1.3* The system shall be designed so that failure of equipment or a fault on one or more installation wiring conductors of one notification appliance circuit shall not result in functional loss of any other notification appliance circuit.

3-8.4.1.1.4* Notification appliance circuits and any other circuits necessary for the operation of the notification appliance circuits shall be protected from the point at which they exit the control unit until the point that they enter the notification zone that they serve using one or more of the following methods:

- (1) A 2-hour rated cable assembly
- (2) A 2-hour rated shaft or enclosure
- (3) A 2-hour rated stairwell in a building fully sprinklered in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*

3-8.4.1.2* Distinctive Evacuation Signal.

3-8.4.1.2.1 To meet the requirements of 1-5.4.7, the fire alarm signal used to notify building occupants of the need to evacuate (leave the building) shall be in accordance with ANSI S3.41, *Audible Emergency Evacuation Signal*.

3-8.4.1.2.2 The use of the American national standard evacuation signal shall be restricted to situations where it is desired that all occupants hearing the signal evacuate the building immediately. It shall not be used where, with the approval of the authority having jurisdiction, the planned action during a fire emergency is not evacuation, but rather is the relocation of occupants or their protection in place as directed by fire-fighting personnel.

3-8.4.1.2.3* The American national standard evacuation signal shall be synchronized within a notification zone.

3-8.4.1.3 Emergency Voice/Alarm Communications. Emergency voice/alarm communications service shall be provided by a system with automatic or manual voice capability that is installed to provide voice instructions to the building occupants where it is intended that there be only partial or selective evacuation or directed relocation of building occupants in the event of a fire.

Exception: If emergency voice/alarm communications are used to automatically and simultaneously notify all occupants to evacuate the protected premises during a fire emergency, manual or selective paging shall not be required, but, if provided, shall meet the requirements of Section 3-8.4.1.3.

3-8.4.1.3.1 Application. Subparagraph 3-8.4.1.3 describes the requirements for emergency voice/alarm communications. The primary purpose is to provide dedicated manual and automatic facilities for the origination, control, and transmission of information and instructions pertaining to a fire alarm

emergency to the occupants (including fire department personnel) of the building. It shall be the intent of 3-8.4.1.3 to establish the minimum requirements for emergency voice/alarm communications.

3-8.4.1.3.2 Monitoring of the integrity of speaker amplifiers, tone-generating equipment, and two-way telephone communications circuits shall be in accordance with 1-5.8.6.

3-8.4.1.3.3 Fire Command Center Survivability.

3-8.4.1.3.3.1 A fire command center shall be provided in accordance with 3-8.4.1.3.3.

Exception: If emergency voice/alarm communications are used to automatically and simultaneously notify all occupants to evacuate the protected premises during a fire emergency, a fire command center shall not be required, but, if provided, shall meet the requirements of 3-8.4.1.3.

3-8.4.1.3.3.2 The fire command center and the central control unit shall be located within a minimum 1-hour rated fire-resistive area and shall have a minimum 3-ft (1-m) clearance from the front of the fire command center control equipment.

Exception: If approved by the authority having jurisdiction, the fire command center control equipment shall be permitted to be located in a lobby or other approved space.

3-8.4.1.3.3.3 If the fire command center control equipment is remote from the central control equipment, the following requirements shall apply:

- (1) The interconnecting wiring shall be provided with mechanical protection by installing the wiring in metal conduit or metal raceway.
- (2) The interconnecting wiring shall be provided with resistance to attack from a fire by routing the wiring through areas whose characteristics are at least equal to the limited-combustible characteristics defined in NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.
- (3) If the interconnecting wiring exceeds 100 ft (30 m), additional resistance to attack from a fire shall be provided by doing either of the following:
 - a. Installing the wiring in metal conduit or metal raceway in a 2-hour fire-rated enclosure
 - b. Enclosing the wiring in a 2-hour fire-rated cable assembly and installing the cable in metal conduit or metal raceway

3-8.4.1.3.4 Power Supplies.

3-8.4.1.3.4.1 The wiring between the central control equipment and the primary power supply shall be routed through areas whose characteristics are at least equal to the limited-combustible characteristics as defined in NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

3-8.4.1.3.4.2 The secondary (standby) power supply shall be provided in accordance with 1-5.2.5.

Exception: Where emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency in meeting the requirements of 1-5.2.5, the secondary supply shall be required to be capable of operating the system during a fire or other emergency condition for a period of 5 minutes rather than 2 hours.

3-8.4.1.3.5 Voice/Alarm Signaling Service.

3-8.4.1.3.5.1* General. The purpose of the voice/alarm signaling service shall be to provide an automatic response to the receipt of a signal indicative of a fire emergency. Subsequent manual control capability of the transmission and audible reproduction of evacuation tone signals, alert tone signals, and intelligible voice directions on a selective and all-call basis, as determined by the authority having jurisdiction, shall also be required from the fire command center.

Exception No. 1: If the fire command center or remote monitoring location is constantly attended by trained operators, and operator acknowledgment of receipt of a fire alarm signal is received within 30 seconds, automatic response shall not be required.

Exception No. 2: If emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency, the ability to give voice directions on a selective basis shall not be required but, if provided, shall meet the requirements of 3-8.4.1.3.

3-8.4.1.3.5.2 Multichannel Capability. If required by the authority having jurisdiction, the system shall allow the application of an evacuation signal to one or more zones and, at the same time, shall allow voice paging to the other zones selectively or in any combination.

3-8.4.1.3.5.3 Functional Sequence.

3-8.4.1.3.5.3.1 In response to an initiating signal indicative of a fire emergency, the system shall automatically transmit the following either immediately or after a delay acceptable to the authority having jurisdiction.

(a) If the emergency voice/alarm communications service is used to transmit a voice evacuation message, the voice message shall be preceded and followed by a minimum of two cycles of the audible emergency evacuation signal specified in 3-8.4.1.2.

(b) If the emergency voice/alarm communications service is used to transmit relocation instructions or other non-evacuation messages, a continuous alert tone of 3-second to 10-second duration followed by a message (or messages where multichannel capability is provided) shall be repeated at least three times to direct the occupants of the alarm signal initiation zone and other zones in accordance with the building's fire evacuation plan.

(c) An evacuation signal shall be transmitted to the alarm signal initiation zone and other zones in accordance with the building's fire evacuation plan.

Exception: If emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency, and the functional sequence described in 3-8.4.1.3.5.3.1(a) is provided, the capability to notify portions of the protected premises selectively shall not be required, but, if provided, shall meet the requirements of 3-8.4.1.3.

3-8.4.1.3.5.3.2 Failure of the message described by 3-8.4.1.3.5.3.1(a), if used, shall sound the evacuation signal automatically. Provisions for manual initiation of voice instructions or evacuation signal generation shall be provided.

Exception No. 1: Other functional sequences shall be permitted if approved by the authority having jurisdiction.

Exception No. 2: If emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency, provision for manual

initiation of voice instructions shall not be required, but, if provided, shall meet the requirements of 3-8.4.1.3.

3-8.4.1.3.5.3.3 Live voice instructions shall override all previously initiated signals on that channel and shall have priority over any subsequent automatically initiated signals on that channel. If multichannel application is required, subsequent alarms shall be activated in accordance with 3-8.4.1.3.5.2.

Exception: If emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency, the ability to give live voice instructions shall not be required, but, if provided, shall meet the requirements of 3-8.4.1.3.

3-8.4.1.3.5.3.4 If provided, manual controls for emergency voice/alarm communications shall be arranged to provide visible indication of the on-off status for their associated evacuation zones.

3-8.4.1.3.5.4 Voice and Tone Devices. The alert tone preceding any message shall be permitted to be a part of the voice message or to be transmitted automatically from a separate tone generator.

3-8.4.1.3.5.5 Fire Command Center.

3-8.4.1.3.5.5.1* A fire command center shall be provided at a building entrance or other location approved by the authority having jurisdiction. The fire command center shall provide a communications center for the arriving fire department and shall provide for control and display of the status of detection, alarm, and communications systems. The fire command center shall be permitted to be physically combined with other building operations and security centers as permitted by the authority having jurisdiction. Operating controls for use by the fire department shall be clearly marked.

3-8.4.1.3.5.5.2 The fire command center shall control the emergency voice/alarm communications signaling service and, if provided, the two-way telephone communications service. All controls for manual initiation of voice instructions and evacuation signals shall be located or secured to restrict access to trained and authorized personnel.

3-8.4.1.3.5.5.3* If there are multiple fire command centers, the center in control shall be identified by a visible indication at that center.

3-8.4.1.3.5.6 Loudspeakers.

3-8.4.1.3.5.6.1 Loudspeakers and their enclosures shall be installed in accordance with Chapter 4.

3-8.4.1.3.5.6.2* There shall be at least two loudspeakers located in each paging zone of the building. Each of the loudspeakers shall meet the requirements of Chapter 4.

3-8.4.1.3.5.6.3 Each elevator car shall be equipped with a single loudspeaker connected to the paging zone that serves the elevator group in which the elevator is located.

Exception: If permitted by the authority having jurisdiction, or if in existing elevator cars where two-way communications by approved means are provided between each elevator car and the fire command center.

3-8.4.1.3.5.6.4 Each enclosed stairway exceeding two stories in height shall be equipped with loudspeakers connected to a separate paging zone.

3-8.4.1.3.6 Evacuation Signal Zoning.

3-8.4.1.3.6.1* Undivided fire or smoke areas shall not be divided into multiple evacuation signaling zones.

3-8.4.1.3.6.2 If multiple notification appliance circuits are provided within a single evacuation signaling zone, all of the notification appliances within the zone shall be arranged to activate simultaneously, either automatically or by actuation of a common, manual control.

Exception: Where the different notification appliance circuits within an evacuation signaling zone perform separate functions, for example, pre-signal and general alarm signals, predischARGE and dischARGE signals.

3-8.4.1.3.7 Two-Way Telephone Communications Service.

3-8.4.1.3.7.1 Two-way telephone communications equipment shall be listed for two-way telephone communications service and installed in accordance with 3-8.4.1.3.7.

3-8.4.1.3.7.2 Two-way telephone communications service, if provided, shall be for use by the fire service. Additional uses, if specifically permitted by the authority having jurisdiction, shall be permitted to include signaling and communications for a building fire warden organization, signaling and communications for reporting a fire and other emergencies (for example, voice call box service, signaling, and communications for guard's tour service), and other uses. Variation of equipment and system operation provided to facilitate additional use of the two-way telephone communications service shall not adversely affect performance when used by the fire service.

3-8.4.1.3.7.3* Two-way telephone communications service shall be capable of permitting the simultaneous operation of any five telephone stations in a common talk mode.

3-8.4.1.3.7.4 A notification signal at the fire command center, distinctive from any other alarm or trouble signal, shall indicate the off-hook condition of a calling telephone circuit. If a selective talk telephone communications service is supplied, a distinctive visible indicator shall be furnished for each selectable circuit so that all circuits with telephones off-hook are continuously and visibly indicated.

Exception: If emergency voice/alarm communications are used to notify all occupants automatically and simultaneously to evacuate the protected premises during a fire emergency, signals from the two-way telephone system shall be required to indicate only at a location approved by the authority having jurisdiction.

3-8.4.1.3.7.5 A means for silencing the audible call-in signal sounding appliance shall be permitted, provided it is key-operated, in a locked cabinet, or provided with protection to prevent use by unauthorized persons. The means shall operate a visible indicator and sound a trouble signal whenever the means is in the silence position and there are no telephone circuits in an off-hook condition. If a selective talk system is used, such a switch shall be permitted, provided subsequent telephone circuits going off-hook operate the distinctive off-hook audible signal sounding appliance.

3-8.4.1.3.7.6 Minimum Systems. As a minimum (for fire service use only), two-way telephone systems shall be common talk (that is, a conference or party line circuit), providing at least one telephone station or jack per floor and at least one telephone station or jack per exit stairway. In buildings equipped with a fire pump(s), a telephone station or jack shall be provided in each fire pump room.

3-8.4.1.3.7.7 Fire Warden Use. If the two-way telephone system is intended to be used by fire wardens in addition to the fire service, the minimum requirement shall be a selective talk system (where phones are selected from the fire command center). Systems intended for fire warden use shall provide telephone stations or jacks as required for fire service use and additional telephone stations or jacks as necessary to provide at least one telephone station or jack in each voice paging zone. Telephone circuits shall be selectable from the fire command center either individually or, if approved by the authority having jurisdiction, by floor or stairwell.

3-8.4.1.3.7.8 If the control equipment provided does not indicate the location of the caller (common talk systems), each telephone station or telephone jack shall be clearly and permanently labeled to allow the caller to identify his or her location to the fire command center by voice.

3-8.4.1.3.7.9 If telephone jacks are provided, two or more portable handsets, as determined by the authority having jurisdiction, shall be stored at the fire command center for use by emergency responders.

3-8.4.2* Signal Annunciation.

3-8.4.2.1 Protected premises fire alarm systems shall be arranged to annunciate alarm, supervisory, and trouble signals in accordance with 1-5.7.

3-8.4.2.2 Concealed Detectors. If a remote alarm indicator is provided for an automatic fire detector in a concealed location, the location of the detector and the area protected by the detector shall be prominently indicated at the remote alarm indicator by a permanently attached placard or by other approved means.

3-8.4.3 Suppression System Actuation.

3-8.4.3.1 If automatic or manual activation of a fire suppression system is to be performed through a fire alarm control unit, the control unit shall be listed for releasing service.

3-8.4.3.2 Each releasing device (for example, solenoid, relay) shall be monitored for integrity (supervised) in accordance with applicable NFPA standards.

3-8.4.3.3 The integrity of the installation wiring shall be monitored in accordance with the requirements of Chapter 1.

3-8.4.3.4 Fire alarm systems used for fire suppression releasing service shall be provided with a disconnect switch to allow the system to be tested without activating the fire suppression systems. Operation of the disconnect switch shall cause a trouble signal at the fire alarm control unit.

3-8.4.3.5 Sequence of operation shall be consistent with the applicable suppression system standards.

3-8.4.3.6* Each space protected by an automatic fire suppression system actuated by the fire alarm system shall contain one or more automatic fire detectors installed in accordance with Chapter 2.

3-8.4.3.7 Suppression systems or groups of systems shall be controlled by a single control unit that monitors the associated initiating device(s), actuates the associated releasing device(s), and controls the associated agent release notification appliances. If the releasing panel is located in a protected premises having a separate fire alarm system, it shall be monitored by, but shall not be dependent on or affected by, the

operation or failure of the protected premises fire alarm system.

Exception: If the configuration of multiple control units is listed for releasing device service, and if a trouble condition or manual disconnect on either control unit causes a trouble or supervisory signal, the initiating devices on one control unit shall be permitted to actuate releasing devices on another control unit.

3-8.4.3.8 Fire alarm systems performing suppression system releasing functions shall be installed in such a manner that they are effectively protected from damage caused by activation of the suppression system(s) they control.

3-8.4.4 Off-Premises Signals.

3-8.4.4.1 Systems requiring transmission of signals to continuously attended locations providing supervising station service (for example, central station, proprietary, supervising station, remote supervising station) shall also comply with the applicable requirements of Chapter 5.

3-8.4.4.2 Trouble Signals to Supervising Station.

3-8.4.4.2.1 Relays or modules providing transmission of trouble signals to a supervising station shall be arranged to provide fail-safe operation.

3-8.4.4.2.2 Means provided to transmit trouble signals to supervising stations shall be arranged so as to transmit a trouble signal to the supervising station for any trouble condition received at the protected premises control unit, including loss of primary or secondary power.

3-8.5 Guard's Tour Supervisory Service.

3-8.5.1 Guard's tour reporting stations shall be listed for the application.

3-8.5.2 The number of guard's tour reporting stations, their locations, and the route to be followed by the guard for operating the stations shall be approved for the particular installation in accordance with NFPA 601, *Standard for Security Services in Fire Loss Prevention*.

3-8.5.3 A permanent record indicating every time each signal-transmitting station is operated shall be made at the main control unit. Where intermediate stations that do not transmit a signal are employed in conjunction with signal-transmitting stations, distinctive signals shall be transmitted at the beginning and end of each tour of a guard, and a signal-transmitting station shall be provided at intervals not exceeding 10 stations. Intermediate stations that do not transmit a signal shall be capable of operation only in a fixed sequence.

3-8.6 Suppressed (Exception Reporting) Signal System.

3-8.6.1 The suppressed signal system shall comply with the provisions of 3-8.5.2.

3-8.6.2 The system shall transmit a start signal to the signal-receiving location and shall be initiated by the guard at the start of continuous tour rounds.

3-8.6.3 The system shall automatically transmit a delinquency signal within 15 minutes after the predetermined actuation time if the guard fails to actuate a tour station as scheduled.

3-8.6.4 A finish signal shall be transmitted within a predetermined interval after the guard's completion of each tour of the premises.

3-8.6.5 For periods of over 24 hours during which tours are continuously conducted, a start signal shall be transmitted at least every 24 hours.

3-8.6.6 The start, delinquency, and finish signals shall be recorded at the signal-receiving location.

3-9 Protected Premises Fire Safety Functions.

3-9.1 Scope. The provisions of Section 3-9 shall cover the minimum requirements for the interconnection of protected premises fire safety functions (for example, fan control, door control) to the fire alarm system in accordance with 1-5.4.1.

3-9.2 General.

3-9.2.1 A listed relay or other listed appliance connected to the fire alarm system used to initiate control of protected premises fire safety functions shall be located within 3 ft (1 m) of the controlled circuit or appliance. The relay or other appliance shall function within the voltage and current limitations of the fire alarm control unit. The installation wiring between the fire alarm control unit and the relay or other appliance shall be monitored for integrity.

Exception: Relays or appliances that operate on loss of power shall be considered self-monitoring for integrity.

3-9.2.2 Fire safety functions shall not interfere with other operations of the fire alarm system.

3-9.2.3 The method(s) of interconnection between the fire alarm system and controlled electrical and mechanical systems shall be monitored for integrity in accordance with 1-5.8; shall comply with the applicable provisions of NFPA 70, *National Electrical Code*, Article 760; and shall be achieved by one of the following recognized means:

- (1) Electrical contacts listed for the connected load
- (2) Listed digital data interfaces, such as serial communications ports and gateways
- (3) Other listed methods

3-9.2.4 Fire safety function control devices and gateways shall be listed as compatible with the fire alarm control unit so as to prevent interference with control unit operation caused by controlled devices and to ensure transmission of data to operate the controlled devices.

3-9.2.5 If a fire alarm system is a component of a life safety network, and it communicates data to other systems providing life safety functions or it receives data from such systems, the following shall apply:

(a) The path used for communicating data shall be monitored for integrity. This shall include monitoring the physical communication media and the ability to maintain intelligible communications.

(b) Data received from the network shall not affect the operation of the fire alarm system in any way other than to display the status of life safety network components.

(c) Where non-fire alarm systems are interconnected to the fire alarm system using a network or other digital communication technique, a signal (for example, heartbeat, poll, ping, query) shall be generated between the fire alarm system and the non-fire alarm system. Failure of proper receipt by the fire alarm system of confirmation of the transmission shall indicate a trouble signal within 200 seconds.

3-9.2.6 The operation of all fire safety functions shall be verified by an operational test at the time of system acceptance.

3-9.3 Elevator Recall for Fire Fighters' Service.

3-9.3.1* System-type smoke detectors located in elevator lobbies, elevator hoistways, and elevator machine rooms used to initiate fire fighters' service recall shall be connected to the building fire alarm system. In facilities without a building fire alarm system, these smoke detectors shall be connected to a dedicated fire alarm system control unit that shall be designated as "elevator recall control and supervisory panel," permanently identified on the control unit and on the record drawings. Unless otherwise required by the authority having jurisdiction, only the elevator lobby, elevator hoistway, and the elevator machine room smoke detectors shall be used to recall elevators for fire fighters' service.

3-9.3.2 Each elevator lobby, elevator hoistway, and elevator machine room smoke detector shall be capable of initiating elevator recall when all other devices on the same initiating device circuit have been manually or automatically placed in the alarm condition.

3-9.3.3 A lobby smoke detector shall be located on the ceiling within 21 ft (6.4 m) of the centerline of each elevator door within the elevator bank under control of the detector.

Exception: For lobby ceiling configurations exceeding 15 ft (4.6 m) in height or that are other than flat and smooth, detector locations shall be determined in accordance with Chapter 2.

3-9.3.4 Smoke detectors shall not be installed in elevator hoistways.

Exception No. 1: Where the top of the elevator hoistway is protected by automatic sprinklers.

Exception No. 2: Where a smoke detector is installed to activate the elevator hoistway smoke relief equipment.

3-9.3.5 If ambient conditions prohibit installation of automatic smoke detection, other automatic fire detection shall be permitted.

3-9.3.6 When actuated, each elevator lobby, elevator hoistway, and elevator machine room smoke detector shall initiate an alarm condition on the building fire alarm system and shall visibly indicate, at the control unit and required remote annunciators, the alarm initiation circuit or zone from which the alarm originated. Actuation from elevator hoistway and elevator machine room smoke detectors shall cause separate and distinct visible annunciation at the control unit and required annunciators to alert fire fighters and other emergency personnel that the elevators are no longer safe to use. Actuation of these detectors shall not be required to actuate the system notification appliances where the alarm signal is indicated at a constantly attended location.

Exception: If approved by the authority having jurisdiction, the elevator hoistway and machine room smoke detectors shall be permitted to initiate a supervisory signal.

3-9.3.7* For each group of elevators within a building, three separate elevator control circuits shall be terminated at the designated elevator controller within the group's elevator machine room(s). The operation of the elevators shall be in accordance with Rules 211.3 through 211.8 of ANSI/ASME A17.1, *Safety Code for Elevators and Escalators*. The smoke detectors shall actuate the three elevator control circuits as follows:

(a) The smoke detector located in the designated elevator recall lobby shall actuate the first elevator control circuit. In addition, if the elevator is equipped with front and rear doors,

the smoke detectors in both lobbies at the designated level shall actuate the first elevator control circuit.

(b) The smoke detectors in the remaining elevator lobbies shall actuate the second elevator control circuit.

(c) The smoke detectors in elevator hoistways and the elevator machine room(s) shall actuate the third elevator control circuit. In addition, if the elevator machine room is located at the designated level, its smoke detector shall also actuate the first elevator control circuit.

3-9.4 Elevator Shutdown.

3-9.4.1* Where heat detectors are used to shut down elevator power prior to sprinkler operation, the detector shall have both a lower temperature rating and a higher sensitivity as compared to the sprinkler.

3-9.4.2 If heat detectors are used to shut down elevator power prior to sprinkler operation, they shall be placed within 2 ft (610 mm) of each sprinkler head and be installed in accordance with the requirements of Chapter 2. Alternatively, engineering methods, such as specified in Appendix B, shall be permitted to be used to select and place heat detectors to ensure response prior to any sprinkler head operation under a variety of fire growth rate scenarios.

3-9.4.3* If pressure or waterflow switches are used to shut down elevator power immediately upon or prior to the discharge of water from sprinklers, the use of devices with time delay switches or time delay capability shall not be permitted.

3-9.4.4* Control circuits to shut down elevator power shall be monitored for presence of operating voltage. Loss of voltage to the control circuit for the disconnecting means shall cause a supervisory signal to be indicated at the control unit and required remote annunciators.

3-9.5 Heating, Ventilation, and Air-Conditioning (HVAC) Systems.

3-9.5.1 The provisions of 3-9.5 shall apply to the basic method by which a fire alarm system interfaces with the HVAC systems.

3-9.5.2 If connected to the fire alarm system serving the protected premises, all detection devices used to cause the operation of HVAC systems smoke dampers, fire dampers, fan control, smoke doors, and fire doors shall be monitored for integrity in accordance with 1-5.8.

3-9.5.3 Connections between fire alarm systems and the HVAC system for the purpose of monitoring and control shall operate and be monitored in accordance with applicable NFPA standards. Smoke detectors mounted in the air ducts of HVAC systems shall initiate either an alarm signal at the protected premises or a supervisory signal at a constantly attended location or supervising station.

3-9.5.4 If the fire alarm control unit activates the HVAC system for the purpose of smoke control, the automatic alarm-initiating zones shall be coordinated with the smoke-control zones they actuate.

3-9.6 Door Release Service.

3-9.6.1 The provisions of 3-9.6 shall apply to the methods of connection of door hold-open release devices and to integral door hold-open release, closer, and smoke detection devices.

3-9.6.2 All detection devices used for door hold-open release service shall be monitored for integrity in accordance with 1-5.8.

Exception: Smoke detectors used only for door release and not for open area protection.

3-9.6.3 All door hold-open release and integral door release and closure devices used for release service shall be monitored for integrity in accordance with 3-9.2.

3-9.6.4 Magnetic door holders that allow doors to close upon loss of operating power shall not be required to have a secondary power source.

3-9.7 Door Unlocking Devices.

3-9.7.1 Any device or system intended to actuate the locking or unlocking of exits shall be connected to the fire alarm system serving the protected premises.

3-9.7.2 All exits connected in accordance with 3-9.7.1 shall unlock upon receipt of any fire alarm signal by means of the fire alarm system serving the protected premises.

Exception: Where otherwise required or permitted by the authority having jurisdiction or other codes.

3-9.7.3* All exits connected in accordance with 3-9.7.1 shall unlock upon loss of the primary power to the fire alarm system serving the protected premises. The secondary power supply shall not be utilized to maintain these doors in the locked condition.

3-9.7.4 If exit doors are unlocked by the fire alarm system, the unlocking function shall occur prior to or concurrent with activation of any public-mode notification appliances in the area(s) served by the normally locked exits.

3-10* Special Requirements for Low-Power Radio (Wireless) Systems.

3-10.1* Compliance with Section 3-10 shall require the use of low-power radio equipment specifically listed for the purpose.

3-10.2 Power Supplies. A primary battery (dry cell) shall be permitted to be used as the sole power source of a low-power radio transmitter where all of the following conditions are met:

(a) Each transmitter shall serve only one device and shall be individually identified at the receiver/control unit.

(b) The battery shall be capable of operating the low-power radio transmitter for not less than 1 year before the battery depletion threshold is reached.

(c) A battery depletion signal shall be transmitted before the battery has depleted to a level insufficient to support alarm transmission after 7 additional days of non-alarm operation. This signal shall be distinctive from alarm, supervisory, tamper, and trouble signals; shall visibly identify the affected low-power radio transmitter; and, when silenced, shall automatically re-sound at least once every 4 hours.

(d) Catastrophic (open or short) battery failure shall cause a trouble signal identifying the affected low-power radio transmitter at its receiver/control unit. When silenced, the trouble signal shall automatically re-sound at least once every 4 hours.

(e) Any mode of failure of a primary battery in a low-power radio transmitter shall not affect any other low-power radio transmitter.

3-10.3 Alarm Signals.

3-10.3.1* When actuated, each low-power radio transmitter shall automatically transmit an alarm signal.

3-10.3.2 Each low-power radio transmitter shall automatically repeat alarm transmission at intervals not exceeding 60 seconds until the initiating device is returned to its non-alarm condition.

3-10.3.3 Fire alarm signals shall have priority over all other signals.

3-10.3.4 Low-power wireless systems shall comply with the requirements of 1-5.4.1.2 and 1-5.4.2.2.

3-10.3.5 An alarm signal from a low-power radio transmitter shall latch at its receiver/control unit until manually reset and shall identify the particular initiating device in alarm.

3-10.4 Monitoring for Integrity.

3-10.4.1 The low-power radio transmitter shall be specifically listed as using a transmission method that is highly resistant to misinterpretation of simultaneous transmissions and to interference (for example, impulse noise and adjacent channel interference).

3-10.4.2 The occurrence of any single fault that disables transmission between any low-power radio transmitter and the receiver/control unit shall cause a latching trouble signal within 200 seconds.

Exception: Where Federal Communications Commission (FCC) regulations prevent meeting the 200-second requirement, the time period for a low-power radio transmitter with only a single, connected alarm-initiating device shall be permitted to be increased to four times the minimum time interval permitted for a 1-second transmission up to the following:

(a) Four hours maximum for a transmitter serving a single initiating device

(b) Four hours maximum for a retransmission device (repeater) where disabling of the repeater or its transmission does not prevent the receipt of signals at the receiver/control unit from any initiating device transmitter

3-10.4.3 A single fault on the signaling channel shall not cause an alarm signal.

3-10.4.4 The periodic transmission required to comply with 3-10.4.2 from a low-power radio transmitter shall ensure successful alarm transmission capability.

3-10.4.5 Removal of a low-power radio transmitter from its installed location shall cause immediate transmission of a distinctive supervisory signal that indicates its removal and individually identifies the affected device.

Exception: This requirement shall not apply to dwelling unit fire warning systems.

3-10.4.6 Reception of any unwanted (interfering) transmission by a retransmission device (repeater) or by the main receiver/control unit, for a continuous period of 20 seconds or more, shall cause an audible and visible trouble indication at the main receiver/control unit. This indication shall identify the specific trouble condition as an interfering signal.

3-10.5 Suppression systems or groups of systems shall be controlled by a single control unit that monitors the associated initiating devices, actuates the associated releasing device(s), and

controls the associated agent release notification appliances. If the releasing panel is located in a protected premises having a separate fire alarm system, it shall be monitored for alarm, supervisory and trouble signals by, but shall not be dependent on or affected by, the operation or failure of the protected premises fire alarm system.

Exception: If the configuration of multiple control units is listed for releasing device service, and if a trouble condition or manual disconnect on either control unit causes a trouble or supervisory signal, the initiating devices on one control unit shall be permitted to actuate releasing devices on another control unit.

3-10.6 Fire alarm systems performing suppression system releasing functions shall be installed in such a manner that they are effectively protected from damage caused by activation of the suppression system(s) they control.

3-10.7 Output Signals from Receiver/Control. When the receiver/control is used to activate remote appliances, such as notification appliances and relays, by wireless means, the remote appliances shall meet the following requirements:

- (1) Power supplies shall comply with Chapter 1 or the requirements of 3-10.2.
- (2) All supervision requirements of Chapter 1, Chapter 3, or 3-10.4 shall apply.
- (3) The maximum allowable response delay from activation of an initiating device to activation of required alarm functions shall be 90 seconds.
- (4) Each receiver/control shall automatically repeat alarm transmission at intervals not exceeding 60 seconds or until confirmation that the output appliance has received the alarm signal.
- (5) The appliances shall continue to operate (latch-in) until manually reset at the receiver/control.

Chapter 4 Notification Appliances for Fire Alarm Systems

4-1* Scope.

4-1.1 Requirements. Chapter 4 shall cover requirements for the performance, location, and mounting of fire alarm system notification appliances used to initiate evacuation or relocation of the occupants, or for providing information to occupants or staff. Chapter 4 shall also cover the requirements for the performance, location, and mounting of annunciators, displays, and printers used to display or record information for use by protected premises occupants or staff, responding emergency personnel, or supervising station personnel.

4-1.2 Use. These requirements shall be used with other NFPA standards that deal specifically with fire alarm, extinguishment, or control systems. Notification appliances for fire alarm systems shall add to fire protection by providing stimuli for initiating emergency action.

4-1.3 All notification appliances installed in conformity with Chapter 4 shall be listed for the purpose for which they are used.

4-1.4 The requirements of Chapter 4 shall be intended to address the reception of a notification signal and not the signal's information content.

4-1.5 Interconnection of Appliances. The interconnection of appliances, the control configurations, the power supplies,

and the use of the information provided by notification appliances for fire alarm systems shall be described in Chapter 1 and Chapter 3.

4-2 General.

4-2.1 Nameplates.

4-2.1.1 Notification appliances shall include on their nameplates reference to electrical requirements and rated audible or visible performance, or both, as defined by the listing authority.

4-2.1.2 The audible appliances shall include on their nameplates reference to their parameters or reference to installation documents (supplied with the appliance) that include the parameters in accordance with 4-3.2. The visible appliances shall include on their nameplates reference to their parameters or reference to installation documents (supplied with the appliance) that include the parameters in accordance with 4-4.2.1.

4-2.2 Physical Construction. Appliances intended for use in special environments, such as, outdoors versus indoors, high or low temperatures, high humidity, dusty conditions, and hazardous locations, or where subject to tampering shall be listed for the intended application.

4-2.3* Mechanical Protection. If subject to obvious mechanical damage, appliances shall be suitably protected. If guards or covers are employed, they shall be listed for use with the appliance. Their effect on the appliance's field performance shall be in accordance with the listing requirements.

4-2.4 Mounting. In all cases, appliances shall be supported independently of their attachments to the circuit conductors and shall be mounted in accordance with the manufacturer's instruction.

4-2.5* Connection to the Fire Alarm System. Terminals or leads, or their equivalent, shall be provided on each notification appliance for the express purpose of connecting into the fire alarm system to monitor the integrity of the connections.

4-3 Audible Characteristics.

4-3.1 General Requirements.

4-3.1.1* An average ambient sound level greater than 105 dBA shall require the use of a visible signal appliance(s) in accordance with Section 4-4.

4-3.1.2 The total sound pressure level produced by combining the ambient sound pressure level with all audible signaling appliances operating shall not exceed 120 dBA anywhere in the occupied area.

4-3.1.3 Sound within the occupied area, from a temporary or abnormal source, shall not be required to be included in measuring maximum ambient sound level.

4-3.1.4* Mechanical Equipment Rooms. If audible appliances are installed in mechanical equipment rooms, the average ambient sound level used for design guidance shall be at least 85 dBA for all occupancies.

4-3.1.5* Emergency voice/alarm communications systems shall be capable of the reproduction of prerecorded, synthesized, or live (for example, microphone, telephone handset, and radio) messages with voice intelligibility.

4-3.2* Public Mode Audible Requirements.

4-3.2.1 Audible notification appliances intended for operation in the public mode shall have a sound level of not less than 75 dBA at 10 ft (3 m) or more than 120 dBA at the minimum hearing distance from the audible appliance.

4-3.2.2* To ensure that audible public mode signals are clearly heard, they shall have a sound level at least 15 dBA above the average ambient sound level or 5 dBA above the maximum sound level having a duration of at least 60 seconds, whichever is greater, measured 5 ft (1.5 m) above the floor in the occupiable area.

Exception No. 1: Audible alarm notification appliances installed in elevator cars shall be permitted to use the audibility criteria for private mode appliances detailed in 4-3.3.2.

Exception No. 2: If approved by the authority having jurisdiction, audible alarm notification appliances installed in restrooms shall be permitted to use the audibility criteria for private mode appliances detailed in 4-3.3.2.

Exception No. 3: If permitted by the authority having jurisdiction, a fire alarm system arranged to stop or reduce ambient noise shall be permitted to produce a sound level at least 15 dBA above the reduced average ambient sound level or 5 dBA above the maximum sound level having a duration of at least 60 seconds after reduction of the ambient noise level, whichever is greater, measured 5 ft (1.5 m) above the floor in the occupiable area. Visible notification appliances shall be installed in the affected areas in accordance with Sections 4-4 or 4-5. Relays, circuits, or interfaces necessary to stop or reduce ambient noise shall meet the requirements of Chapters 1 and 3.

4-3.3 Private Mode Audible Requirements.

4-3.3.1 Private Mode. Audible notification appliances intended for operation in the private mode shall have a sound level of not less than 45 dBA at 10 ft (3 m) or more than 120 dBA at the minimum hearing distance from the audible appliance.

4-3.3.2 To ensure that audible private mode signals are clearly heard, they shall have a sound level at least 10 dBA above the average ambient sound level or 5 dBA above the maximum sound level having a duration of at least 60 seconds, whichever is greater, measured 5 ft (1.5 m) above the floor in the occupiable area.

4-3.4 Sleeping Areas. Where audible appliances are installed to provide signals for sleeping areas, they shall have a sound level of at least 15 dBA above the average ambient sound level or 5 dBA above the maximum sound level having a duration of at least 60 seconds or a sound level of at least 70 dBA, whichever is greater, measured at the pillow level in the occupiable area. If any barrier, such as a door, curtain, or retractable partition, is located between the notification appliance and the pillow, the sound pressure level shall be measured with the barrier placed between the appliance and the pillow.

4-3.5 Location of Audible Notification Appliances.

4-3.5.1 If ceiling heights allow, wall-mounted appliances shall have their tops above the finished floors at heights of not less than 90 in. (2.30 m) and below the finished ceilings at heights of not less than 6 in. (152 mm). This requirement shall not preclude ceiling-mounted or recessed appliances.

Exception: Different mounting heights shall be permitted by the authority having jurisdiction provided the sound pressure level requirements of 4-3.2 and 4-3.3 are met.

4-3.5.2 If combination audible/visible appliances are installed, the location of the installed appliance shall be determined by the requirements of 4-4.4.

Exception: Where the combination audible/visible appliance serves as an integral part of a smoke detector, the mounting location shall be in accordance with Chapter 8.

4-4* Visible Characteristics, Public Mode.

4-4.1* There are two methods of visible signaling. These are methods in which the message of notification of an emergency condition is conveyed by direct viewing of the illuminating appliance or by means of illumination of the surrounding area. Public mode visible signaling shall meet the requirements of Section 4-4 using visible notification appliances.

4-4.2 Light Pulse Characteristics. The flash rate shall not exceed two flashes per second (2 Hz) nor be less than one flash every second (1 Hz) throughout the listed voltage range of the appliance.

4-4.2.1 A maximum pulse duration shall be 0.2 seconds with a maximum duty cycle of 40 percent. The pulse duration shall be defined as the time interval between initial and final points of 10 percent of maximum signal.

4-4.2.2* The light source color shall be clear or nominal white and shall not exceed 1000 cd (effective intensity).

4-4.3* Appliance Photometrics.

4-4.3.1 Visible notification appliances used in the public mode shall be located and shall be of a type, size, intensity, and number so that the operating effect of the appliance is seen by the intended viewers regardless of the viewer's orientation.

4-4.3.2 The light output shall comply with the polar dispersion requirements of UL 1971, *Standard for Safety Signaling Devices for the Hearing Impaired*, or equivalent.

4-4.4 Appliance Location. Wall-mounted appliances shall be mounted such that the entire lens is not less than 80 in. (2.03 m) and not greater than 96 in. (2.43 m) above the finished floor.

4-4.4.1* Spacing in Rooms.

4-4.4.1.1 Spacing shall be in accordance with Tables 4-4.4.1.1(a) and (b) and Figure 4-4.4.1.1.

Visible notification appliances shall be installed in accordance with Table 4-4.4.1.1(a), using one of the following:

- (1) *A single visible notification appliance.
- (2) Two visible notification appliances located on opposite walls.
- (3) *More than two appliances in any field of view, spaced a minimum of 55 ft (16.76 m) from each other in rooms 80 ft × 80 ft (24.4 m × 24.4 m) or greater.
- (4) More than two visible notification appliances in the same room or adjacent space within the field of view that flash in synchronization. This requirement shall not preclude synchronization of appliances that are not within the same field of view.

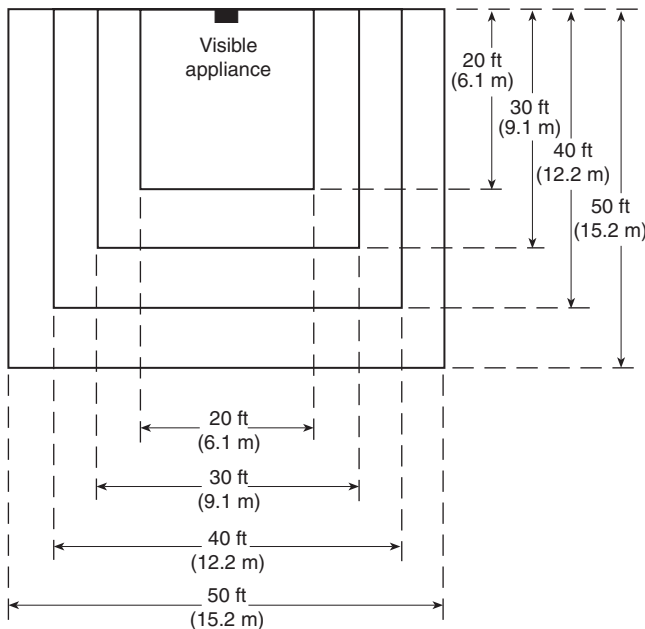
Table 4-4.4.1.1(a) Room Spacing for Wall-Mounted Visible Appliances

Maximum Room Size		Minimum Required Light Output (Effective Intensity) (cd)		
		One Light per Room	Two Lights per Room (Located on Opposite Wall)	Four Lights per Room; One Light per Wall
ft	m			
20 × 20	6.1 × 6.1	15	NA	NA
30 × 30	9.14 × 9.14	30	15	NA
40 × 40	12.2 × 12.2	60	30	15
50 × 50	15.2 × 15.2	95	60	30
60 × 60	18.3 × 18.3	135	95	30
70 × 70	21.3 × 21.3	185	95	60
80 × 80	24.4 × 24.4	240	135	60
90 × 90	27.4 × 27.4	305	185	95
100 × 100	30.5 × 30.5	375	240	95
110 × 110	33.5 × 33.5	455	240	135
120 × 120	36.6 × 36.6	540	305	135
130 × 130	39.6 × 39.6	635	375	185

NA: Not allowable.

Table 4-4.4.1.1(b) Room Spacing for Ceiling-Mounted Visible Appliances

Maximum Room Size		Maximum Ceiling Height		Minimum Required Light Output (Effective Intensity); One Light (cd)
ft	m	ft	m	
20 × 20	6.1 × 6.1	10	3.05	15
30 × 30	9.14 × 9.14	10	3.05	30
40 × 40	12.2 × 12.2	10	3.05	60
50 × 50	15.2 × 15.2	10	3.05	95
20 × 20	6.1 × 6.1	20	6.1	30
30 × 30	9.14 × 9.14	20	6.1	45
40 × 40	12.2 × 12.2	20	6.1	80
50 × 50	15.2 × 15.2	20	6.1	115
20 × 20	6.1 × 6.1	30	9.14	55
30 × 30	9.14 × 9.14	30	9.14	75
40 × 40	12.2 × 12.2	30	9.14	115
50 × 50	15.2 × 15.2	30	9.14	150

Figure 4-4.4.1.1 Room spacing for wall-mounted visible appliances.

Note: Figure 4-4.4.1.1 is based on locating the visible signaling appliance at the halfway distance of the longest wall. In square rooms with appliances not centered or nonsquare rooms, the effective intensity (cd) from one visible signaling appliance shall be determined by maximum room size dimensions obtained either by measuring the distance to the farthest wall or by doubling the distance to the farthest adjacent wall, whichever is greater, as shown in Table 4-4.4.1.1(a).

4-4.4.1.2 Room spacing for wall-mounted appliances shall be based on locating the visible notification appliance at the halfway distance of the longest wall. In square rooms with appliances not centered or nonsquare rooms, the effective intensity (cd) from one visible notification appliance shall be determined by maximum room size dimensions obtained either by measuring the distance to the farthest wall or by doubling the distance to the farthest adjacent wall, whichever is greater, as required by Table 4-4.4.1.1(a) and Figure 4-4.4.1.1.

4-4.4.1.3 If a room configuration is not square, the square room size that allows the entire room to be encompassed or allows the room to be subdivided into multiple squares shall be used.

4-4.4.1.4 If ceiling heights exceed 30 ft (9.14 m), visible notification appliances shall be suspended at or below 30 ft (9.14 m) or wall-mounted in accordance with Table 4-4.4.1.1(a).

4-4.4.1.5 Table 4-4.4.1.1(b) shall be used if the visible notification appliance is at the center of the room. If the visible notification appliance is not located at the center of the room, the effective intensity (cd) shall be determined by doubling the distance from the appliance to the farthest wall to obtain the maximum room size.

4-4.4.2* Spacing in Corridors.

4-4.4.2.1 Table 4-4.4.2.1 shall apply to corridors not exceeding 20 ft (6.1 m) in width. For corridors greater than 20 ft (6.1 m) wide, Figure 4-4.4.1.1 and Tables 4-4.4.1.1(a) and (b) shall apply. In a corridor application, visible appliances shall be rated not less than 15 cd.

Table 4-4.4.2.1 Corridor Spacing for Visible Appliances

Corridor Length		Minimum Number of 15-cd Visible Appliances Required
ft	m	
0 – 30	0 – 9.14	1
31 – 130	9.45 – 39.6	2
131 – 230	39.93 – 70	3
231 – 330	70.4 – 100.6	4
331 – 430	100.9 – 131.1	5
431 – 530	131.4 – 161.5	6

4-4.4.2.2* Visible notification appliances shall be located not more than 15 ft (4.57 m) from the end of the corridor with a separation not greater than 100 ft (30.4 m) between appliances. If there is an interruption of the concentrated viewing path, such as a fire door, an elevation change, or any other obstruction, the area shall be treated as a separate corridor.

4-4.4.2.3 In corridors where there are more than two visible notification appliances in any field of view, they shall be spaced a minimum of 55 ft (16.76 m) from each other or they shall flash in synchronization.

4-4.4.3 Sleeping Areas.

4-4.4.3.1 Combination smoke detectors and visible notification appliances shall be installed in accordance with the applicable requirements of Chapter 2, Chapter 4, and Chapter 8.

4-4.4.3.2* Table 4-4.4.3.2 shall apply to sleeping areas that have no linear dimension greater than 16 ft (4.87 m). For larger rooms, the visible notification appliance shall be located within 16 ft (4.87 m) of the pillow.

Table 4-4.4.3.2 Effective Intensity Requirements for Sleeping Area Visible Notification Appliances

Distance from Ceiling to Top of Lens		Intensity (cd)
in.	mm	
≥ 24	610	110
< 24	610	177

4-4.4.4* If visible notification appliances are required, a minimum of one appliance shall be installed in the concentrated viewing path.

4-5 Visible Characteristics, Private Mode. Visible notification appliances used in the private mode shall be of a sufficient quantity and intensity, and located so as to meet the intent of the user and the authority having jurisdiction.

4-6 Supplementary Visible Signaling Method. A supplementary visible notification appliance shall be intended to augment an audible or visible signal.

4-6.1 A supplementary visible notification appliance shall comply with its marked rated performance.

4-6.2 Supplementary visible notification appliances shall be permitted to be located less than 80 in. (2.03 m) above the floor.

4-7 Textual Audible Appliances.

4-7.1 Fire Alarm Speaker Appliances.

4-7.1.1 Fire alarm speaker appliances shall comply with Section 4-3.

4-7.1.2* The sound pressure level, in dBA, of the fire alarm speaker appliance evacuation tone signals of the particular mode installed (public or private) shall comply with all the requirements in 4-3.2 (public) or 4-3.3 (private).

4-7.2 Telephone Appliances.

4-7.2.1 Telephone appliances shall be in accordance with EIA Tr 41.3, *Telephones*.

4-7.2.2 Wall-mounted telephone appliances or related jacks shall be not less than 36 in. (914 mm) and not more than 66 in. (1676 mm) above floor level with clear access to the appliance that is at least 30 in. (762 mm) wide.

Exception: If accessible to the general public, one telephone appliance per location shall be not more than 48 in. (1219 mm) above floor level.

4-8* Textual Visible Appliances.

4-8.1 Application. Textual visible appliances shall be permitted if used in addition to audible or visible, or both, notification appliances.

4-8.2 Performance. The information produced by textual visible appliances shall be legible.

4-8.3 Location.

4-8.3.1 Private Mode. All textual visible notification appliances in the private mode shall be located in rooms that are accessible only to those persons directly concerned with the implementation and direction of emergency action initiation and procedure in the areas protected by the fire alarm system.

Exception: In locations where required by the authority having jurisdiction.

4-8.3.2 Public Mode. Textual visible notification appliances used in the public mode shall be located to ensure readability by the occupants or inhabitants of the protected area.

Chapter 5 Supervising Station Fire Alarm Systems

5-1* Scope. Chapter 5 shall cover the requirements for the performance, installation, and operation of fire alarm systems at a continuously attended supervising station and between the protected premises and the continuously attended supervising station.

5-2 Fire Alarm Systems for Central Station Service. The requirements of Chapters 1 and 7 and Section 5-5 shall apply to central station fire alarm systems, unless they conflict with the requirements of this section.

5-2.1 Scope. Section 5-2 shall describe the general requirements and use of fire alarm systems to provide central station service as defined in Section 1-4.

5-2.2 General.

5-2.2.1 Fire alarm systems for central station service shall include the central station physical plant, exterior communications channels, subsidiary stations, and signaling equipment located at the protected premises.

5-2.2.2* Section 5-2 shall apply to central station service, which consists of the following elements:

- (1) Installation of fire alarm transmitters
- (2) Alarm, guard, supervisory, and trouble signal monitoring
- (3) Retransmission
- (4) Associated record keeping and reporting
- (5) Testing and maintenance
- (6) Runner service

The central station service elements shall be provided under contract to a subscriber by one of the following:

(a) A listed central station that provides all of the elements of central station service with its own facilities and personnel.

(b) A listed central station that provides, as a minimum, the signal monitoring, retransmission, and associated record keeping and reporting with its own facilities and personnel and that shall be permitted to subcontract all or any part of the installation, testing, and maintenance and runner service.

(c) A listed fire alarm service—local company that provides the installation and testing and maintenance with its own facilities and personnel and that subcontracts the monitoring, retransmission, and associated record keeping and reporting to a listed central station. The required runner service shall be provided by the listed fire alarm service—local company with its own personnel or the listed central station with its own personnel.

5-2.2.3 The prime contractor shall conspicuously indicate that the fire alarm system providing service at a protected premises complies with all the requirements of this code by providing a means of third party verification, as specified in 5-2.2.3.1 or 5-2.2.3.2.

5-2.2.3.1 The installation shall be certificated.

5-2.2.3.1.1 Fire alarm systems providing service that complies with all the requirements of this code shall be certified by the organization that has listed the central station, and a document attesting to this certification shall be located on or within 36 in. (1 m) of the fire alarm system control unit or, if no control unit exists, on or within 36 in. (1 m) of a fire alarm system component.

5-2.2.3.1.2 A central repository of issued certification documents, accessible to the authority having jurisdiction, shall be maintained by the organization that has listed the central station.

5-2.2.3.2 The installation shall be placarded.

5-2.2.3.2.1 Fire alarm systems providing service that complies with all the requirements of this code shall be conspicuously marked by the central station to indicate compliance. The marking shall be by one or more placards that meet the requirements of the organization that has listed the central station and requires the placard.

5-2.2.3.2.2 The placard(s) shall be 20 in.² (130 cm²) or larger, shall be located on or within 36 in. (1 m) of the fire alarm system control unit or, if no control unit exists, on or within 36 in. (1 m) of a fire alarm system component, and shall identify the central station by name and telephone number.

5-2.2.4* Fire alarm system service that does not comply with all the requirements of Section 5-2 shall not be designated as central station service.

5-2.2.5* For the purpose of Section 5-2, the subscriber shall notify the prime contractor, in writing, of the identity of the authority(ies) having jurisdiction.

5-2.3 Facilities.

5-2.3.1 The central station building or that portion of a building occupied by a central station shall conform to the construction, fire protection, restricted access, emergency lighting, and power facilities requirements of the latest edition of ANSI/UL 827, *Standard for Safety Central-Station for Watchman, Fire-Alarm and Supervisory Services*.

5-2.3.2 Subsidiary station buildings or those portions of buildings occupied by subsidiary stations shall conform to the construction, fire protection, restricted access, emergency lighting, and power facilities requirements of the latest edition of ANSI/UL 827, *Standard for Safety Central-Station for Watchman, Fire-Alarm and Supervisory Services*.

5-2.3.2.1 All intrusion, fire, power, and environmental control systems for subsidiary station buildings shall be monitored by the central station in accordance with 5-2.3.

5-2.3.2.2 The subsidiary facility shall be inspected at least monthly by central station personnel for the purpose of verifying the operation of all supervised equipment, all telephones, all battery conditions, and all fluid levels of batteries and generators.

5-2.3.2.3 In the event of the failure of equipment at the subsidiary station or the communications channel to the central station, a backup shall be operational within 90 seconds. Restoration of a failed unit shall be accomplished within 5 days.

5-2.3.2.4 There shall be continuous supervision of each communications channel between the subsidiary station and the central station.

5-2.3.2.5 When the communications channel between the subsidiary station and the supervising station fails, the communications shall be switched to an alternate path. Public switched telephone network facilities shall be used only as an alternate path.

5-2.3.2.6 In the subsidiary station, there shall be a communications path, such as a cellular telephone, that is independent of the telephone cable between the subsidiary station and the serving wire center.

5-2.3.2.7 A plan of action to provide for restoration of services specified by this code shall exist for each subsidiary station.

5-2.3.2.7.1 This plan shall provide for restoration of services within 4 hours of any impairment that causes loss of signals from the subsidiary station to the central station.

5-2.3.2.7.2 There shall be an exercise to demonstrate the adequacy of the plan at least annually.

5-2.4 Equipment.

5-2.4.1 The central station and all subsidiary stations shall be equipped so as to receive and record all signals in accordance with 5-5.5. Circuit-adjusting means for emergency operation shall be permitted to be automatic or to be provided through manual operation upon receipt of a trouble signal. Computer-

aided alarm and supervisory signal processing hardware and software shall be listed for the specific application.

5-2.4.2 Power supplies shall comply with the requirements of Chapter 1.

5-2.4.3 Transmission means shall comply with the requirements of Section 5-5.

5-2.4.4* Two independent means shall be provided to retransmit a fire alarm signal to the designated public fire service communications center.

5-2.4.4.1 The use of a universal emergency number, for example 911 public safety answering point, shall not meet the intent of this code for the principal means of retransmission.

5-2.4.4.2 If the principal means of retransmission is not equipped to allow the communications center to acknowledge receipt of each fire alarm report, both means shall be used to retransmit.

5-2.4.4.3* If required by the authority having jurisdiction, one of the means of retransmission shall be supervised so that interruption of retransmission circuit (channel) communications integrity results in a trouble signal at the central station.

5-2.4.4.4 The retransmission means shall be tested in accordance with Chapter 7.

5-2.4.4.5 The retransmission signal and the time and date of retransmission shall be recorded at the central station.

5-2.5 Personnel.

5-2.5.1 The central station shall have sufficient personnel, but not less than two persons, on duty at the central station at all times to ensure disposition of signals in accordance with the requirements of 5-2.6.1.

5-2.5.2 Operation and supervision shall be the primary functions of the operators, and no other interest or activity shall take precedence over the protective service.

5-2.6 Operations.

5-2.6.1 Disposition of Signals.

5-2.6.1.1 Alarm signals initiated by manual fire alarm boxes, automatic fire detectors, waterflow from the automatic sprinkler system, or actuation of other fire suppression system(s) or equipment shall be treated as fire alarms.

The central station shall perform the following actions:

- (1) *Immediately retransmit the alarm to the public fire service communications center
- (2) Dispatch a runner or technician to the protected premises to arrive within 1 hour after receipt of a signal if equipment needs to be manually reset by the prime contractor
- (3) Immediately notify the subscriber
- (4) Provide notice to the subscriber or authority having jurisdiction, or both, if required

Exception: If the alarm signal results from a prearranged test, the actions specified by 5-2.6.1.1(1) and (3) shall not be required.

5-2.6.1.2 Guard's Tour Supervisory Signal.

5-2.6.1.2.1 Upon failure to receive a guard's tour supervisory signal within a 15-minute maximum grace period, the central station shall perform the following actions:

- (1) Communicate without unreasonable delay with personnel at the protected premises
- (2) Dispatch a runner to the protected premises to arrive within 30 minutes of the delinquency if communications cannot be established
- (3) Report all delinquencies to the subscriber or authority having jurisdiction, or both, if required

5-2.6.1.2.2 Failure of the guard to follow a prescribed route in transmitting signals shall be handled as a delinquency.

5-2.6.1.3* Upon receipt of a supervisory signal from a sprinkler system, other fire suppression system(s), or other equipment, the central station shall perform the following actions:

- (1) *Communicate immediately with the person(s) designated by the subscriber
- (2) Dispatch a runner or maintenance person to arrive within 1 hour to investigate

Exception: Where the supervisory signal is cleared in accordance with a scheduled procedure determined by 5-2.6.1.3(1).

- (3) Notify the fire department or law enforcement agency, or both, if required
- (4) Notify the authority having jurisdiction when sprinkler systems or other fire suppression systems or equipment has been wholly or partially out of service for 8 hours
- (5) When service has been restored, provide notice, if required, to the subscriber or the authority having jurisdiction, or both, as to the nature of the signal, the time of occurrence, and the restoration of service when equipment has been out of service for 8 hours or more

Exception: If the supervisory signal results from a prearranged test, the actions specified by 5-2.6.1.3 (1), (3), and (5) shall not be required.

5-2.6.1.4 Upon receipt of trouble signals or other signals pertaining solely to matters of equipment maintenance of the fire alarm systems, the central station shall perform the following actions:

- (1) *Communicate immediately with persons designated by the subscriber
- (2) Dispatch personnel to arrive within 4 hours to initiate maintenance, if necessary
- (3) Provide notice, if required, to the subscriber or the authority having jurisdiction, or both, as to the nature of the interruption, the time of occurrence, and the restoration of service, when the interruption is more than 8 hours

5-2.6.1.5 All test signals received shall be recorded to indicate date, time, and type.

5-2.6.1.5.1 Test signals initiated by the subscriber, including those for the benefit of an authority having jurisdiction, shall be acknowledged by central station personnel whenever the subscriber or authority inquires.

5-2.6.1.5.2* Any test signal not received by the central station shall be investigated immediately and action shall be taken to reestablish system integrity.

5-2.6.1.5.3 The central station shall dispatch personnel to arrive within 1 hour if protected premises equipment needs to be manually reset after testing.

5-2.6.2 Record Keeping and Reporting.

5-2.6.2.1 Complete records of all signals received shall be retained for at least 1 year.

5-2.6.2.2 Testing and maintenance records shall be retained as required by 7-5.3.

5-2.6.2.3 The central station shall make arrangements to furnish reports of signals received to the authority having jurisdiction in a manner approved by the authority having jurisdiction.

5-2.7 Testing and Maintenance.

5-2.7.1 Testing and maintenance for central station service shall be performed in accordance with Chapter 7.

5-2.7.2 The prime contractor shall provide each of its representatives and each alarm system user with a unique personal identification code.

5-2.7.3 In order to authorize the placing of an alarm system into test status, a representative of the prime contractor or an alarm system user shall first provide the central station with his or her personal identification code.

5-3 Proprietary Supervising Station Systems. The requirements of Chapters 1 and 7 and Section 5-5 shall apply to proprietary fire alarm systems, unless they conflict with the requirements of this section.

5-3.1 Scope. Section 5-3 describes the operational procedures for the supervising facilities of proprietary fire alarm systems. It provides the minimum requirements for the facilities, equipment, personnel, operation, and testing and maintenance of the proprietary supervising station.

5-3.2 General.

5-3.2.1 Proprietary supervising stations shall be operated by trained, competent personnel in constant attendance who are responsible to the owner of the protected property. The requirements of 5-3.5.3 shall apply.

5-3.2.2 The protected property shall be either a contiguous property or noncontiguous properties under one ownership.

5-3.2.3 If a protected premises master control unit is integral to or co-located with the supervising station equipment, the requirements of Section 5-5 shall not apply.

5-3.2.4* The systems of Section 5-3 shall be permitted to be interconnected to other systems intended to make the premises safer in the event of fire or other emergencies indicative of hazards to life or property.

5-3.3 Facilities.

5-3.3.1 The proprietary supervising station shall be located in a fire-resistive, detached building or in a cutoff room and shall not be exposed to the hazardous parts of the premises that are protected.

5-3.3.2 Access to the proprietary supervising station shall be restricted to those persons directly concerned with the implementation and direction of emergency action and procedure.

5-3.3.3 The proprietary supervising station, as well as remotely located power rooms for batteries or engine-driven generators, shall be provided with portable fire extinguishers that comply with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

5-3.3.4 Emergency Lighting System.

5-3.3.4.1 The proprietary supervising station shall be provided with an automatic emergency lighting system. The emer-

gency source shall be independent of the primary lighting source.

5-3.3.4.2 In the event of a loss of the primary lighting for the supervising station, the emergency lighting system shall provide illumination for a period of not less than 26 hours to permit the operators to carry on operations, and shall be tested in accordance with the requirements of Chapter 7.

5-3.3.5 If 25 or more protected buildings or premises are connected to a subsidiary station, both of the following shall be provided at the subsidiary station:

- (1) Automatic means for receiving and recording signals under emergency-staffing conditions
- (2) A telephone

5-3.4 Equipment.

5-3.4.1 Signal-receiving equipment in a proprietary supervising station shall comply with 5-3.4.

5-3.4.2 Provision shall be made to designate the building in which a signal originates. The floor, section, or other subdivision of the building shall be designated at the proprietary supervising station or at the building that is protected.

Exception: Where the area, height, or special conditions of occupancy make detailed designation unessential as approved by the authority having jurisdiction. This detailed designation shall use indicating appliances accepted by the authority having jurisdiction.

5-3.4.3 The proprietary supervising station shall have, in addition to a recording device, two different means for alerting the operator when each signal is received that indicates a change of state of any connected initiating device circuit. One of these means shall be an audible signal, which shall persist until manually acknowledged. Means shall include the receipt of alarm signals, supervisory signals, and trouble signals, including signals indicating restoration.

5-3.4.4 If means is provided in the proprietary supervising station to identify the type of signal received, a common audible indicating appliance shall be permitted to be used for alarm, supervisory, and trouble indication.

5-3.4.5 At a proprietary supervising station, an audible trouble signal shall be permitted to be silenced, provided the act of silencing does not prevent the signal from operating immediately upon receipt of a subsequent trouble signal.

5-3.4.6 All signals required to be received by the proprietary supervising station that show a change in status shall be automatically and permanently recorded, including time and date of occurrence. This record shall be in a form that expedites operator interpretation in accordance with any one of the following.

(a) If a visual display is used that automatically provides change of status information for each required signal, including type and location of occurrence, any form of automatic permanent visual record shall be permitted. The recorded information shall include the content described above. The visual display shall show status information content at all times and shall be distinctly different after the operator has manually acknowledged each signal. Acknowledgment shall produce recorded information indicating the time and date of acknowledgment.

(b) If a visual display is not provided, required signal content information shall be automatically recorded on duplicate permanent visual recording instruments.

One recording instrument shall be used for recording all incoming signals, while the other shall be used for required fire, supervisory, and trouble signals only. Failure to acknowledge a signal shall not prevent subsequent signals from recording. Restoration of the signal to its prior condition shall be recorded.

(c) In the event that a system combines the use of a sequential visual display and recorded permanent visual presentation, the required signal content information shall be displayed and recorded. The visual information component shall be retained either on the display until manually acknowledged or repeated at intervals not greater than 5 seconds, for durations of 2 seconds each, until manually acknowledged. Each new displayed status change shall be accompanied by an audible indication that shall persist until manual acknowledgment of the signal is performed.

A means shall be provided for the operator to redisplay the status of required signal initiating inputs that have been acknowledged but not yet restored. If the system retains the signal on the visual display until manually acknowledged, subsequent recorded presentations shall not be inhibited upon failure to acknowledge. Fire alarm signals shall be segregated on a separate visual display in this configuration.

Exception: Fire alarm signals shall not be required to be segregated on a separate display if given priority status on the common visual display.

5-3.4.7 The maximum elapsed time from sensing a fire alarm at an initiating device or initiating device circuit until it is recorded or displayed at the proprietary supervising station shall not exceed 90 seconds.

5-3.4.8 To facilitate the prompt receipt of fire alarm signals from systems handling other types of signals that are able to produce multiple simultaneous status changes, the requirements of either of the following shall be met:

- (1) In addition to the maximum processing time for a single alarm, the system shall record simultaneous status changes at a rate not slower than either a quantity of 50, or 10 percent of the total number of initiating device circuits connected, within 90 seconds, whichever number is smaller, without loss of any signal.
- (2) In addition to the maximum processing time, the system shall either display or record fire alarm signals at a rate not slower than one every 10 seconds, regardless of the rate or number of status changes occurring, without loss of any signals.

Exception: If fire alarm, waterflow alarm, and sprinkler supervisory signals and their associated trouble signals are the only signals processed by the system, the rate of recording shall not be slower than one signal every 30 seconds.

5-3.4.9 Trouble signals required by 1-5.8 and their restoration shall be automatically indicated and recorded at the proprietary supervising station within 200 seconds.

5-3.4.10 The recorded information for the occurrence of any trouble condition of signaling line circuit, leg facility, or trunk facility that prevents receipt of alarm signals at the proprietary supervising station shall be such that the operator is able to determine the presence of the trouble condition. Trouble conditions in a leg facility shall not affect or delay receipt of

signals at the proprietary supervising station from other leg facilities on the same trunk facility.

5-3.5 Personnel.

5-3.5.1 At least two operators shall be on duty at all times. One of the two operators shall be permitted to be a runner.

Exception: If the means for transmitting alarms to the fire department is automatic, at least one operator shall be on duty at all times.

5-3.5.2 When the runner is not in attendance at the proprietary supervising station, the runner shall establish two-way communications with the station at intervals not exceeding 15 minutes.

5-3.5.3 The primary duties of the operator(s) shall be to monitor signals, operate the system, and take such action as shall be required by the authority having jurisdiction. The operator(s) shall not be assigned any additional duties that would take precedence over the primary duties.

5-3.6 Operations.

5-3.6.1 Communications and Transmission Channels.

5-3.6.1.1 All communications and transmission channels between the proprietary supervising station and the protected premises master control unit (panel) shall be operated manually or automatically once every 24 hours to verify operation.

5-3.6.1.2 If a communications or transmission channel fails to operate, the operator shall immediately notify the person(s) identified by the owner or authority having jurisdiction.

5-3.6.2 Operator Controls.

5-3.6.2.1 All operator controls at the proprietary supervising station(s) designated by the authority having jurisdiction shall be operated at each change of shift.

5-3.6.2.2 If operator controls fail, the operator shall immediately notify the person(s) identified by the owner or authority having jurisdiction.

5-3.6.3 Indication of a fire shall be promptly retransmitted to the public fire service communications center or other locations accepted by the authority having jurisdiction, indicating the building or group of buildings from which the alarm has been received.

5-3.6.4* The means of retransmission shall be accepted by the authority having jurisdiction and shall be in accordance with Sections 5-2 or 5-4, or Chapter 6.

Exception: Secondary power supply capacity shall be as required in Chapter 1.

5-3.6.5* Retransmission by coded signals shall be confirmed by two-way voice communications indicating the nature of the alarm.

5-3.6.6 Dispositions of Signals.

5-3.6.6.1 Alarms. Upon receipt of a fire alarm signal, the proprietary supervising station operator shall initiate action to perform the following:

- (1) Immediately notify the fire department, the plant fire brigade, and such other parties as the authority having jurisdiction requires.
- (2) Promptly dispatch a runner to the alarm location (travel time shall not exceed 1 hour).

- (3) Restore the system as soon as possible after disposition of the cause of the alarm signal.

5-3.6.6.2 Guard's Tour Supervisory Signal. If a guard's tour supervisory signal is not received from a guard within a 15-minute maximum grace period, or if a guard fails to follow a prescribed route in transmitting the signals (where a prescribed route has been established), the supervisory signal shall be treated as a delinquency signal. If a guard's tour supervisory signal is delinquent, the proprietary supervising station operator shall initiate action to perform the following:

- (1) Communicate at once with the protected areas or premises by telephone, radio, calling back over the system circuit, or other means accepted by the authority having jurisdiction.
- (2) Dispatch a runner to investigate the delinquency, if communications with the guard cannot be promptly established. (Travel time shall not exceed $\frac{1}{2}$ hour.)

5-3.6.6.3 Supervisory Signals. Upon receipt of sprinkler system and other supervisory signals, the proprietary supervising station operator shall initiate action to perform the following, if required:

- (1) Communicate immediately with the designated person(s) to ascertain the reason for the signal
- (2) Dispatch a runner or maintenance person (travel time not to exceed 1 hour) to investigate, unless supervisory conditions are promptly restored
- (3) Notify the fire department
- (4) Notify the authority having jurisdiction when sprinkler systems are wholly or partially out of service for 8 hours or more
- (5) Provide written notice to the authority having jurisdiction as to the nature of the signal, time of occurrence, and restoration of service, when equipment has been out of service for 8 hours or more

5-3.6.6.4 Trouble Signals. Upon receipt of trouble signals or other signals pertaining solely to matters of equipment maintenance of the fire alarm system, the proprietary supervising station operator shall initiate action to perform the following, if required:

- (1) Communicate immediately with the designated person(s) to ascertain reason for the signal
- (2) Dispatch a runner or maintenance person (travel time not to exceed 1 hour) to investigate
- (3) Notify the fire department
- (4) Notify the authority having jurisdiction when interruption of service exists for 4 hours or more
- (5) Provide written notice to the authority having jurisdiction as to the nature of the signal, time of occurrence, and restoration of service, when equipment has been out of service for 8 hours or more

5-3.6.7 Record Keeping and Reporting.

5-3.6.7.1 Complete records of all signals received shall be retained for at least 1 year.

5-3.6.7.2 Testing and maintenance records shall be retained as required by 7-5.3.

5-3.6.7.3 The proprietary supervising station shall make arrangements to furnish reports of signals received to the authority having jurisdiction in a form the authority will accept.

5-3.7 Testing and Maintenance. Testing and maintenance of proprietary fire alarm systems shall be performed in accordance with Chapter 7.

5-4 Remote Supervising Station Fire Alarm Systems. The requirements of Chapters 1 and 7 and Section 5-5 shall apply to remote supervising station fire alarm systems, unless they conflict with the requirements of this section.

5-4.1 Scope. Section 5-4 shall apply where central station service is neither required nor elected. Section 5-4 shall describe the installation, maintenance, testing, and use of a remote supervising station fire alarm system that serves properties under various ownership from a remote supervising station where trained, competent personnel are in constant attendance. Section 5-4 shall cover the minimum requirements for the remote supervising station physical facilities, equipment, operating personnel, response, retransmission, signals, reports, and testing.

5-4.2 General.

5-4.2.1 Remote supervising station fire alarm systems shall provide an automatic audible and visible indication of alarm and, if required, of supervisory and trouble conditions at a location remote from the protected premises. A manual or automatic permanent record of these conditions shall be provided.

5-4.2.2 Section 5-4 shall not require the use of audible or visible notification appliances other than those required at the remote supervising station. If it is desired to provide fire alarm evacuation signals in the protected premises, the alarm signals, circuits, and controls shall comply with the provisions of Chapter 3 and Chapter 4 in addition to the provisions of Section 5-4.

5-4.2.3 The loading capacities of the remote supervising station equipment for any approved method of transmission shall be as designated in Section 5-5.

5-4.3* Facilities.

5-4.3.1 If a remote supervising station connection is used to transmit an alarm signal, the signal shall be received at the public fire service communications center, at a fire station, or at the governmental agency that has a public responsibility for taking prescribed action to ensure response upon receipt of a fire alarm signal.

Exception: If such an agency is unwilling to receive alarm signals or permits the acceptance of another location by the authority having jurisdiction, such alternate location shall have personnel on duty at all times who are trained to receive the alarm signal and immediately retransmit it to the fire department.

5-4.3.2 Supervisory and trouble signals shall be handled at a constantly attended location that has personnel on duty who are trained to recognize the type of signal received and to take prescribed action. The location shall be permitted to be other than that at which alarm signals are received.

5-4.3.3 If locations other than the public fire service communications center are used for the receipt of signals, access to receiving equipment shall be restricted in accordance with the requirements of the authority having jurisdiction.

5-4.4 Equipment.

5-4.4.1 Signal-receiving equipment shall indicate receipt of each signal both audibly and visibly.

5-4.4.1.1 Audible signals shall meet the requirements of Chapter 4 for the private operating mode.

5-4.4.1.2 Means for silencing alarm, supervisory, and trouble signals shall be provided and shall be arranged so that subsequent signals shall re-sound.

5-4.4.1.3 A trouble signal shall be received when the system or any portion of the system at the protected premises is placed in a bypass or test mode.

5-4.4.1.4 An audible and visible indication shall be provided upon restoration of the system after receipt of any signal.

5-4.4.1.5 If visible means are provided in the remote supervising station to identify the type of signal received, a common audible notification appliance shall be permitted to be used.

5-4.4.2 Power supplies shall comply with the requirements of Chapter 1.

Exception: In a remote supervising station fire alarm system where the alarm and supervisory signals are transmitted over a listed supervised one-way radio system, 24 hours of secondary (standby) power shall be permitted in lieu of 60 hours, as required in 1-5.2.5.3, at the radio alarm repeater station receivers (RARSR), provided that personnel are dispatched to arrive within 4 hours after detection of failure to initiate maintenance.

5-4.4.3 Transmission means shall comply with the requirements of Section 5-5.

5-4.4.4 Retransmission of an alarm signal, if required, shall be by one of the following methods, which appear in descending order of preference as follows.

(a) A dedicated circuit that is independent of any switched telephone network. This circuit shall be permitted to be used for voice or data communications.

(b) A one-way (outgoing only) telephone at the remote supervising station that utilizes the public switched telephone network. This telephone shall be used primarily for voice transmission of alarms to a telephone at the public fire service communications center that cannot be used for outgoing calls.

(c) A private radio system using the fire department frequency, where permitted by the fire department.

(d) Other methods accepted by the authority having jurisdiction.

5-4.5 Personnel.

5-4.5.1 The remote supervising station shall have sufficient personnel, but not less than two persons, on duty at the remote supervising station at all times to ensure disposition of signals in accordance with the requirements of 5-4.6.

5-4.5.2 Duties pertaining to other than operation of the remote supervising station receiving and transmitting equipment shall be permitted subject to the approval of the authority having jurisdiction.

5-4.6 Operations.

5-4.6.1 If the remote supervising station is at a location other than the public fire service communications center, alarm signals shall be immediately retransmitted to the public fire service communications center.

5-4.6.2 Upon receipt of an alarm, supervisory, or trouble signal by the remote supervising station other than the public fire service communications center, the operator on duty shall be

responsible for notifying the owner or the owner's designated representative immediately.

5-4.6.3 All operator controls at the remote supervising station shall be operated at the beginning of each shift or change in personnel, and the status of all alarm, supervisory, and trouble signals shall be noted and recorded.

5-4.7 Record Keeping and Reporting.

5-4.7.1 A permanent record of the time, date, and location of all signals and restorations received and the action taken shall be maintained for at least 1 year and shall be made available to the authority having jurisdiction. These records shall be permitted to be created by manual means.

5-4.7.2 Testing and maintenance records shall be retained as required in 7-5.3. These records shall be permitted to be created by manual means.

5-4.8 Testing and Maintenance. Testing and maintenance for remote supervising stations shall be performed in accordance with Chapter 7.

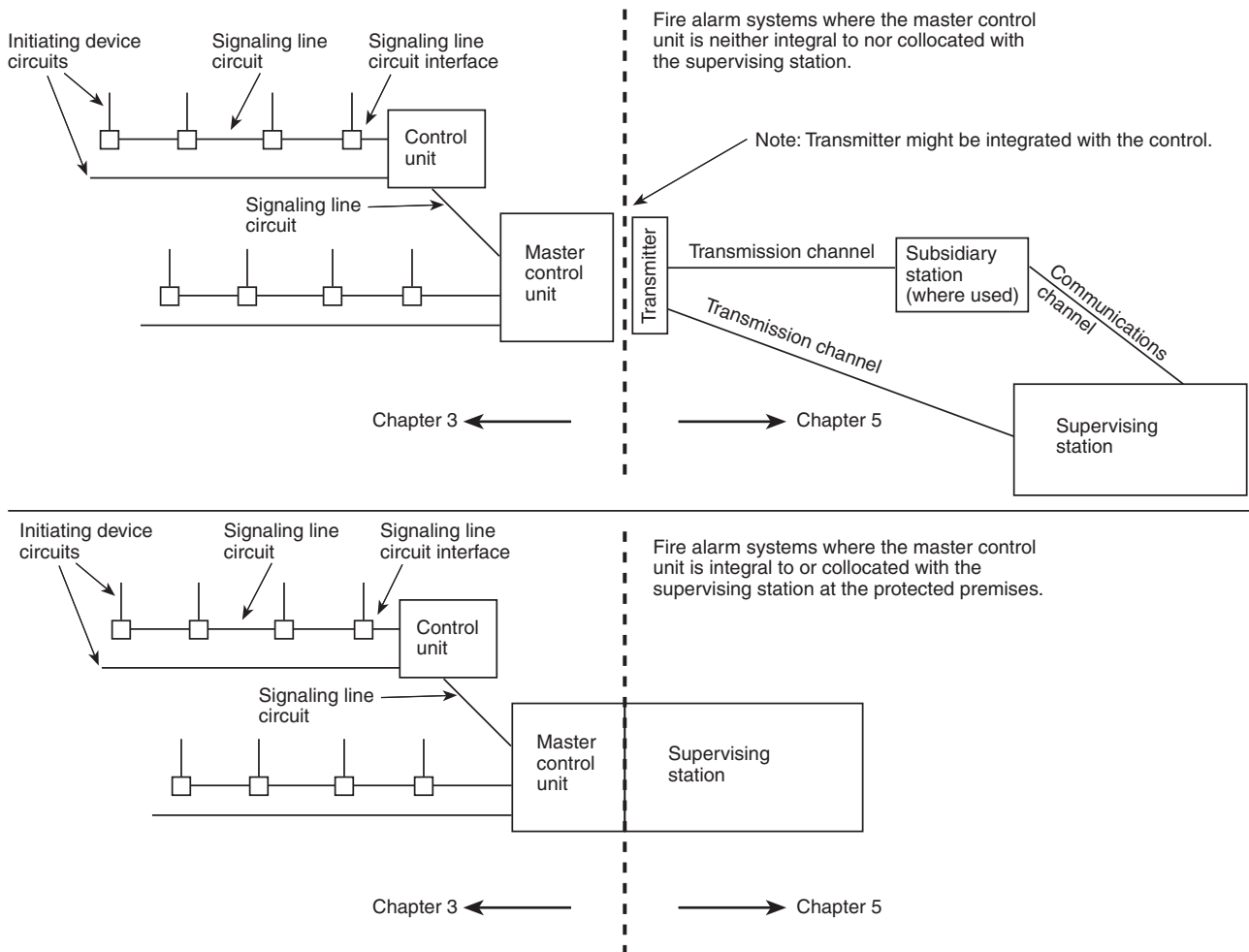
5-5 Communications Methods for Supervising Station Fire Alarm Systems. The requirements of Chapters 1 and 7 shall apply to continuously attended supervising station fire alarm systems, unless they conflict with the requirements of this section.

5-5.1* Scope. Section 5-5 and Figure 5-5.1 shall describe the requirements for the methods of communications between the protected premises and the supervising station. These requirements shall include the following:

- (1) The transmitter located at the protected premises
- (2) The transmission channel between the protected premises and the supervising station or subsidiary station
- (3) If used, any subsidiary station and its communications channel
- (4) The signal receiving, processing, display, and recording equipment at the supervising station

Exception: Transmission channels owned by and under the control of the protected premises owner, that are not facilities leased from a supplier of communications service capabilities, such as video cable, telephone, or other communications services that are also offered to other customers.

Figure 5-5.1 Division of scope.



5-5.2 General.

5-5.2.1 Applicable Requirements.

5-5.2.1.1 If the protected premises master control unit is neither integral to nor co-located with the supervising station, the communications methods of Section 5-5 shall be used to connect the protected premises to either a subsidiary station, if used, or a supervising station providing central station service in accordance with Section 5-2, proprietary service in accordance with Section 5-3, or remote station service in accordance with Section 5-4. These communications methods shall be permitted to include the following:

- (1) Active multiplex circuits that are part of a supervising station, including systems derived channels
- (2) Digital alarm communicator systems, including digital alarm radio systems
- (3) McCulloh systems
- (4) Two-way radio frequency (RF) multiplex systems
- (5) One-way radio alarm systems
- (6) Directly-connected noncoded systems

5-5.2.1.2* Nothing in Chapter 5 shall be interpreted as prohibiting the use of listed equipment using alternate communications methods that provide a level of reliability and supervision consistent with the requirements of Chapter 1 and the intended level of protection.

5-5.2.1.3 For multiple building premises, the requirements of 1-5.7.4 shall apply to the alarm, supervisory, and trouble signals transmitted to the supervising station.

5-5.2.2 Equipment.

5-5.2.2.1 Fire alarm system equipment and installations shall comply with Federal Communication Commission (FCC) rules and regulations, as applicable, concerning the following:

- (1) Electromagnetic radiation
- (2) Use of radio frequencies
- (3) Connection to the public switched telephone network of telephone equipment, systems, and protection apparatus

5-5.2.2.2 Radio receiving equipment shall be installed in compliance with NFPA 70, *National Electrical Code*®, Article 810.

5-5.2.2.3 The external antennas of all radio transmitting and receiving equipment shall be protected in order to minimize the possibility of damage by static discharge or lightning.

5-5.2.3 Adverse Conditions.

5-5.2.3.1 For active and two-way RF multiplex systems, the occurrence of an adverse condition on the transmission channel between a protected premises and the supervising station that prevents the transmission of any status change signal shall be automatically indicated and recorded at the supervising station. This indication and record shall identify the affected portions of the system so that the supervising station operator will be able to determine the location of the adverse condition by trunk or leg facility, or both.

5-5.2.3.2 For a one-way radio alarm system, the system shall be supervised to ensure that at least two independent radio alarm repeater station receivers (RARSR) are receiving signals for each radio alarm transmitter (RAT) during each 24-hour period. The occurrence of a failure to receive a signal by either RARSR shall be automatically indicated and recorded at the supervising station. The indication shall identify which RARSR failed to receive such supervisory signals. Received test

signals shall not be required to be indicated at the supervising station.

5-5.2.3.3 For active and two-way RF multiplex systems that are part of a central station fire alarm system, restoration of service to the affected portions of the system shall be automatically recorded. When service is restored, the first status change of any initiating device circuit, or any initiating device directly connected to a signaling line circuit, or any combination thereof that occurred at any of the affected premises during the service interruption, also shall be recorded.

5-5.2.4 Dual Control.

5-5.2.4.1 Dual control, if required, shall provide for redundancy in the form of a standby circuit or other alternate means of transmitting signals over the primary trunk portion of a transmission channel. The same method of signal transmission shall be permitted to be used over separate routes, or alternate methods of signal transmission shall be permitted to be used. Public switched telephone network facilities shall be used only as an alternate method of transmitting signals.

5-5.2.4.2 If using facilities leased from a telephone company, that portion of the primary trunk facility between the supervising station and its serving wire center shall not be required to comply with the separate routing requirement of the primary trunk facility. Dual control, if used, shall require supervision as follows.

- (1) Dedicated facilities that are able to be used on a full-time basis, and whose use is limited to signaling purposes as defined in this code, shall be exercised at least once every hour.
- (2) Public switched telephone network facilities shall be exercised at least once every 24 hours.

5-5.3 Communications Methods.

5-5.3.1 Active Multiplex Transmission Systems.

5-5.3.1.1 The multiplex transmission channel shall terminate in a transmitter at the protected premises and in a system unit at the supervising station. The derived channel shall terminate in a transmitter at the protected premises and in derived channel equipment at a subsidiary station location or a telephone company wire center. The derived channel equipment at the subsidiary station location or a telephone company wire center shall select or establish the communications with the supervising station.

5-5.3.1.2* Operation of the transmission channel shall conform to the requirements of this code whether channels are private facilities, such as microwave, or leased facilities furnished by a communications utility company. If private signal transmission facilities are used, the equipment necessary to transmit signals shall also comply with the requirements for duplicate equipment or replacement of critical components, as described in 5-5.5.2. The trunk transmission channels shall be dedicated facilities for the main channel. For Type 1 multiplex systems, the public switched telephone network facilities shall be permitted to be used for the alternate channel.

Exception: Derived channel scanners with no more than 32 legs shall be permitted to use the public switched telephone network for the main channel.

5-5.3.1.2.1 Derived channel signals shall be permitted to be transmitted over the leg facility, which shall be permitted to

be shared by the telephone equipment under all on-hook and off-hook operating conditions.

5-5.3.1.2.2 If derived channel equipment uses the public switched telephone network to communicate with a supervising station, such equipment shall meet the requirements of 5-5.3.2.

5-5.3.1.2.3 The maximum end-to-end operating time parameters allowed for an active multiplex system are as follows.

(a) The maximum allowable time lapse from the initiation of a single fire alarm signal until it is recorded at the supervising station shall not exceed 90 seconds. When any number of subsequent fire alarm signals occur at any rate, they shall be recorded at a rate no slower than one every 10 additional seconds.

(b) *The maximum allowable time lapse from the occurrence of an adverse condition in any transmission channel until recording of the adverse condition is started shall not exceed 90 seconds for Type 1 and Type 2 systems and 200 seconds for Type 3 systems. The requirements of 5-5.3.1.3 shall apply.

(c) In addition to the maximum operating time allowed for fire alarm signals, the requirements of one of the following shall be met:

- (1) A system unit that has more than 500 initiating device circuits shall be able to record not less than 50 simultaneous status changes in 90 seconds.
- (2) A system unit having fewer than 500 initiating device circuits shall be able to record not less than 10 percent of the total number of simultaneous status changes within 90 seconds.

Exception: Proprietary supervising station systems that have operating time requirements specified in 5-3.4.7 through 5-3.4.9.

5-5.3.1.3 System Classification. Active multiplex systems shall be divided into three categories based on their ability to perform under adverse conditions of their transmission channels. The system classifications shall be as follows.

(a) A Type 1 system shall have dual control as described in 5-5.2.4. An adverse condition on a trunk or leg facility shall not prevent the transmission of signals from any other trunk or leg facility, except those signals dependent on the portion of the transmission channel in which the adverse condition has occurred. An adverse condition limited to a leg facility shall not interrupt service on any trunk or other leg facility. The requirements of 5-5.2.1, 5-5.2.2, and 5-5.2.3 shall be met by Type 1 systems.

(b) A Type 2 system shall have the same requirements as a Type 1 system.

Exception: Dual control of the primary trunk facility shall not be required.

(c) A Type 3 system shall automatically indicate and record at the supervising station the occurrence of an adverse condition on the transmission channel between a protected premises and the supervising station. The requirements of 5-5.2 shall be met.

Exception: The requirements of 5-5.2.4 shall not apply.

5-5.3.1.4 System Loading Capacities. The capacities of active multiplex systems are based on the overall reliability of the signal receiving, processing, display, and recording equipment at the supervising and subsidiary stations, and the capability to transmit signals during adverse conditions of the signal trans-

mission facilities. Allowable capacities of active multiplex systems shall be in accordance with Table 5-5.3.1.4.

Table 5-5.3.1.4 Loading Capacities for Active Multiplex Systems

Trunks	System Type		
	Type 1	Type 2	Type 3
Maximum number of fire alarm service initiating device circuits per primary trunk facility	5,120	1,280	256
Maximum number of leg facilities for fire alarm service per primary trunk facility	512	128	64
Maximum number of leg facilities for all types of fire alarm service per secondary trunk facility ^a	128	128	128
Maximum number of all types of initiating device circuits per primary trunk facility in any combination ^a	10,240	2,560	512
Maximum number of leg facilities for all types of fire alarm service per primary trunk facility in any combination ^a	1,024	256	128
System Units at the Supervising Station			
Maximum number of all types of initiating device circuits per system unit ^a	10,240 ^b	10,240 ^b	10,240 ^b
Maximum number of fire protecting buildings and premises per system unit	512 ^b	512 ^b	512 ^b
Maximum number of fire alarm service initiating device circuits per system unit	5,120 ^b	5,120 ^b	5,120 ^b
Systems Emitting from Subsidiary Station^c	—	—	—

^aIncludes every initiating device circuit (for example, waterflow, fire alarm, supervisory, guard, burglary, hold-up).

^bParagraph 5-5.3.1.5 shall apply.

^cSame as system units at the supervising station.

5-5.3.1.5 Exceptions to Loading Capacities Listed in Table 5-5.3.1.4. If the signal receiving, processing, display, and recording equipment are duplicated at the supervising station and a switchover is able to be accomplished in not more than 30 seconds with no loss of signals during this period, the capacity of a system unit shall be unlimited.

5-5.3.2 Digital Alarm Communicator Systems.

5-5.3.2.1 Digital Alarm Communicator Transmitter (DACT).

5-5.3.2.1.1 A DACT shall be connected to the public switched telephone network upstream of any private telephone system at the protected premises. In addition, the connections to the public switched telephone network shall be under the control of the subscriber for whom service is being provided by the supervising station fire alarm system. Special attention shall be required to ensure that this connection is made only to a loop start telephone circuit and not to a ground start telephone circuit.

Exception: If public cellular telephone service is used as a secondary means of transmission, the requirements of 5-5.3.2.1.1 shall not apply to the cellular telephone service.

5-5.3.2.1.2 All information exchanged between the DACT at the protected premises and the digital alarm communicator receiver (DACR) at the supervising or subsidiary station shall be by digital code or some other approved means. Signal repetition, digital parity check, or some other approved means of signal verification shall be used.

5-5.3.2.1.3* A DACT shall be configured so that when it is required to transmit a signal to the supervising station, it shall seize the telephone line (going off-hook) at the protected premises and disconnect an outgoing or incoming telephone call and prevent use of the telephone line for outgoing telephone calls until signal transmission has been completed. A DACT shall not be connected to a party line telephone facility.

5-5.3.2.1.4 A DACT shall have the means to satisfactorily obtain a dial tone, dial the number(s) of the DACR, obtain verification that the DACR is able to receive signals, transmit the signal, and receive acknowledgment that the DACR has accepted that signal. In no event shall the time from going off-hook to on-hook exceed 90 seconds per attempt.

5-5.3.2.1.5* A DACT shall have means to reset and retry if the first attempt to complete a signal transmission sequence is unsuccessful. A failure to complete connection shall not prevent subsequent attempts to transmit an alarm where such alarm is generated from any other initiating device circuit or signaling line circuit, or both. Additional attempts shall be made until the signal transmission sequence has been completed, up to a minimum of 5 and a maximum of 10 attempts.

If the maximum number of attempts to complete the sequence is reached, an indication of the failure shall be made at the premises.

5-5.3.2.1.6 DACT Transmission Channels.

5-5.3.2.1.6.1 A DACT shall employ one of the following combinations of transmission channels:

- (1) Two telephone lines (numbers)
- (2) One telephone line (number) and one cellular telephone connection
- (3) One telephone line (number) and a one-way radio system
- (4) One telephone line (number) equipped with a derived local channel
- (5) One telephone line (number) and a one-way private radio alarm system
- (6) One telephone line (number) and a private microwave radio system
- (7) One telephone line (number) and a two-way RF multiplex system

- (8) *A single integrated services digital network (ISDN) telephone line using a terminal adapter specifically listed for supervising station fire alarm service, where the path between the transmitter and the switched telephone network serving central office is monitored for integrity so that the occurrence of an adverse condition in the path shall be annunciated at the supervising station within 200 seconds

5-5.3.2.1.6.2 The following requirements shall apply to all combinations in 5-5.3.2.1.6.1:

- (1) Both channels shall be supervised in a manner approved for the means of transmission employed.
- (2) Both channels shall be tested at intervals not exceeding 24 hours.

Exception No. 1: For public cellular telephone service, a verification (test) signal shall be transmitted at least monthly.

Exception No. 2: Where two telephone lines (numbers) are used, it shall be permitted to test each telephone line (number) at alternating 24-hour intervals.

- (3) The failure of either channel shall send a trouble signal on the other channel within 4 minutes.
- (4) When one transmission channel has failed, all status change signals shall be sent over the other channel.

Exception: Where used in combination with a DACT, a derived local channel shall not be required to send status change signals other than those indicating that adverse conditions exist on the telephone line (number).

- (5) The primary channel shall be capable of delivering an indication to the DACT that the message has been received by the supervising station.
- (6) The first attempt to send a status change signal shall use the primary channel.

Exception: Where the primary channel is known to have failed.

- (7) Simultaneous transmission over both channels shall be permitted.
- (8) Failure of telephone lines (numbers) or cellular service shall be annunciated locally.

5-5.3.2.1.7 DACT Transmission Means.

5-5.3.2.1.7.1 A DACT shall be connected to two separate means of transmission at the protected premises. The DACT shall be capable of selecting the operable means of transmission in the event of failure of the other means. The primary means of transmission shall be a telephone line (number) connected to the public switched network.

5-5.3.2.1.7.2 The first transmission attempt shall utilize the primary means of transmission.

5-5.3.2.1.8 Each DACT shall be programmed to call a second DACR line (number) when the signal transmission sequence to the first called line (number) is unsuccessful.

5-5.3.2.1.9* If long distance telephone service, including WATS, is used, the second telephone number shall be provided by a different long distance service provider if there are multiple providers.

5-5.3.2.1.10 Each DACT shall automatically initiate and complete a test signal transmission sequence to its associated DACR at least once every 24 hours. A successful signal transmission sequence of any other type within the same 24-hour period shall fulfill the requirement to verify the integrity of the

reporting system, provided signal processing is automated so that 24-hour delinquencies are individually acknowledged by supervising station personnel.

5-5.3.2.1.11* If a DACT is programmed to call a telephone line (number) that is call forwarded to the line (number) of the DACR, a means shall be implemented to verify the integrity of the call forwarding feature every 4 hours.

5-5.3.2.2 Digital Alarm Communicator Receiver (DACR).

5-5.3.2.2.1 Equipment.

5-5.3.2.2.1.1 Spare DACRs shall be provided in the supervising or subsidiary station. The spare DACRs shall be able to be switched into the place of a failed unit within 30 seconds after detection of failure.

One spare DACR shall be permitted to serve as a backup for up to five DACRs in use.

5-5.3.2.2.1.2 The number of incoming telephone lines to a DACR shall be limited to eight lines.

Exception: If the signal receiving, processing, display, and recording equipment at the supervising or subsidiary station is duplicated and a switchover is able to be accomplished in less than 30 seconds with no loss of signal during this period, the number of incoming lines to the unit shall be permitted to be unlimited.

5-5.3.2.2.2 Transmission Channel.

5-5.3.2.2.2.1* The DACR equipment at the supervising or subsidiary station shall be connected to a minimum of two separate incoming telephone lines (numbers). If the lines (numbers) are in a single hunt group, they shall be individually accessible; otherwise, separate hunt groups shall be required. These lines (numbers) shall be used for no other purpose than receiving signals from a DACT. These lines (numbers) shall be unlisted.

5-5.3.2.2.2.2 The failure of any telephone line (number) connected to a DACR due to loss of line voltage shall be annunciated visually and audibly in the supervising station.

5-5.3.2.2.2.3* The loading capacity for a hunt group shall be in accordance with Table 5-5.3.2.2.2.3 or be capable of demonstrating a 90 percent probability of immediately answering an incoming call.

Each supervised burglar alarm (open/close) or each suppressed guard tour transmitter shall reduce the allowable DACTs as follows:

- (1) Up to a four-line hunt group, by 10
- (2) Up to a five-line hunt group, by 7
- (3) Up to a six-line hunt group, by 6
- (4) Up to a seven-line hunt group, by 5
- (5) Up to an eight-line hunt group, by 4

Each guard tour transmitter shall reduce the allowable DACTs as follows:

- (1) Up to a four-line hunt group, by 30
- (2) Up to a five-line hunt group, by 21
- (3) Up to a six-line hunt group, by 18
- (4) Up to a seven-line hunt group, by 15
- (5) Up to an eight-line hunt group, by 12

Table 5-5.3.2.2.2.3 Loading Capacities for Hunt Groups

System Loading at the Supervising Station	Number of Lines in Hunt Group				
	1	2	3	4	5-8
With DACR lines processed in parallel					
Number of initiating circuits	NA	5,000	10,000	20,000	20,000
Number of DACTs*	NA	500	1,500	3,000	3,000
With DACR lines processed serially (put on hold, then answered one at a time)					
Number of initiating circuits	NA	3,000	5,000	6,000	6,000
Number of DACTs*	NA	300	800	1,000	1,000

NA: Not allowed.

*Table 5-5.3.2.2.2.3 shall be based on an average distribution of calls and an average connected time of 30 seconds for a message. The loading figures in the table shall presume that the lines are in a hunt group, that is, DACT is able to access any line not in use. A single-line DACR shall not be allowed (NA) for any of the configurations shown.

5-5.3.2.2.2.4* A signal shall be received on each individual incoming DACR line at least once every 24 hours.

5-5.3.2.2.2.5 The failure to receive a test signal from the protected premises shall be treated as a trouble signal. The requirements of 5-2.6.1.4 shall apply.

5-5.3.2.3 Digital Alarm Radio System (DARS).

5-5.3.2.3.1 If any DACT signal transmission is unsuccessful, the information shall be transmitted by means of the digital alarm radio transmitter (DART). The DACT shall continue its transmission sequence as required by 5-5.3.2.1.5.

5-5.3.2.3.2 The DARS shall be capable of demonstrating a minimum of 90 percent probability of successfully completing each transmission sequence.

5-5.3.2.3.3 Transmission sequences shall be repeated a minimum of five times. The digital alarm radio transmitter (DART) transmission shall be permitted to be terminated in less than five sequences if the DACT successfully communicates to the DACR.

5-5.3.2.3.4 Each DART shall automatically initiate and complete a test signal transmission sequence to its associated digital alarm radio receiver (DARR) at least once every 24 hours. A successful DART signal transmission sequence of any other type within the same 24-hour period shall fulfill the requirement to test the integrity of the reporting system, provided signal processing is automated so that 24-hour delinquencies are individually acknowledged by supervising station personnel.

5-5.3.2.4 Digital Alarm Radio Transmitter (DART). A DART shall transmit a digital code or another approved signal by use of radio transmission to its associated digital alarm radio receiver (DARR). Signal repetition, digital parity check, or

another approved means of signal verification shall be used. The DART shall comply with applicable FCC rules consistent with its operating frequency.

5-5.3.2.5 Digital Alarm Radio Receiver (DARR) Equipment.

5-5.3.2.5.1 A spare DARR shall be provided in the supervising station and shall be able to be switched into the place of a failed unit within 30 seconds after detection of failure.

5-5.3.2.5.2 Facilities shall be provided at the supervising station for supervisory and control functions of subsidiary and repeater station radio receiving equipment. This shall be accomplished via a supervised circuit where the radio equipment is remotely located from the supervising or subsidiary station. The following conditions shall be supervised at the supervising station:

- (1) Failure of ac power supplying the radio equipment
- (2) Malfunction of receiver
- (3) Malfunction of antenna and interconnecting cable
- (4) Indication of automatic switchover of the DARR
- (5) Malfunction of data transmission line between the DARR and the supervising or subsidiary station

5-5.3.3 McCulloh Systems.

5-5.3.3.1 Transmitters.

5-5.3.3.1.1 A coded alarm signal from a transmitter shall consist of not less than three complete rounds of the number or code transmitted.

5-5.3.3.1.2* A coded fire alarm box shall produce not less than three signal impulses for each revolution of the coded signal wheel or another approved device.

5-5.3.3.1.3 Circuit-adjusting means for emergency operating shall be permitted to be either automatic or be provided through manual operation upon receipt of a trouble signal.

5-5.3.3.1.4* Equipment shall be provided at the supervising or subsidiary station on all circuits extending from the supervising or subsidiary station that is utilized for McCulloh systems for performing the following:

- (1) Tests on current on each circuit under nontransmitting conditions
- (2) Tests on current on each side of the circuit with the receiving equipment conditioned for an open circuit

5-5.3.3.2 Transmission Channels.

5-5.3.3.2.1 Circuits between the protected premises and the supervising or subsidiary station that are essential to the actuation or operation of devices that initiate a signal indicative of fire shall be arranged so that the occurrence of a single break or single ground fault does not prevent transmission of an alarm.

Exception No. 1: Circuits wholly within the supervising or subsidiary station.

Exception No. 2: The carrier system portion of circuits.

5-5.3.3.2.2 The occurrence of a single break or a single ground fault on any circuit shall not of itself cause a false signal that is able to be interpreted as an alarm of fire. If such a single fault prevents the functioning of any circuit, its occurrence shall be indicated automatically at the supervising station by a trouble signal that compels attention and that is distinguishable from signals other than those indicative of an abnormal condition of supervised parts of a fire suppression system(s).

5-5.3.3.2.3 The circuits and devices shall be arranged to receive and record a signal identifiable as to location of origin, and provisions shall be made for identifying transmission to the public fire service communications center.

5-5.3.3.2.4 Multipoint transmission channels between the protected premises and the supervising or subsidiary station and within the protected premises, consisting of one or more coded transmitters and an associated system unit(s), shall meet the requirements of either 5-5.3.3.2.5 or 5-5.3.3.2.6.

5-5.3.3.2.5 If end-to-end metallic continuity is present, signals shall be received from other points under any one of the following transmission channel fault conditions at one point on the line:

- (1) Open
- (2) Ground
- (3) *Wire-to-wire short
- (4) Open and ground

5-5.3.3.2.6 If end-to-end metallic continuity is not present, the nonmetallic portion of transmission channels shall meet all of the following requirements.

(a) Two nonmetallic channels or one channel plus a means for immediate transfer to a standby channel shall be provided for each transmission channel, with a maximum of eight transmission channels being associated with each standby channel, or shall be furnished over one channel, provided that service is limited to one plant.

(b) The two nonmetallic channels (or one channel with standby arrangement) for each transmission channel shall be provided by one of the following means, shown in descending order of preference:

- (1) Over separate facilities and separate routes
- (2) Over separate facilities in the same route
- (3) Over the same facilities in the same route

(c) Failure of a nonmetallic channel or any portion thereof shall be indicated immediately and automatically in the supervising station.

(d) Signals shall be received from other points under any one of the following fault conditions at one point on the metallic portion of the transmission channel:

- (1) Open
- (2) Ground
- (3) *Wire-to-wire short

5-5.3.3.3 Loading Capacity of McCulloh Circuits.

5-5.3.3.3.1 The number of transmitters connected to any transmission channel shall be limited to eliminate interference. The total number of code wheels or other approved devices connected to a single transmission channel shall not exceed 250. Alarm signal transmission channels shall be reserved exclusively for fire alarm signal transmitting service.

Exception: As provided in 5-5.3.3.3.4.

5-5.3.3.3.2 The number of waterflow switches permitted to be connected to actuate a single transmitter shall not exceed five switches.

5-5.3.3.3.3 The number of supervisory switches permitted to be connected to actuate a single transmitter shall not exceed 20 switches.

5-5.3.3.3.4 Combined alarm and supervisory transmission channels shall comply with the following:

- (1) If both sprinkler supervisory signals and fire or waterflow alarm signals are transmitted over the same transmission channel, provision shall be made to obtain either alarm signal precedence or continuous repetition of the alarm signal to prevent the loss of any alarm signal.
- (2) Other signal transmitters (for example, burglar, industrial processes) on an alarm transmission channel shall not exceed five.

5-5.3.3.3.5* If signals from manual fire alarm boxes and waterflow alarm transmitters within a building are transmitted over the same transmission channel and are operating at the same time, there shall be no interference with the fire box signals. Provision of the shunt noninterfering method of operation shall be permitted for this performance.

5-5.3.3.3.6 One alarm transmission channel shall serve not more than 25 plants. A plant shall be permitted to consist of one or more buildings under the same ownership, and the circuit arrangement shall be such that an alarm signal cannot be received from more than one transmitter at a time within a plant. If such noninterference is not provided, each building shall be a plant.

5-5.3.3.3.7 One sprinkler supervisory transmission channel circuit shall serve not more than 25 plants. A plant shall be permitted to consist of one or more buildings under the same ownership.

5-5.3.3.3.8 Connections to a guard supervisory transmission channel or to a combination manual fire alarm and guard transmission channel shall be limited so that not more than 60 scheduled guard report signals are transmitted in any 1-hour period. Patrol scheduling shall be such as to eliminate interference between guard report signals.

5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems.

5-5.3.4.1 The maximum end-to-end operating time parameters allowed for a two-way RF multiplex system are as follows.

(a) The maximum allowable time lapse from the initiation of a single fire alarm signal until it is recorded at the supervising station shall not exceed 90 seconds. When any number of subsequent fire alarm signals occur at any rate, they shall be recorded at a rate no slower than one every additional 10 seconds.

(b) The maximum allowable time lapse from the occurrence of an adverse condition in any transmission channel until recording of the adverse condition is started shall not exceed 90 seconds for Type 4 and Type 5 systems. The requirements of 5-5.3.4.4 shall apply.

(c) In addition to the maximum operating time allowed for fire alarm signals, the requirements of one of the following paragraphs shall be met:

- (1) A system unit that has more than 500 initiating device circuits shall be able to record not less than 50 simultaneous status changes in 90 seconds.
- (2) A system unit that has fewer than 500 initiating device circuits shall be able to record not less than 10 percent of the total number of simultaneous status changes within 90 seconds.

5-5.3.4.2 Facilities shall be provided at the supervising station for the following supervisory and control functions of the supervising or subsidiary station and the repeater station radio transmitting and receiving equipment. This shall be accom-

plished via a supervised circuit where the radio equipment is remotely located from the system unit.

The following conditions shall be supervised at the supervising station:

- (1) RF transmitter in use (radiating)
- (2) Failure of ac power supplying the radio equipment
- (3) RF receiver malfunction
- (4) Indication of automatic switchover

Independent deactivation of either RF transmitter shall be controlled from the supervising station.

5-5.3.4.3 Transmission Channel.

5-5.3.4.3.1 The RF multiplex transmission channel shall terminate in a RF transmitter/receiver at the protected premises and in a system unit at the supervising or subsidiary station.

5-5.3.4.3.2 Operation of the transmission channel shall conform to the requirements of this code whether channels are private facilities, such as microwave, or leased facilities furnished by a communications utility company. If private signal transmission facilities are used, the equipment necessary to transmit signals shall also comply with requirements for duplicate equipment or replacement of critical components, as described in 5-5.5.2.

5-5.3.4.4* Two-way RF multiplex systems shall be divided into the following two categories based on their ability to perform under adverse conditions. System classifications shall be Type 4 or Type 5.

A Type 4 system shall have two or more control sites configured as follows:

- (1) Each site shall have an RF receiver interconnected to the supervising or subsidiary station by a separate channel.
- (2) The RF transmitter/receiver located at the protected premises shall be within transmission range of at least two RF receiving sites.
- (3) The system shall contain two RF transmitters that are one of the following:
 - a. Located at one site with the capability of interrogating all of the RF transmitters/receivers on the premises
 - b. Dispersed with all of the RF transmitters/receivers on the premises having the capability to be interrogated by two different RF transmitters
- (4) Each RF transmitter shall maintain a status that allows immediate use at all times. Facilities shall be provided in the supervising or subsidiary station to operate any off-line RF transmitter at least once every 8 hours.
- (5) Any failure of one of the RF receivers shall in no way interfere with the operation of the system from the other RF receiver. Failure of any receiver shall be annunciated at the supervising station.
- (6) A physically separate channel shall be required between each RF transmitter or RF receiver site, or both, and the system unit.

A Type 5 system shall have a single control site configured as follows:

- (1) A minimum of one RF receiving site
- (2) A minimum of one RF transmitting site

5-5.3.4.5 Loading Capacities.

5-5.3.4.5.1 The loading capacities of two-way RF multiplex systems are based on the overall reliability of the signal receiving, processing, display, and recording equipment at the supervising

or subsidiary station and the capability to transmit signals during adverse conditions of the transmission channels. Allowable loading capacities shall comply with Table 5-5.3.4.5.1.

Table 5-5.3.4.5.1 Loading Capacities for Two-Way RF Multiplex Systems

Trunks	System Type	
	Type 4	Type 5
Maximum number of fire alarm service initiating device circuits per primary trunk facility	5,120	1,280
Maximum number of leg facilities for fire alarm service per primary trunk facility	512	128
Maximum number of leg facilities for all types of fire alarm service per secondary trunk facility ^a	128	128
Maximum number of all types of initiating device circuits per primary trunk facility in any combination	10,240	2,560
Maximum number of leg facilities for types of fire alarm service per primary trunk facility in any combination ^a	1,024	256
System Units at the Supervising Station		
Maximum number of all types of initiating device circuits per system unit ^a	10,240 ^b	10,240 ^b
Maximum number of fire protected buildings and premises per system unit	512 ^b	512 ^b
Maximum number of fire alarm service initiating device circuits per system	5,120 ^b	5,120 ^b
Systems Emitting from Subsidiary Station^c	—	—

^aIncludes every initiating device circuit (for example, waterflow, fire alarm supervisory, guard, burglary, hold-up).

^bParagraph 5-5.3.4.5.2 shall apply.

^cSame as system units at the supervising station.

5-5.3.4.5.2 Exceptions to Loading Capacities Listed in Table 5-5.3.4.5.1.

The capacity of a system unit shall be unlimited if the signal receiving, processing, display, and recording equipment are duplicated at the supervising station and a switchover is able to be accomplished in not more than 30 seconds with no loss of signals during this period.

5-5.3.5 One-Way Private Radio Alarm Systems.

5-5.3.5.1 The requirements of 5-5.3.5 for a radio alarm repeater station receiver (RARSR) shall be satisfied if signals from each radio alarm transmitter (RAT) are received and

supervised, in accordance with Chapter 5, by at least two independently powered, independently operating, and separately located RARSRs.

5-5.3.5.2* The end-to-end operating time parameters allowed for a one-way radio alarm system shall be as follows:

- (1) There shall be a 90 percent probability that the time between the initiation of a single fire alarm signal until it is recorded at the supervising station will not exceed 90 seconds.
- (2) There shall be a 99 percent probability that the time between the initiation of a single fire alarm signal until it is recorded at the supervising station will not exceed 180 seconds.
- (3) There shall be a 99.999 percent probability that the time between the initiation of a single fire alarm signal until it is recorded at the supervising station will not exceed 7.5 minutes (450 seconds), at which time the RAT shall cease transmitting. When any number of subsequent fire alarm signals occur at any rate, they shall be recorded at an average rate no slower than one every additional 10 seconds.
- (4) In addition to the maximum operating time allowed for fire signals, the system shall be able to record not less than 12 simultaneous status changes within 90 seconds at the supervising station.

5-5.3.5.3 Supervision.

5-5.3.5.3.1 Equipment shall be provided at the supervising station for the supervisory and control functions of the supervising or subsidiary station and for the repeater station radio transmitting and receiving equipment. This shall be accomplished via a supervised circuit where the radio equipment is remotely located from the system unit. The following conditions shall be supervised at the supervising station:

- (1) Failure of ac power supplying the radio equipment
- (2) Malfunction of RF receiver
- (3) Indication of automatic switchover, if applicable

5-5.3.5.3.2 Protected Premises.

5-5.3.5.3.2.1 Interconnections between elements of transmitting equipment, including any antennas, shall be supervised either to cause an indication of failure at the protected premises or to transmit a trouble signal to the supervising station.

5-5.3.5.3.2.2 If elements of transmitting equipment are physically separated, the wiring or cabling between them shall be protected by conduit.

5-5.3.5.4 Transmission Channels.

5-5.3.5.4.1 The one-way RF transmission channel shall originate with a one-way RF transmitting device at the protected premises and shall terminate at the RF receiving system of an RARSR capable of receiving transmissions from such transmitting devices.

5-5.3.5.4.2 A receiving network transmission channel shall terminate at an RARSR at one end and with either another RARSR or a radio alarm supervising station receiver (RASSR) at the other end.

5-5.3.5.4.3 Operation of receiving network transmission channels shall conform to the requirements of this code whether channels are private facilities, such as microwave, or leased facilities furnished by a communications utility com-

pany. If private signal transmission facilities are used, the equipment necessary to transmit signals shall also comply with requirements for duplicate equipment or replacement of critical components as described in 5-5.5.2.

5-5.3.5.4.4 The system shall provide information that indicates the quality of the received signal for each RASSR supervising each RAT in accordance with 5-5.3.5 and shall provide information at the supervising station when such signal quality falls below the minimum signal quality levels set forth in 5-5.3.5.

5-5.3.5.4.5 Each RAT shall be installed in such a manner so as to provide a signal quality over at least two independent one-way RF transmission channels, of the minimum quality level specified, that satisfies the performance requirements in 5-5.2.2 and 5-5.5.

5-5.3.5.5 Nonpublic one-way radio alarm systems shall be divided into two categories based on the following number of RASSRs present in the system.

- (1) A Type 6 system shall have one RASSR and at least two RASSRs.
- (2) A Type 7 system shall have more than one RASSR and at least two RASSRs.

In a Type 7 system, when more than one RASSR is out of service and, as a result, any RATs are no longer being supervised, the affected supervising station shall be notified.

In a Type 6 system, when any RASSR is out of service, a trouble signal shall be annunciated at the supervising station.

5-5.3.5.6 The loading capacities of one-way radio alarm systems are based on the overall reliability of the signal receiving, processing, display, and recording equipment at the supervising or subsidiary station and the capability to transmit signals during adverse conditions of the transmission channels. Allowable loading capacities shall be in accordance with Table 5-5.3.5.6.

5-5.3.5.7 Exceptions to Loading Capacities Listed in Table 5-5.3.5.6. If the signal receiving, processing, display, and recording equipment is duplicated at the supervising station and a switchover is able to be accomplished in not more than 30 seconds with no loss of signals during this period, the capacity of a system unit shall be unlimited.

5-5.3.6 Directly Connected Noncoded Systems.

5-5.3.6.1 Circuits for transmission of alarm signals between the fire alarm control unit or the transmitter in the protected premises and the supervising station shall be arranged so as to comply with either of the following provisions.

(a) These circuits shall be arranged so that the occurrence of a single break or single ground fault does not prevent the transmission of an alarm signal. Circuits complying with this paragraph shall be automatically self-adjusting in the event of either a single break or a single ground fault and shall be automatically self-restoring in the event that the break or fault is corrected.

(b) These circuits shall be arranged so that they are isolated from ground (except for reference ground detection) and so that a single ground fault does not prevent the transmission of an alarm signal. Circuits complying with this paragraph shall be provided with a ground reference circuit so as to detect and indicate automatically the existence of a single ground fault.

Table 5-5.3.5.6 Loading Capacities of One-Way Radio Alarm Systems

Radio Alarm Repeater Station Receiver (RASSR)	System Type	
	Type 6	Type 7
Maximum number of fire alarm service initiating device circuits per RASSR	5,120	5,120
Maximum number of RATs for fire	512	512
Maximum number of all types of initiating device circuits per RASSR in any combination ^a	10,240	10,240
Maximum number of RATs for all types of fire alarm service per RASSR in any combination ^{a,c}	1,024	1,024
System Units at the Supervising Station		
Maximum number of all types of initiating device circuits per system unit ^a	10,240 ^b	10,240 ^b
Maximum number of fire-protected buildings and premises per system unit	512 ^b	512 ^b
Maximum number of fire alarm service initiating device circuits per system unit	5,120 ^b	5,120 ^b

Notes:

1. Each guard tour transmitter shall reduce the allowable RATs by 15.
2. Each two-way protected premises radio transmitter shall reduce the allowable RATs by two.

^aIncludes every initiating device circuit (for example, waterflow, fire alarm, supervisory, guard, burglary, hold-up).

^bParagraph 5-5.3.5.7 shall apply.

^cEach supervised BA (open/close) or each suppressed guard tour transmitter shall reduce the allowable RATs by five.

Exception: A multiple ground-fault condition that would prevent alarm operation shall be indicated by an alarm or by a trouble signal.

5-5.3.6.2 Circuits for transmission of supervisory signals shall be separate from alarm circuits. These circuits within the protected premises and between the protected premises and the supervising station shall be arranged as described in 5-5.3.6.1(a) or (b).

Exception: If the reception of alarm signals and supervisory signals at the same supervising station is permitted by the authority having jurisdiction, the supervisory signals do not interfere with the alarm signals, and alarm signals have priority, the same circuit between the protected premises and the supervising station shall be permitted to be used for alarm and supervisory signals.

5-5.3.6.3 The occurrence of a single break or a single ground fault on any circuit shall not of itself cause a false signal that is able to be interpreted as an alarm of fire.

5-5.3.6.4 The requirements of 5-5.3.6.1 and 5-5.3.6.2 shall not apply to the following circuits:

- (1) Circuits wholly within the supervising station
- (2) Circuits wholly within the protected premises extending from one or more automatic fire detectors or other non-coded initiating devices other than waterflow devices to a transmitter or control unit
- (3) Power supply leads wholly within the building or buildings protected

5-5.3.6.5 Loading Capacity of Circuits.

5-5.3.6.5.1 The number of initiating devices connected to any signaling circuit and the number of plants that shall be permitted to be served by a signal circuit shall be determined by the authority having jurisdiction and shall not exceed the limitations specified in 5-5.3.6.5.

A plant shall be permitted to consist of one or more buildings under the same ownership.

5-5.3.6.5.2* A single circuit shall not serve more than one plant.

5-5.3.7 Private Microwave Radio Systems.

5-5.3.7.1* If a private microwave radio is used as the transmission channel and communications channel, supervised transmitting and receiving equipment shall be provided at supervising, subsidiary, and repeater stations.

5-5.3.7.2 If more than five protected buildings or premises or 50 initiating devices or initiating device circuits are being serviced by a private radio carrier, the supervising, subsidiary, and repeater station radio facilities shall meet all of the following criteria.

(a) Dual supervised transmitters, arranged for automatic switching from one to the other in case of trouble, shall be installed. If the transmitters are located where someone is always on duty, switchboard facilities shall be permitted to be manually operated, provided the switching is able to be carried out within 30 seconds. If the transmitters are located where no one is continuously on duty, the circuit extending between the supervising station and the transmitters shall be a supervised circuit.

(b) *Transmitters shall be operated on a time ratio of 2:1 within each 24 hours.

(c) Dual receivers shall be installed with a means for selecting a usable output from one of the two receivers. The failure of one shall in no way interfere with the operation of the other. Failure of either receiver shall be annunciated.

5-5.3.7.3 Means shall be provided at the supervising station for the supervision and control of supervising, subsidiary, and repeater station radio transmitting and receiving equipment. If the radio equipment is remote from the supervising station, this shall be accomplished via a supervised circuit.

The following conditions shall be supervised at the supervising station:

- (1) Transmitter in use (radiating)
- (2) Failure of ac power supplying the radio equipment
- (3) Receiver malfunction
- (4) Indication of automatic switchover

It shall be possible to independently deactivate either transmitter from the supervising station.

5-5.4 Other Transmission Technologies.

5-5.4.1 Other transmission technologies shall include those transmission technologies that operate on principles different from transmission technologies covered by 5-5.3.1 through 5-5.3.7. Such transmission technologies shall be permitted to be installed if they conform to the requirements of 5-5.4 and to all other applicable requirements of this code.

5-5.4.2 Fire alarm system equipment and installations shall comply with the Federal Communications Commission (FCC) rules and regulations, as applicable, concerning electromagnetic radiation, use of radio frequencies, and connections to the public switched telephone network of telephone equipment, systems, and protection apparatus.

5-5.4.3 Equipment shall be installed in compliance with NFPA 70, *National Electrical Code*.

5-5.4.4 Provision shall be made to monitor the integrity of the transmission technology and its communications path.

5-5.4.4.1 Any failure shall be annunciated at the supervising station within 5 minutes of the failure.

5-5.4.4.2 If communications cannot be established with the supervising station, an indication of this failure to communicate shall be annunciated at the protected premises.

5-5.4.4.3 If a portion of the communications path cannot be monitored for integrity, a redundant communications path shall be provided.

5-5.4.4.3.1 Provision shall be made to monitor the integrity of the redundant communications path.

5-5.4.4.3.2 Failure of both the primary and redundant communications paths shall be annunciated at the supervising station within not more than 24 hours of the failure.

5-5.4.4.4 System units at the supervising station shall be restored to service within 30 minutes of a failure.

5-5.4.4.5 The transmission technology shall be designed so that upon failure of a transmission channel serving a system unit at the supervising station, the loss of the ability to monitor shall not affect more than 3000 transmitters.

5-5.4.5 Spare System Unit Equipment.

5-5.4.5.1 Sufficient spare equipment shall be maintained at the supervising station such that any failed piece of equipment can be replaced and the systems unit restored to full operation.

5-5.4.5.2 The complement of spare parts shall be sufficient to replace any failed critical component.

Exception: If multiples of the same components are used at the supervising station, the ratio of available spare parts to units in service shall be 1 to 5 minimum.

5-5.4.6 Loading Capacity of a System Unit.

5-5.4.6.1 The maximum number of independent fire alarm systems connected to a single system unit shall be limited to 512.

5-5.4.6.2 If duplicate spare system units are maintained at the supervising station and switchover can be achieved in 30 seconds, then the system capacity is unlimited.

5-5.4.7 End-to-End Communication Time for an Alarm. The maximum duration between the initiation of an alarm signal at the protected premises, transmission of the signal, and subsequent display and recording of the alarm signal at the supervising station shall not exceed 90 seconds.

5-5.4.8 Unique Premises Identifier. If a transmitter shares a transmission or communications channel with other transmitters, it shall have a unique transmitter identifier.

5-5.4.9 Recording and Display Rate of Subsequent Alarms. Recording and display of alarms at the supervising station shall be at a rate no slower than one complete signal every 10 seconds.

5-5.4.10 Signal Error Detection and Correction.

5-5.4.10.1 Communication of alarm, supervisory, and trouble signals shall be in a highly reliable manner to prevent degradation of the signal in transit, which in turn would result in either of the following:

- (1) Failure of the signal to be displayed and recorded at the supervising station
- (2) An incorrect corrupted signal displayed and recorded at the supervising station

5-5.4.10.2 Enhanced reliability of the signal shall be achieved by any of the following:

- (1) Signal repetition — multiple transmissions repeating the same signal
- (2) Parity check — a mathematically check sum algorithm of a digital message that verifies correlation between transmitted and received message
- (3) An equivalent means to (1) or (2) that provides a certainty of 99.99 percent that the received message is identical to the transmitted message.

5-5.4.11 Signal Priority. If the communications methodology is shared with any other usage, all fire alarm, supervisory, and trouble signals shall take precedence, in that respective order of priority, over all other signals.

Exception: Signals from hold-up alarms or other signals indicating life-threatening situations shall be permitted to take precedence over supervisory and trouble signals if acceptable to the authority having jurisdiction.

5-5.4.12 Sharing Communications Equipment On-Premises. If the fire alarm transmitter is sharing on-premises communications equipment, the shared equipment shall be listed for the purpose. If on-premises communications equipment is not listed for the purpose, the fire alarm transmitter shall be installed ahead of the unlisted communications equipment.

5-5.4.13 Service Provider Diversity. When a redundant path is required, the alternate path shall be provided by a public communications service provider different from the primary path, if available.

5-5.4.14 Throughput Probability. When the supervising station does not regularly communicate with the transmitter at least once every 200 seconds, then the throughput probability of the alarm transmission must be at least 90 percent in 90 seconds, 99 percent in 180 seconds, or 99.999 percent in 450 seconds.

5-5.4.15 Unique Flaws Not Covered by This Code. If a communications technology has a unique flaw that could result in

the failure to communicate a signal, the implementation of that technology for fire alarm signaling shall compensate for that flaw so as to eliminate the risk of missing a fire alarm signal.

5-5.5 Display and Recording Requirements for All Transmission Technologies.

5-5.5.1* Any status changes, including the initiation or restoration to normal of a trouble condition, that occur in an initiating device or in any interconnecting circuits or equipment, including the local protected premises controls from the location of the initiating device(s) to the supervising station, shall be presented in a form to expedite prompt operator interpretation. Status change signals shall provide the following information.

(a) *Type of Signal.* Identification of the type of signal to show whether it is an alarm, supervisory, delinquency, or trouble signal

(b) *Condition.* Identification of the signal to differentiate between an initiation of an alarm, supervisory, delinquency, or trouble signal and a clearing from one or more of these conditions

(c) *Location.* Identification of the point of origin of each status change signal

5-5.5.2* If duplicate equipment for signal receiving, processing, display, and recording is not provided, the installed equipment shall be designed so that any critical assembly is able to be replaced from on-premises spares and the system is able to be restored to service within 30 minutes. A critical assembly shall be an assembly in which a malfunction prevents the receipt and interpretation of signals by the supervising station operator.

Exception: Proprietary and remote station systems.

5-5.5.3* Any method of recording and display or indication of change of status signals shall be permitted, provided all of the following conditions are met.

(a) Each change of status signal requiring action to be taken by the operator shall result in an audible signal and not less than two independent methods of identifying the type, condition, and location of the status change.

(b) Each change of status signal shall be automatically recorded. The record shall provide the type of signal, condition, and location as required by 5-5.5.1 in addition to the time and date the signal was received.

(c) Failure of an operator to acknowledge or act upon a change of status signal shall not prevent subsequent alarm signals from being received, indicated or displayed, and recorded.

(d) Change of status signals requiring action to be taken by the operator shall be displayed or indicated in a manner that clearly differentiates them from those that have been acted upon and acknowledged.

(e) Each incoming signal to a DACR or DARR shall cause an audible signal that persists until manually acknowledged.

Exception: Test signals required by 5-5.3.2.1.10 received at a DACR or a DARR.

5-5.6 Testing and Maintenance Requirements for All Transmission Technologies. Testing and maintenance of communications methods shall be in accordance with the requirements of Chapter 7.

Chapter 6 Public Fire Alarm Reporting Systems

6-1 Public Fire Alarm Reporting Systems. If permitted by the authority having jurisdiction, use of systems described in Chapter 6 shall be permitted to provide defined reporting functions from or within private premises.

6-1.1 The requirements of Chapters 1 and 7 shall apply to public and auxiliary fire alarm reporting systems, unless they conflict with the requirements of this chapter.

6-1.2 Scope. This chapter covers the general requirements and use of public and auxiliary fire alarm reporting systems. These systems include the equipment necessary to effect the transmission and reception of fire alarms or other emergency calls connected to the public fire alarm reporting system.

6-2 General Fundamentals.

6-2.1* If implemented at the option of the authority having jurisdiction, a public fire alarm reporting system shall be designed, installed, operated, and maintained to provide the maximum practicable reliability for transmission and receipt of fire alarms.

6-2.2 A public fire alarm reporting system, as described herein, shall be permitted to be used for the transmission of other signals or calls of a public emergency nature, provided such transmission does not interfere with the transmission and receipt of fire alarms.

6-2.3 If applicable, electronic computer/data processing equipment shall be protected in accordance with NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*.

6-2.4 If a Type A system is required, automatic retransmission of alarms from boxes by use of electronic equipment shall be permitted, provided the following conditions are met:

- (1) Approved facilities are provided for the automatic receipt, storage, retrieval, and retransmission of alarms in the order received.
- (2) Override capability is provided to the operator(s) so that manual transmission at the dispatch facilities is immediately able to be used.

6-3 Management and Maintenance. The requirements of Chapter 7 shall apply.

6-3.1 All systems shall be under the control of a responsible jurisdictional employee. If maintenance is provided by an organization or person other than the municipality or its employees, complete written records of the installation, maintenance, test, and extension of the system shall be forwarded to the responsible employee as soon as possible.

6-3.2 Maintenance by an organization or person other than from the jurisdiction or an employee of the jurisdiction shall be by written contract, guaranteeing performance acceptable to the authority having jurisdiction.

6-3.3 All equipment shall be accessible to the authority having jurisdiction for the purpose of maintenance.

6-4 Equipment and Installation.

6-4.1 Means for actuation of alarms by the public shall be located where they are conspicuous and accessible for operation.

6-4.2 Records of wired public fire alarm reporting system circuits shall include the following:

- (1) Outline plans showing terminals and box sequence
- (2) Diagrams of applicable office wiring
- (3) List of materials used, including trade name, manufacturer, and year of purchase or installation

6-4.2.1 Public fire alarm reporting systems as defined in this chapter, shall, in their entirety, be subject to a complete operational acceptance test upon completion of system installation. This test(s) shall be made in accordance with the requirements of the authority having jurisdiction. However, in no case shall the operational functions tested be less than those stipulated in Chapter 7. Acceptance tests shall also be performed on any alarm reporting devices as identified in this chapter that are added subsequent to the installation of the initial system.

6-4.3 Publicly accessible boxes shall be recognizable as such. Boxes shall have operating instructions plainly marked on the exterior surface.

6-4.4 The actuating device shall be of such design and so located as to make the method of its use apparent.

6-4.5 Publicly accessible boxes shall be conspicuous. Their color shall be distinctive.

6-4.6 All publicly accessible boxes mounted on support poles shall be identified by a wide band of distinctive colors or signs placed 8 ft (2.44 m) above the ground and visible from all directions wherever possible.

6-4.7* Indicating lights of a distinctive color, visible for at least 1500 ft (460 m), shall be installed over publicly accessible boxes in mercantile and manufacturing areas. Equipping the street light nearest the box with a distinctively colored light shall meet this requirement.

6-4.8 Boxes shall be mounted in an approved manner on poles, pedestals, or structural surfaces as directed by the authority having jurisdiction.

6-4.9 Concurrent operation of at least four boxes shall not result in the loss of an alarm.

6-5 Publicly Accessible Fire Service Boxes (Street Boxes).

6-5.1 Street boxes, when in an abnormal condition, shall leave the circuit usable.

6-5.2 Street boxes shall be designed so that recycling does not occur if a box actuating device is held in the actuating position. Street boxes shall be ready to accept a new signal as soon as the actuating device is released.

6-5.3* Street boxes, when actuated, shall give a visible or audible indication to the user that the box is operating or that the signal has been transmitted to the communications center.

6-5.4 The street box housing shall protect the internal components from the weather.

6-5.5 Doors on street boxes shall remain operable under adverse climatic conditions, including icing and salt spray.

6-5.6 Street boxes shall be recognizable as such. Street boxes shall have instructions for use plainly marked on their exterior surfaces.

6-5.7 Street boxes shall be securely mounted on poles, pedestals, or structural surfaces as directed by the authority having jurisdiction.

6-5.8 Street boxes shall be as conspicuous as possible. Their color shall be distinctive, and they shall be visible from as many directions as possible. A wide band of distinctive colors visible over the tops of parked cars or adequate signs completely visible from all directions shall be applied to supporting poles.

6-5.9* Location-designating lights of distinctive color, visible for at least 1500 ft (460 m) in all directions, shall be installed over street boxes. The street light nearest the street box, if equipped with a distinctively colored light, shall be considered as meeting this requirement.

6-5.10 Street box cases and parts that are, at any time, accessible to users shall be of insulating materials or permanently and effectively grounded. All ground connections to street boxes shall comply with the requirements of NFPA 70, *National Electrical Code*[®], Article 250.

6-5.11 If a street box is installed inside a structure, it shall be placed as close as is practicable to the point of entrance of the circuit, and the exterior wire shall be installed in conduit or electrical metallic tubing in accordance with Chapter 3 of NFPA 70, *National Electrical Code*.

6-5.12 Coded Radio Street Boxes.

6-5.12.1 Coded radio street boxes shall be designed and operated in compliance with all applicable rules and regulations of the FCC, as well as with the requirements established herein.

6-5.12.2 Coded radio street boxes shall provide no less than three specific and individually identifiable functions to the communications center, in addition to the street box number, as follows:

- (1) Test
- (2) Tamper
- (3) Fire

6-5.12.3* Coded radio street boxes shall transmit to the communications center no less than one repetition for "test," no less than one repetition for "tamper," and no less than three repetitions for "fire."

6-5.12.4 If multifunction coded radio street boxes are used to transmit to the communications center a request(s) for emergency service or assistance in addition to those stipulated in 6-5.12.2, each such additional message function shall be individually identifiable.

6-5.12.5 Multifunction coded radio street boxes shall be designed so as to prevent the loss of supplemental or concurrently actuated messages.

6-5.12.6 An actuating device held or locked in the activating position shall not prevent the activation and transmission of other messages.

6-5.12.7 Power Source.

6-5.12.7.1 Box primary power shall be permitted to be from a utility distribution system, a photovoltaic power system, or user power, or shall be self-powered using either an integral battery or other stored energy source, as approved by the authority having jurisdiction.

6-5.12.7.2 Self-powered boxes shall have sufficient power for uninterrupted operation for a period of not less than 6 months. Self-powered boxes shall transmit a low power warning message to the communications center for at least 15 days prior to the time the power source will fail to operate the box. This message shall be part of all subsequent transmissions.

Use of a charger to extend the life of a self-powered box shall be permitted if the charger does not interfere with box operation. The box shall be capable of operation for not less than 6 months with the charger disconnected.

6-5.12.7.3 Boxes powered by a utility distribution system shall have an integral standby, sealed, rechargeable battery that is capable of powering box functions for at least 60 hours in the event of primary power failure. Transfer to standby battery power shall be automatic and without interruption to box operation. If operating from primary power, the box shall be capable of operation with a dead or disconnected battery. A local trouble indication shall activate upon primary power failure. A battery charger shall be provided in compliance with 1-5.2.8.2, except as modified herein.

If the primary power has failed, boxes shall transmit a power failure message to the communications center as part of subsequent test messages until primary power is restored. A low-battery message shall be transmitted to the communications center if the remaining battery standby time is less than 54 hours.

6-5.12.7.4 Photovoltaic power systems shall provide box operation for not less than 6 months.

Photovoltaic power systems shall be supervised. The battery shall have power to sustain operation for a minimum period of 15 days without recharging. The box shall transmit a trouble message to the communications center when the charger has failed for more than 24 hours. This message shall be part of all subsequent transmissions. If the remaining battery standby duration is less than 10 days, a low-battery message shall be transmitted to the communications center.

6-5.12.7.5 User-powered boxes shall have an automatic self-test feature.

6-5.13 Telephone Street Boxes.

6-5.13.1 If a handset is used, the caps on the transmitter and receiver shall be secured to reduce the probability of the telephone street box being disabled due to vandalism.

6-5.13.2 Telephone street boxes shall be designed to allow the communications center operator to determine whether or not the telephone street box has been restored to normal condition after use.

6-6* Location.

6-6.1 The location of publicly accessible boxes shall be designated by the authority having jurisdiction.

6-6.2 Schools, hospitals, nursing homes, and places of public assembly shall have a box located at the main entrance, as directed by the authority having jurisdiction.

6-7 Power Supply.

6-7.1 General.

6-7.1.1 Batteries, motor-generators, or rectifiers shall be able to supply all connected circuits without exceeding the capacity of any battery or overloading any generator or rectifier, so that circuits developing grounds or crosses with other circuits each

shall be able to be supplied by an independent source to the extent required by 6-7.1.8.

6-7.1.2 Provision shall be made in the operating room for supplying any circuit from any battery, generator, or rectifier. Enclosed fuses shall be provided at points where supplies for individual circuits are taken from common leads. Necessary switches, testing, and signal transmitting and receiving devices shall be provided to allow the isolation, control, and test of each circuit up to at least 10 percent of the total number of box and dispatch circuits, but never less than two circuits.

6-7.1.3 If common-current source systems are grounded, the ground shall not exceed 10 percent of resistance of any connected circuit and shall be located at one side of the battery. Visual and audible indicating devices shall be provided for each box and dispatch circuit to give immediate warning of ground leakage endangering operability.

6-7.1.4 Local circuits at communications centers shall be supplied either in common with box circuits or coded radio-receiving system circuits or by a separate power source. The source of power for local circuits required to operate the essential features of the system shall be supervised.

6-7.1.5 Visual and audible means to indicate a 15 percent or greater reduction of normal power supply (rated voltage) shall be provided.

6-7.1.6 If the electrical service/capacity of the equipment required under 2-1.6 of NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, is adequate to satisfy the needs of equipment in this chapter, such equipment shall not be required to be duplicated.

6-7.1.7 The forms and arrangements of power supply shall be as classified in 6-7.1.7.

6-7.1.8 Form 4.

6-7.1.8.1 Each box circuit or coded radio receiving system shall be served by the following:

(a) **Form 4A.* An inverter, powered from a common rectifier, receiving power by a single source of alternating current with a floating storage battery having a 24-hour standby capacity.

(b) **Form 4B.* An inverter, powered from a common rectifier, receiving power from two sources of alternating current with a floating storage battery having a 4-hour standby capacity.

(c) *Form 4A and Form 4B.* It shall be permitted to distribute the system load between two or more common rectifiers and batteries.

(d) **Form 4C.* A rectifier, converter, or motor-generator receiving power from two sources of alternating current with transfer facilities to apply power from the secondary source to the system within 30 seconds.

6-7.1.8.2 Form 4A and Form 4B shall be permitted to distribute the system load between two or more common rectifiers and batteries.

6-7.2 Rectifiers, Converters, Inverters, and Motor-Generators.

6-7.2.1 Rectifiers shall be supplied through an isolating transformer that takes energy from a circuit not to exceed 250 volts.

6-7.2.2 Complete spare units or spare parts shall be in reserve.

6-7.2.3 One spare rectifier shall be provided for each ten required for operation, but in no case shall less than one be provided.

6-7.2.4 Leads from rectifiers or motor-generators, with storage battery floating, shall have fuses rated at not less than 1 ampere and not more than 200 percent of maximum connected load. If not provided with battery floating, the fuse shall be not less than 3 amperes.

6-7.3 Engine-Driven Generator Sets.

6-7.3.1 The provisions of 6-7.3 shall apply to generators driven by internal combustion engines.

6-7.3.2 The installation of engine-driven generator sets shall conform to the provisions of NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, and NFPA 110, *Standard for Emergency and Standby Power Systems*.

Exception: Where restricted by the provisions of 6-7.3.

6-7.3.3 The engine-driven generator shall be located in a ventilated cutoff area of the building that houses the alarm-receiving equipment.

6-7.3.3.1 The area that houses the unit shall be used for no other purpose than for storage of spare parts or equipment.

6-7.3.3.2 Exhaust fumes shall be discharged directly outside the building.

6-7.3.4 Liquid fuel shall be stored in outside underground tanks and gravity feed shall not be used. Fuel shall be provided for 24 hours of operation at full load where a reliable source of fuel supply is able to be provided, at any time, on a 2-hour notice. If a source of supply is not reliable or able to be provided on a 2-hour notice, special arrangements shall be made for refueling as necessary. A supply for 48 hours of operation at full load shall be maintained.

6-7.3.5 Liquefied petroleum gas and natural gas installations shall meet the requirements of NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Liquefied Petroleum Gas Code*.

6-7.3.6 The unit, as a minimum, shall have the capacity to supply power to operate all fire alarm facilities and emergency lighting of the operating rooms or communications building.

6-7.3.7 A separate storage battery on automatic float charger shall be provided for starting the engine-driven generator.

6-7.3.8 If more than one engine-driven generator is provided, each shall be provided with a separate fuel line and transfer pump.

6-7.4 Float-Charged Batteries.

6-7.4.1 Float-charged batteries shall be of the storage type. Primary batteries (dry cells) shall not be used. All cells shall be of the sealed type.

6-7.4.2 Float-charged batteries shall be located on the same floor of the building as the operating equipment and shall be available for maintenance and inspection.

6-7.4.3 Batteries shall be mounted to provide effective insulation from the ground and from other batteries. The mounting shall be suitably protected against deterioration, and shall provide stability, especially in geographic areas subject to seismic disturbance.

6-8 Requirements for Metallic Systems and Metallic Interconnections.

6-8.1 Circuit Conductors.

6-8.1.1 Wires shall be terminated so as to prevent breaking from vibration or stress.

6-8.1.2 Circuit conductors on terminal racks shall be identified and isolated from conductors of other systems wherever possible and shall be suitably protected from mechanical injury.

6-8.1.3 Exterior cable and wire shall conform to International Municipal Signal Association (IMSA) specifications or an approved equivalent.

Exception: If circuit conductors are provided by a public utility on a lease basis, IMSA specifications shall not apply.

6-8.1.4 If a public box is installed inside a building, the circuit from the point of entrance to the public box shall be installed in rigid metal, intermediate metal conduit, or electrical metallic tubing in accordance with NFPA 70, *National Electrical Code*.

Exception: This requirement shall not apply to coded radio box systems.

6-8.2 Cables.

6-8.2.1 General.

6-8.2.1.1 Exterior cable and wire shall conform to IMSA specifications or an approved equivalent.

6-8.2.1.1.1 Overhead, underground, or direct burial cables shall be specifically approved for the purpose.

6-8.2.1.1.2 Cables used in interior installations shall comply with NFPA 70, *National Electrical Code*.

6-8.2.1.2 Paper or pressed pulp insulation shall not be permitted.

Exception: Cables containing conductors with such insulation shall be permitted if pressurized with dry air or nitrogen.

6-8.2.1.2.1 Loss of pressure in cables shall be indicated by a visual or audible warning system, located where an individual is in constant attendance who is able to interpret the pressure readings and who has authority to have the indicated abnormal condition corrected.

6-8.2.1.3 Natural rubber-sheathed cable shall not be used if it is able to be exposed to oil, grease, or other substances or conditions that tend to deteriorate the cable sheath. Braided-sheathed cable shall be used only inside of buildings if it is run in conduit or metal raceways.

6-8.2.1.4 Other municipally controlled signal wires shall be permitted to be installed in the same cable with fire alarm wires. Cables controlled by or containing wires of private signaling organizations shall be permitted to be used for fire alarm purposes only by permission of the authority having jurisdiction.

6-8.2.1.5 Signaling wires that are able to introduce a hazard, because of the source of current supply, shall be protected in accordance with NFPA 70, *National Electrical Code*.

6-8.2.1.6 All cables with all taps and splices made shall be tested for insulation resistance when installed, but before connection to terminals. Such tests shall indicate an insulation resistance of at least 200 megohms per mile between any one conductor and all other conductors, the sheath, and the ground.

6-8.2.2 Underground Cables.

6-8.2.2.1 Underground cables in duct or direct burial shall be brought aboveground only at points where liability of mechanical injury or of disablement from heat incidental to fires in adjacent buildings is minimized.

6-8.2.2.2 Cables shall be permitted in duct systems and manholes containing low-tension fire alarm system conductors only, except low-tension secondary power cables shall be permitted. If in duct systems or manholes that contain power circuit conductors in excess of 250 volts to ground, fire alarm cables shall be located as far as possible from such power cables and shall be separated from them by a noncombustible barrier or by such other means as is practicable to protect the fire alarm cables from injury.

6-8.2.2.3 All cables installed in manholes shall be racked and marked for identification.

6-8.2.2.4 All conduits or ducts entering buildings from underground duct systems shall be effectively sealed against moisture or gases entering the building.

6-8.2.2.5 Cable joints shall be located only in manholes, fire stations, and other locations where accessibility is provided and where there is little liability of injury to the cable due to either falling walls or operations in the buildings. Open cable joints shall be made to provide and maintain conductivity, insulation, and protection at least equal to that afforded by the cables that are joined. Cable ends shall be sealed against moisture.

6-8.2.2.6 Direct-burial cable, without enclosure in ducts, shall be laid in grass plots, under sidewalks, or in other places where the ground is not likely to be opened for other underground construction. If splices are made, such splices shall, if practicable, be accessible for inspection and tests. Such cables shall be buried at least 18 in. (0.5 m) deep and, where crossing streets or other areas likely to be opened for other underground construction, shall be in duct or conduit or be covered by creosoted planking of at least 2 in. × 4 in. (50 mm × 100 mm) with half-round grooves, spiked or banded together after the cable is installed.

6-8.2.3 Aerial Construction.

6-8.2.3.1 Fire alarm wires shall be run under all other wires except communications wires. Suitable precautions shall be provided if passing through trees, under bridges, over railroads, and at other places where injury or deterioration is possible. Wires and cables shall not be attached to a crossarm that carries electric light and power wires, except circuits carrying up to 220 volts for public communications use, and then only if the 220-volt circuits are tagged or otherwise identified.

6-8.2.3.2 Aerial cable shall be supported by messenger wire of approved tensile strength.

Exception: Two-conductor cable that has conductors of No. 20 AWG or larger size and has mechanical strength equal to No. 10 AWG hard-drawn copper.

6-8.2.3.3 Single wire shall meet IMSA specifications and shall not be smaller than No. 10 Roebbling gauge if of galvanized iron or steel, No. 10 AWG if of hard-drawn copper, No. 12 AWG if of approved copper-covered steel, or No. 6 AWG if of aluminum. Span lengths shall not exceed the manufacturer's recommendations.

6-8.2.3.4 Wires to buildings shall contact only intended supports and shall enter through an approved weatherhead or suitable sleeves slanting upward and inward. Drip loops shall be formed on wires outside of buildings.

6-8.2.4 Leads Down Poles.

6-8.2.4.1 Leads down poles shall be protected against mechanical injury. Any metallic covering shall form a continuous conducting path to ground. Installation, in all cases, shall prevent water from entering the conduit or box.

6-8.2.4.2 Leads to boxes shall have 600-volt insulation approved for wet locations, as defined in NFPA 70, *National Electrical Code*.

6-8.2.5 Wiring Inside Buildings.

6-8.2.5.1 At the communications center, conductors shall extend as directly as possible to the operating room in conduits, ducts, shafts, raceways, or overhead racks and troughs of a type of construction affording protection against fire and mechanical injury.

6-8.2.5.2 All conductors inside buildings shall be in conduit, electrical tubing, metal molding, or raceways. Installation shall be in accordance with NFPA 70, *National Electrical Code*.

6-8.2.5.3 Conductors shall have an approved insulation. The insulation or other outer covering shall be flame retardant and moisture resistant.

6-8.2.5.4 Conductors shall be installed as far as possible without joints. Splices shall be permitted only in listed junction or terminal boxes. Fire alarm circuits shall be identified by the use of red covers or doors and the words "municipal fire alarm circuit" shall be clearly marked on all terminal and junction locations to prevent unintentional interference. Wire terminals, terminal boxes, splices, and joints shall conform to NFPA 70, *National Electrical Code*.

6-8.2.5.5 Conductors bunched together in a vertical run that connects two or more floors shall have a flame-retardant covering that is able to prevent the carrying of fire from floor to floor.

Exception: This requirement shall not apply where the conductors are encased in a metallic conduit or located in a fire-resistive shaft having fire stops at each floor.

6-8.2.5.6 Cable and wiring exposed to a fire hazard shall be protected in an approved manner.

6-8.2.5.7 Cable terminals and cross-connecting facilities shall be located in or adjacent to the operations room.

6-8.2.5.8 If signal conductors and electric light and power wires are run in the same shaft, they shall be separated by at least 2 in. (51 mm), or either system shall be encased in a non-combustible enclosure.

6-9 Facilities for Signal Transmission.

6-9.1 Circuits.

6-9.1.1 General.

6-9.1.1.1 ANSI/IEEE C2, *National Electrical Safety Code*, shall be used as a guide for the installation of outdoor circuitry.

6-9.1.1.2 Installation shall provide for the following:

- (1) Continuity of service
- (2) Protection from mechanical damage

- (3) Disablement from heat that is incidental to fire
- (4) Protection from falling walls
- (5) Damage by floods, corrosive vapors, or other causes

6-9.1.1.3 Open local circuits within single buildings shall be permitted in accordance with Chapter 3.

6-9.1.1.4 All circuits shall be routed so as to allow tracing of circuits for trouble.

6-9.1.1.5 Circuits shall not pass over, under, through, or be attached to buildings or property not owned by or under the control of the authority having jurisdiction or the agency responsible for maintaining the system.

Exception: Where the circuit is terminated at a public fire alarm reporting system initiating device on the premises and where a means, approved by the authority having jurisdiction, is provided to disconnect the circuit from the building or property.

6-9.1.2 Box Circuits. A means provided only to the authority having jurisdiction or the agency responsible for maintaining the public fire alarm reporting system shall be provided for disconnecting the circuit inside the building. Definite notification shall be given to the designated building representative when the interior box(es) is out of service.

6-9.1.3 Tie Circuits.

6-9.1.3.1 A separate tie circuit shall be provided from the communications center to each subsidiary communications center.

6-9.1.3.2 The tie circuit between the communications center and the subsidiary communications center shall not be used for any other purpose.

6-9.1.3.3 In a Type B wire system, if all boxes in the system are of the succession type, it shall be permitted to use the tie circuit as a dispatch circuit to the extent permitted by NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*.

6-9.1.4* Circuit Protection.

6-9.1.4.1 General.

6-9.1.4.1.1 The protective devices shall be located close to or be combined with the cable terminals.

6-9.1.4.1.2 Surge arresters for the purpose shall be provided. Surge arresters shall be marked with the name of the manufacturer and model designation.

6-9.1.4.1.3 All surge arresters shall be connected to a ground in accordance with NFPA 70, *National Electrical Code*.

6-9.1.4.1.4 All fuses shall be plainly marked with their rated ampere capacity. All fuses rated over 2 amperes shall be of the enclosed type.

6-9.1.4.1.5 Circuit protection required at the communications center shall be provided in every building that houses communications center equipment.

6-9.1.4.1.6 Each conductor entering a fire station from partially or entirely aerial lines shall be protected by a lightning arrester.

6-9.1.4.2 Communications Center.

6-9.1.4.2.1 All conductors entering the communications center shall be protected by the following devices, in the order named, starting from the exterior circuit:

- (1) A fuse rated at 3 amperes minimum to 7 amperes maximum and not less than 2000 volts
- (2) A surge arrester(s)
- (3) A fuse or circuit breaker rated at $1/2$ ampere

6-9.1.4.2.2 The $1/2$ -ampere protection on the tie circuits shall be omitted at subsidiary communications centers.

6-9.1.4.3 Protection on Aerial Construction.

6-9.1.4.3.1 At junction points of open aerial conductors and cable, each conductor shall be protected by a surge arrester(s) of the weatherproof type. There also shall be a connection between the lightning arrester ground, any metallic sheath, and messenger wire.

6-9.1.4.3.2 Aerial open-wire and non-messenger-supported, two-conductor cable circuits shall be protected by a surge arrester(s) at intervals not to exceed 2000 ft (610 m).

6-9.1.4.3.3 Surge arresters, other than of the air-gap or self-restoring type, shall not be installed in fire alarm circuits.

6-9.1.4.3.4 All protective devices shall be accessible for maintenance and inspection.

6-10 Power.

6-10.1 Requirements for Constant-Current Systems.

6-10.1.1 Means shall be provided for manually regulating the current in box circuits so that the operating current is maintained within 10 percent of normal throughout changes in external circuit resistance from 20 percent above to 50 percent below normal.

6-10.1.2 The voltage supplied to maintain normal line current on box circuits shall not exceed 150 volts, measured under no-load conditions, and shall be such that the line current cannot be reduced below the approved operating value by the simultaneous operation of four boxes.

6-10.1.3 Visual and audible means to indicate a 20 percent or greater reduction in the normal current in any alarm circuit shall be provided. All devices connected in series with any alarm circuit shall function when the alarm circuit current is reduced to 70 percent of normal.

6-10.1.4 Meters shall be provided to indicate the current in any box circuit and the voltage of any power source. Meters used in common for two or more circuits shall be provided with cut-in devices designed to reduce the probability of cross-connecting circuits.

6-11 Receiving Equipment — Facilities for Receipt of Box Alarms.

6-11.1 General.

6-11.1.1 Alarms from boxes shall be automatically received and recorded at the communications center.

6-11.1.2 A permanent visual record and an audible signal shall be required to indicate the receipt of an alarm. The permanent record shall indicate the exact location from which the alarm is being transmitted.

The audible signal device shall be permitted to be common to two or more box circuits and arranged so that the fire alarm operator is able to manually silence the signal temporarily by a self-restoring switch.

6-11.1.3 Facilities shall be provided that automatically record the date and time of receipt of each alarm.

Exception: Only the time shall be required to be automatically recorded for voice recordings.

6-11.2 Visual Recording Devices.

6-11.2.1 A device for producing a permanent graphic recording of all alarm, supervisory, trouble, and test signals received or retransmitted, or both, shall be provided at each communications center for each alarm circuit and tie circuit. If each circuit is served by a dedicated recording device, the number of reserve recording devices required on site shall be equal to at least 5 percent of the circuits in service and in no case less than 1 percent. If two or more circuits are served by a common recording device, a reserve recording device shall be provided on site for each circuit connected to a common recorder.

6-11.2.2 In a Type B wire system, one such recording device shall be installed in each fire station and at least one shall be installed in the communications center.

6-11.3 System Integrity.

6-11.3.1 Wired circuits upon which transmission and receipt of alarms depend, shall be constantly monitored for integrity to provide prompt warning of conditions adversely affecting reliability.

6-11.3.2 The power supplied to all required circuits and devices of the system shall be constantly monitored for integrity.

6-11.4 Trouble Signals.

6-11.4.1 Trouble signals shall actuate a sounding device located where there is a responsible person on duty at all times.

6-11.4.2 Trouble signals shall be distinct from alarm signals and shall be indicated by both a visual light and an audible signal.

6-11.4.3 The audible signal shall be permitted to be common to more than one circuit that is monitored for integrity.

6-11.4.4 A switch for silencing the audible trouble signal shall be permitted, provided the visual signal remains operating until the silencing switch is restored to its normal position.

6-11.4.5 The audible signal shall be responsive to faults on any other circuits that occur prior to restoration of the silencing switch to its normal position.

6-12 Remote Receiving Equipment — Facilities for Receipt of Box Alarms at a Remote Communications Center. When the alarm receiving equipment is located at a location other than where the box circuit protection, controls, and power supplies are located, the following requirements, in addition to all of the requirements of Section 6-11, shall apply. All equipment used to provide the primary and remote receiving facilities shall be listed for its intended use and shall be installed in accordance with NFPA 70, *National Electrical Code*.

6-12.1 The monitoring for integrity of all box circuits shall be provided with a visual and audible means to indicate a 20 percent or greater reduction or increase in the normal current in any box alarm circuit. The visual means shall identify the exact circuit affected.

6-12.2 Monitoring for integrity of all power supplies shall be provided with visual and audible means to indicate a loss of

primary or standby power supplies at both the primary and remote communications centers.

6-12.3 A minimum of two separate means of interconnection shall be provided between the primary and remote communications center receiving equipment. This interconnection shall be dedicated and shall not be used for any other purpose.

6-12.4 When data transmission or multiplexing equipment is used that is not an integral part of the alarm-receiving equipment, a visual and audible means shall be provided to monitor the integrity of the external equipment. This shall include monitoring all primary and stand-by power supplies as well as the transmission of data.

6-12.5 Power shall be provided in accordance with Section 6-7. The use of an uninterruptible power supply (UPS) to comply with standby power requirements shall not be permitted.

6-13 Coded Wired Reporting Systems.

6-13.1 For a Type B system, the effectiveness of noninterference and succession functions between box circuits shall be no less than between boxes in any one circuit. The disablement of any metallic box circuit shall cause a warning signal in all other circuits, and, thereafter, the circuit or circuits not otherwise broken shall be automatically restored to operative condition.

6-13.2 Box circuits shall be sufficient in number and laid out so that the areas that would be left without box protection in case of disruption of a circuit do not exceed those covered by 20 properly spaced boxes if all or any part of the circuit is of aerial open-wire, or 30 properly spaced boxes if the circuit is entirely in underground or messenger-supported cable.

6-13.3 If all boxes on any individual circuit and associated equipment are designed and installed to provide for receipt of alarms through the ground in the event of a break in the circuit, the circuit shall be permitted to serve twice the number of aerial open-wire and cable circuits, respectively, as are specified in 6-13.2.

6-13.4 The installation of additional boxes in an area served by the number of properly spaced boxes indicated in 6-13.1 through 6-13.3 shall not constitute geographical overloading of a circuit.

6-13.5 Sounding devices for signals shall be provided for box circuits.

6-13.5.1 A common sounding device for more than one circuit shall be permitted to be used in a Type A system and shall be installed at the communications center.

6-13.5.2 In a Type B system, a sounding device shall be installed in each fire station at the same location as the recording device for that circuit, unless installed at the communications center, where a common sounding device shall be permitted.

6-14 Coded Radio Reporting Systems.

6-14.1 Radio Box Channel (Frequency).

6-14.1.1 The number of boxes permitted on a single frequency shall be governed by the following.

(a) For systems that use one-way transmission in which the individual box automatically initiates the required message (*refer to 6-14.6.3*) using circuitry integral to the boxes, not more than 500 boxes shall be permitted on a single frequency.

(b) For systems that use a two-way concept in which interrogation signals (*refer to 6-14.6.3*) are transmitted to the individual boxes from the communications center on the same frequency used for receipt of alarms, not more than 250 boxes shall be permitted on a single frequency. If interrogation signals are transmitted on a frequency that differs from that used for receipt of alarms, not more than 500 boxes shall be permitted on a single frequency.

(c) A specific frequency shall be designated for both fire and other fire-related or public safety alarm signals and for monitoring for integrity signals.

6-14.1.2 If box message signals to the communications center or acknowledgment of message receipt signals from the communications center to the box are repeated, associated repeating facilities shall conform to the requirements indicated in 7-1.1.4(d) of NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*.

6-14.2 Metallic Interconnections. A means that is available only to the agency responsible for maintaining the public fire alarm reporting system shall be provided for disconnecting the auxiliary loop to the connected property. Notification shall be given to the designated representative of the property when the auxiliary box is not in service.

6-14.3 The antenna transmission line between the transmitter and the antenna shall be installed in rigid metal, intermediate metal conduit, or electrical metallic tubing in accordance with NFPA 70, *National Electrical Code*.

6-14.3.1 Type A System.

6-14.3.1.1* For each frequency used, two separate receiving networks, each including an antenna, an audible alerting device, a receiver, a power supply, signal processing equipment, a means of providing a permanent graphic recording of the incoming message that is both timed and dated, and other associated equipment shall be provided and shall be installed at the communications center. Facilities shall be arranged so that a failure of either receiving network cannot affect the receipt of messages from boxes.

6-14.3.1.2 If the system configuration is such that a polling device is incorporated into the receiving network to allow remote or selective initiation of box tests, a separate such device shall be included in each of the two required receiving networks. The requirements of Chapter 7 shall apply. Furthermore, the polling devices shall be configured for automatic cycle initiation in their primary operating mode, shall be capable of continuous self-monitoring, and shall be integrated into the network(s) to provide automatic switchover and operational continuity in the event of failure of either device.

6-14.3.1.3 Test signals from boxes shall not be required to include the date as part of their permanent recording, provided that the date is automatically printed on the recording tape at the beginning of each calendar day.

6-14.3.2 Type B System.

6-14.3.2.1 For each frequency used, a single, complete receiving network shall be permitted in each fire station, provided the communications center conforms to 6-14.3.1.1. If the jurisdiction maintains two or more alarm reception points in operation, one receiving network shall be permitted to be at each alarm reception point.

6-14.3.2.2 If alarm signals are transmitted to a fire station from the communications center using the coded radio-type receiving equipment in the fire station to receive and record the alarm message, a second receiving network conforming to 6-14.3.2.1 shall be provided at each fire station, and that receiving network shall employ a frequency other than that used for the receipt of box messages.

6-14.4 Power. Power shall be provided in accordance with Section 6-7.

6-14.5 Testing. The requirements of Chapter 7 shall apply.

6-14.6 Supervision.

6-14.6.1 All coded radio box systems shall provide constant monitoring of the frequency in use. Both an audible and a visual indication of any sustained carrier signal, if in excess of 15-second duration, shall be provided for each receiving system at the communications center.

6-14.6.2 The power supplied to all required circuits and devices of the system shall be supervised.

6-14.6.3* Each coded radio box shall automatically transmit a test message at least once in each 24-hour period.

6-14.6.4 Receiving equipment associated with coded radio-type systems, including any related repeater(s), shall be tested at least hourly. The receipt of test messages that do not exceed 60-minute intervals shall meet this requirement.

6-14.6.5 Radio repeaters upon which receipt of alarms depend shall be provided with dual receivers, transmitters, and power supplies. Failure of the primary receiver, transmitter, or power supply shall cause an automatic switchover to the secondary receiver, transmitter, or power supply.

Exception: Manual switchover shall be permitted provided it is completed within 30 seconds.

6-14.6.6 Trouble signals shall actuate a sounding device located where there is always a responsible person on duty.

6-14.6.7 Trouble signals shall be distinct from alarm signals and shall be indicated by both a visual light and an audible signal.

The audible signal shall be permitted to be common to two or more supervised circuits.

A switch for silencing the audible trouble signal shall be permitted if the visual signal remains operating until the silencing switch is restored to its normal position.

6-14.6.8 The audible signal shall be responsive to subsequent faults in other monitored functions prior to restoration of the silencing switch.

6-15 Telephone (Series) Reporting Systems.

6-15.1 A permanent visual recording device installed in the communications center shall be provided to record all incoming box signals. A spare recording device shall be provided for five or more box circuits.

6-15.2 A second visual means of identifying the calling box shall be provided.

6-15.3 Audible signals shall indicate all incoming calls from box circuits.

6-15.4 All voice transmissions from boxes for emergencies shall be recorded with the capability of instant playback.

6-15.5 A voice recording facility shall be provided for each operator handling incoming alarms to eliminate the possibility of interference.

6-15.6 Box circuits shall be sufficient in number and laid out so that the areas that would be left without box protection in case of disruption of a circuit do not exceed those covered by 20 properly spaced boxes if all or any part of the circuit is of aerial open-wire, or 30 properly spaced boxes if the circuit is entirely in underground or messenger-supported cable.

6-15.7 If all boxes on any individual circuit and associated equipment are designed and installed to provide for receipt of alarms through the ground in the event of a break in the circuit, the circuit shall be permitted to serve twice the number of aerial open-wire and cable circuits, respectively, as is specified in 6-15.6.

6-15.8 The installation of additional boxes in an area served by the number of properly spaced boxes indicated in 6-15.6 shall not constitute geographical overloading of a circuit.

6-16 Auxiliary Fire Alarm Systems. The requirements of Chapter 1, 3, and 7 shall apply to auxiliary fire alarm systems, unless they conflict with the requirements of Section 6-16. If permitted by the authority having jurisdiction, the use of systems described in Chapter 6 shall be permitted to provide defined reporting functions from or within private premises.

6-16.1 Scope. Section 6-16 describes the equipment and circuits necessary to connect a protected premises.

6-16.2 General.

6-16.2.1 An auxiliary fire alarm system shall be used only in connection with a public fire alarm reporting system that is approved for the service. A system approved by the authority having jurisdiction shall meet this requirement.

6-16.2.2 Permission for the connection of an auxiliary fire alarm system to a public fire alarm reporting system, and acceptance of the type of auxiliary transmitter and its actuating mechanism, circuits, and components connected thereto, shall be obtained from the authority having jurisdiction.

6-16.2.3 An auxiliary fire alarm system shall be maintained and supervised by a responsible person or corporation.

6-16.2.4 Section 6-16 shall not require the use of audible alarm signals other than those necessary to operate the auxiliary fire alarm system. If it is desired to provide fire alarm evacuation signals in the protected property, the alarms, circuits, and controls shall comply with the provisions of Chapter 3 in addition to the provisions of Section 6-16.

6-16.3 Communications Center Facilities. The communications center facilities shall be in accordance with the requirements of Sections 6-1 through 6-15.

6-16.4 Equipment.

6-16.4.1 Types of Systems. Auxiliary fire alarm systems shall be of the following two types.

(a) **Local Energy Type.*

(1) Local energy systems shall be permitted to be of the coded or noncoded type.

(2) Power supply sources for local energy systems shall conform to Chapter 1.

(b) **Shunt Type.*

- (1) Shunt systems shall be noncoded with respect to any remote electrical tripping or actuating devices.
- (2) All conductors of the shunt circuit shall be installed in accordance with NFPA 70, *National Electrical Code*, Article 346, for rigid conduit, or Article 348, for electrical metallic tubing.
- (3) Both sides of the shunt circuit shall be in the same conduit.
- (4) If an auxiliary transmitter is located within a private premises, it shall be installed in accordance with 6-9.1.
- (5) If a shunt loop is used, it shall not exceed a length of 750 ft (230 m) and shall be in conduit.
- (6) Conductors of the shunt circuits shall not be smaller than No. 14 AWG and shall be insulated as prescribed in NFPA 70, *National Electrical Code*, Article 310.
- (7) The power for shunt-type systems shall be provided by the public fire alarm reporting system.
- (8) A local system made to an auxiliary system by the addition of a relay whose coil is energized by a local power supply and whose normally closed contacts trip a shunt-type master box shall not be permitted.

6-16.4.2 The interface of the two types of auxiliary fire alarm systems with the three types of public fire alarm reporting systems shall be in accordance with Table 6-16.4.2.

Table 6-16.4.2 Application of Public Fire Alarm Reporting Systems with Auxiliary Fire Alarm Systems

Reporting Systems	Local Energy Type	Shunt Type	Parallel Type
Coded wired	Yes	Yes	No
Coded radio	Yes	No	No
Telephone series	Yes	No	No

6-16.4.3 The application of the two types of auxiliary fire alarm systems shall be limited to the initiating devices specified in Table 6-16.4.3.

6-16.4.4 Location of Transmitting Devices.

6-16.4.4.1 Shunt-type auxiliary systems shall be arranged so that one auxiliary transmitter does not serve more than 100,000 ft² (9290 m²) total area.

Exception: Where otherwise permitted by the authority having jurisdiction.

6-16.4.4.2 A separate auxiliary transmitter shall be provided for each building, or where permitted by the authority having jurisdiction, for each group of buildings of single ownership or occupancy.

6-16.4.4.3 The same box shall be permitted to be used as a public fire alarm reporting system box and as a transmitting device for an auxiliary system if permitted by the authority having jurisdiction, provided that the box is located at the outside of the entrance to the protected property.

The fire department shall be permitted to require the box to be equipped with a signal light to differentiate between automatic and manual operation, unless local outside alarms at the protected property serve the same purpose.

Table 6-16.4.3 Application of Initiating Device with Auxiliary Fire Alarm Systems

Initiating Devices	Local Energy Type	Shunt Type	Parallel Type
Manual fire alarm	Yes	Yes	Yes
Waterflow or actuation of the fire extinguishing system(s) or suppression system(s)	Yes	Yes	Yes
Automatic detection devices	Yes	No	Yes

6-16.4.4.4 The transmitting device shall be located as required by the authority having jurisdiction.

6-16.4.4.5 The system shall be designed and arranged so that a single fault on the auxiliary system shall not jeopardize operation of the public fire alarm reporting system and shall not, in case of a single fault on either the auxiliary or public fire alarm reporting system, transmit a false alarm on either system.

Exception: Shunt systems complying with 6-16.4.1(b).

6-16.5 Personnel. Personnel necessary to receive and act on signals from auxiliary fire alarm systems shall be in accordance with the requirements of Sections 6-1 through 6-16 and NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*.

6-16.6 Operations. Operations for auxiliary fire alarm systems shall be in accordance with the requirements of Sections 6-1 through 6-16 and NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*.

6-16.7 Testing and Maintenance. Testing and maintenance of auxiliary fire alarm systems shall be in accordance with the requirements of Chapter 7.

Chapter 7 Inspection, Testing, and Maintenance

7-1 General.

7-1.1 Scope. Chapter 7 shall cover the minimum requirements for the inspection, testing, and maintenance of the fire alarm systems described in Chapter 1, 3, and 5 and for their initiation and notification components described in Chapter 2 and 4. The testing and maintenance requirements for one- and two-family dwelling units shall be located in Chapter 8. Single station detectors used for other than one- and two-family dwelling units shall be tested and maintained in accordance with Chapter 7. More stringent inspection, testing, or maintenance procedures that are required by other parties shall be permitted.

7-1.1.1 Inspection, testing, and maintenance programs shall satisfy the requirements of this code, shall conform to the equipment manufacturer's recommendations, and shall verify correct operation of the fire alarm system.

7-1.1.2 System defects and malfunctions shall be corrected. If a defect or malfunction is not corrected at the conclusion of system inspection, testing, or maintenance, the system owner or the owner's designated representative shall be informed of the impairment in writing within 24 hours.

7-1.1.3 Nothing in Chapter 7 shall be intended to prevent the use of alternate test methods or testing devices. Such methods or devices shall provide the same level of effectiveness, and safety, and shall meet the intent of the requirements of Chapter 7.

7-1.1.4 The requirements of Chapter 7 shall apply to both new and existing systems.

7-1.2 The owner or the owner's designated representative shall be responsible for inspection, testing, and maintenance of the system and alterations or additions to this system. The delegation of responsibility shall be in writing, with a copy of such delegation provided to the authority having jurisdiction upon request.

7-1.2.1 Inspection, testing, or maintenance shall be permitted to be done by a person or organization other than the owner if conducted under a written contract. Testing and maintenance of central station service systems shall be performed under the contractual arrangements specified in 5-2.2.2.

7-1.2.2 Service personnel shall be qualified and experienced in the inspection, testing, and maintenance of fire alarm systems. Examples of qualified personnel shall be permitted to include, but shall not be limited to, individuals with the following qualifications:

- (1) Factory trained and certified
- (2) National Institute for Certification in Engineering Technologies fire alarm certified
- (3) International Municipal Signal Association fire alarm certified
- (4) Certified by a state or local authority
- (5) Trained and qualified personnel employed by an organization listed by a national testing laboratory for the servicing of fire alarm systems

7-1.3* Notification.

7-1.3.1 Before proceeding with any testing, all persons and facilities receiving alarm, supervisory, or trouble signals, and all building occupants, shall be notified of the testing to prevent unnecessary response. At the conclusion of testing, those previously notified (and others, as necessary) shall be notified that testing has been concluded.

7-1.3.2 The owner or the owner's designated representative and service personnel shall coordinate system testing to prevent interruption of critical building systems or equipment.

7-1.4 Prior to system maintenance or testing, the system certificate and the information regarding the system and system alterations, including specifications, wiring diagrams, and floor plans, shall be provided by the owner or a designated representative to the service personnel upon request.

7-1.5 Releasing Systems. Requirements pertinent to testing the fire alarm systems initiating fire suppression system releasing functions shall be covered by 7-1.5.

7-1.5.1 Testing personnel shall be qualified and experienced in the specific arrangement and operation of a suppression system(s) and a releasing function(s) and cognizant of the hazards associated with inadvertent system discharge.

7-1.5.2 Occupant notification shall be required whenever a fire alarm system configured for releasing service is being serviced or tested.

7-1.5.3 Discharge testing of suppression systems shall not be required by this code. Suppression systems shall be secured from inadvertent actuation, including disconnection of releasing solenoids or electric actuators, closing of valves, other actions, or combinations thereof, for the specific system, for the duration of the fire alarm system testing.

7-1.5.4 Testing shall include verification that the releasing circuits and components energized or actuated by the fire alarm system are electrically supervised and operate as intended on alarm.

7-1.5.5 Suppression systems and releasing components shall be returned to their functional operating condition upon completion of system testing.

7-1.6 System Testing.

7-1.6.1 Initial Acceptance Testing. All new systems shall be inspected and tested in accordance with the requirements of Chapter 7.

7-1.6.2* Reacceptance Testing.

7-1.6.2.1 Reacceptance testing shall be performed after any of the following:

- (1) Added or deleted system components
- (2) Any modification, repair, or adjustment to system hardware or wiring
- (3) Any change to site-specific software.

All components, circuits, systems operations, or site-specific software functions known to be affected by the change or identified by a means that indicates the system operational changes shall be 100 percent tested. In addition, 10 percent of initiating devices that are not directly affected by the change, up to a maximum of 50 devices, also shall be tested, and correct system operation shall be verified. A revised record of completion in accordance with 1-6.2.1 shall be prepared to reflect any changes.

7-1.6.2.2 Changes to all control units connected or controlled by the system executive software shall require a 10 percent functional test of the system, including a test of at least one device on each input and output circuit to verify critical system functions such as notification appliances, control functions, and off-premises reporting.

7-2 Test Methods.

7-2.1* Central Stations. At the request of the authority having jurisdiction, the installation shall be inspected for complete information regarding the system, including specifications, wiring diagrams, and floor plans that have been submitted for approval prior to installation of equipment and wiring.

7-2.2* Fire alarm systems and other systems and equipment that are associated with fire alarm systems and accessory equipment shall be tested according to Table 7-2.2.

Table 7-2.2 Test Methods

Device	Method
1. Control Equipment	
a. Functions	At a minimum, control equipment shall be tested to verify correct receipt of alarm, supervisory, and trouble signals (inputs), operation of evacuation signals and auxiliary functions (outputs), circuit supervision including detection of open circuits and ground faults, and power supply supervision for detection of loss of ac power and disconnection of secondary batteries.
b. Fuses	The rating and supervision shall be verified.
c. Interfaced Equipment	Integrity of single or multiple circuits providing interface between two or more control panels shall be verified. Interfaced equipment connections shall be tested by operating or simulating operation of the equipment being supervised. Signals required to be transmitted shall be verified at the control panel.
d. Lamps and LEDs	Lamps and LEDs shall be illuminated.
e. Primary (Main) Power Supply	All secondary (standby) power shall be disconnected and tested under maximum load, including all alarm appliances requiring simultaneous operation. All secondary (standby) power shall be reconnected at end of test. For redundant power supplies, each shall be tested separately.
2. Engine-Driven Generator	If an engine-driven generator dedicated to the fire alarm system is used as a required power source, operation of the generator shall be verified in accordance with NFPA 110, <i>Standard for Emergency and Standby Power Systems</i> , by the building owner.
3. Secondary (Standby) Power Supply	All primary (main) power supplies shall be disconnected and the occurrence of required trouble indication for loss of primary power shall be verified. The system's standby and alarm current demand shall be measured or verified and, using manufacturer's data, the ability of batteries to meet standby and alarm requirements shall be verified. General alarm systems shall be operated for a minimum of 5 minutes and emergency voice communications systems for a minimum of 15 minutes. Primary (main) power supply shall be reconnected at end of test.
4. Uninterrupted Power Supply (UPS)	If a UPS system dedicated to the fire alarm system is used as a required power source, operation of the UPS system shall be verified by the building owner in accordance with NFPA 111, <i>Standard on Stored Electrical Energy Emergency and Standby Power Systems</i> .
5. Batteries — General Tests	
a. Visual Inspection	<p>Prior to conducting any battery testing, the person conducting the test shall ensure that all system software stored in volatile memory is protected from loss.</p> <p>Batteries shall be inspected for corrosion or leakage. Tightness of connections shall be checked and ensured. If necessary, battery terminals or connections shall be cleaned and coated. Electrolyte level in lead-acid batteries shall be visually inspected.</p>
b. Battery Replacement	Batteries shall be replaced in accordance with the recommendations of the alarm equipment manufacturer or when the recharged battery voltage or current falls below the manufacturer's recommendations.
c. Charger Test	Operation of battery charger shall be checked in accordance with charger test for the specific type of battery.
d. Discharge Test	<p>With the battery charger disconnected, the batteries shall be load tested following the manufacturer's recommendations. The voltage level shall not fall below the levels specified.</p> <p><i>Exception: An artificial load equal to the full fire alarm load connected to the battery shall be permitted to be used in conducting this test.</i></p>
e. Load Voltage Test	With the battery charger disconnected, the terminal voltage shall be measured while supplying the maximum load required by its application.

Table 7-2.2 Test Methods (Continued)

Device	Method
	<p>The voltage level shall not fall below the levels specified for the specific type of battery. If the voltage falls below the level specified, corrective action shall be taken and the batteries shall be retested.</p> <p><i>Exception: An artificial load equal to the full fire alarm load connected to the battery shall be permitted to be used in conducting this test.</i></p>
6. Battery Tests (Specific Types)	
a. Primary Battery Load Voltage Test	The maximum load for a No. 6 primary battery shall not be more than 2 amperes per cell. An individual (1.5-volt) cell shall be replaced when a load of 1 ohm reduces the voltage below 1 volt. A 6-volt assembly shall be replaced when a test load of 4 ohms reduces the voltage below 4 volts.
b. Lead-Acid Type	
1. Charger Test	With the batteries fully charged and connected to the charger, the voltage across the batteries shall be measured with a voltmeter. The voltage shall be 2.30 volts per cell ± 0.02 volts at 25°C (77°F) or as specified by the equipment manufacturer.
2. Load Voltage Test	Under load, the battery shall not fall below 2.05 volts per cell.
3. Specific Gravity	The specific gravity of the liquid in the pilot cell or all of the cells shall be measured as required. The specific gravity shall be within the range specified by the manufacturer. Although the specified specific gravity varies from manufacturer to manufacturer, a range of 1.205–1.220 is typical for regular lead-acid batteries, while 1.240–1.260 is typical for high-performance batteries. A hydrometer that shows only a pass or fail condition of the battery and does not indicate the specific gravity shall not be used, because such a reading does not give a true indication of the battery condition.
c. Nickel-Cadmium Type	
1. Charger Test*	With the batteries fully charged and connected to the charger, an ampere meter shall be placed in series with the battery under charge. The charging current shall be in accordance with the manufacturer's recommendations for the type of battery used. In the absence of specific information, $1/30$ to $1/25$ of the battery rating shall be used.
2. Load Voltage Test	Under load, the float voltage for the entire battery shall be 1.42 volts per cell, nominal. If possible, cells shall be measured individually.
d. Sealed Lead-Acid Type	
1. Charger Test	With the batteries fully charged and connected to the charger, the voltage across the batteries shall be measured with a voltmeter. The voltage shall be 2.30 volts per cell ± 0.02 volts at 25°C (77°F) or as specified by the equipment manufacturer.
2. Load Voltage Test	Under load, the battery shall perform in accordance with the battery manufacturer's specifications.
7. Public Reporting System Tests	<p>In addition to the tests and inspection required above, the following requirements shall apply.</p> <p>Manual tests of the power supply for public reporting circuits shall be made and recorded at least once during each 24-hour period. Such tests shall include the following:</p> <p>(a) Current strength of each circuit. Changes in current of any circuit exceeding 10 percent shall be investigated immediately.</p> <p>(b) Voltage across terminals of each circuit inside of terminals of protective devices. Changes in voltage of any circuit exceeding 10 percent shall be investigated immediately.</p>

Table 7-2.2 Test Methods (Continued)

Device	Method
	<p>(c)* Voltage between ground and circuits. If this test shows a reading in excess of 50 percent of that shown in the test specified in (b), the trouble shall be immediately located and cleared. Readings in excess of 25 percent shall be given early attention. These readings shall be taken with a calibrated voltmeter of not more than 100-ohms resistance per volt. Systems in which each circuit is supplied by an independent current source (Forms 3 and 4) require tests between ground and each side of each circuit. Common current source systems (Form 2) require voltage tests between ground and each terminal of each battery and other current source.</p> <p>(d) Ground current reading shall be permitted in lieu of (c). If this method of testing is used, all grounds showing a current reading in excess of 5 percent of the supplied line current shall be given immediate attention.</p> <p>(e) Voltage across terminals of common battery, on switchboard side of fuses.</p> <p>(f) Voltage between common battery terminals and ground. Abnormal ground readings shall be investigated immediately.</p> <p>Tests specified in (e) and (f) shall apply only to those systems using a common battery. If more than one common battery is used, each common battery shall be tested.</p>
8. Transient Suppressors	<p>Lightning protection equipment shall be inspected and maintained per the manufacturer's specifications.</p> <p>Equipment located in moderate to severe areas outlined in NFPA 780, <i>Standard for the Installation of Lightning Protection Systems</i>, Appendix H, shall be inspected semiannually and after any lightning strikes.</p>
9. Control Unit Trouble Signals	
a. Audible and Visual	Operation of panel trouble signals shall be verified as well as ring-back feature for systems using a trouble-silencing switch that requires resetting.
b. Disconnect Switches	If control unit has disconnect or isolating switches, performance of intended function of each switch shall be verified and receipt of trouble signal when a supervised function is disconnected shall also be verified.
c. Ground-Fault Monitoring Circuit	If the system has a ground detection feature, the occurrence of ground-fault indication shall be verified whenever any installation conductor is grounded.
d. Transmission of Signals to Off-Premises Location	<p>Initiating device shall be actuated and receipt of alarm signal at the off-premises location shall be verified.</p> <p>A trouble condition shall be created and receipt of a trouble signal at the off-premises location shall be verified.</p> <p>A supervisory device shall be actuated and receipt of a supervisory signal at the off-premises location shall be verified. If a transmission carrier is capable of operation under a single or multiple fault condition, an initiating device shall be activated during such fault condition and receipt of a trouble signal at the off-premises location shall be verified, in addition to the alarm signal.</p>
10. Remote Annunciators	The correct operation and identification of annunciators shall be verified. If provided, the correct operation of annunciator under a fault condition shall be verified.
11. Conductors/Metallic	
a. Stray Voltage	All installation conductors shall be tested with a volt/ohmmeter to verify that there are no stray (unwanted) voltages between installation conductors or between installation conductors and ground. Unless a different threshold is specified in the system installed equipment manufacturer's specifications, the maximum allowable stray voltage shall not exceed 1 volt ac/dc.
b. Ground Faults	All installation conductors other than those intentionally and permanently grounded shall be tested for isolation from ground per the installed equipment manufacturer's specifications.

Table 7-2.2 Test Methods *(Continued)*

Device	Method
c. Short-Circuit Faults	All installation conductors other than those intentionally connected together shall be tested for conductor-to-conductor isolation per the installed equipment manufacturer's specifications. These same circuits also shall be tested conductor-to-ground.
d. Loop Resistance	With each initiating and indicating circuit installation conductor pair short-circuited at the far end, the resistance of each circuit shall be measured and recorded. It shall be verified that the loop resistance does not exceed the installed equipment manufacturer's specified limits.
12. Conductors/Nonmetallic	
a. Circuit Integrity	Each initiating device, notification appliance, and signaling line circuit shall be tested to confirm that the installation conductors are monitored for integrity in accordance with the requirements of Chapters 1 and 3.
b. Fiber Optics	The fiber-optic transmission line shall be tested in accordance with the manufacturer's instructions by the use of an optical power meter or by an optical time domain reflectometer used to measure the relative power loss of the line. This relative figure for each fiber-optic line shall be recorded in the fire alarm control panel. If the power level drops 2 percent or more from the value recorded during the initial acceptance test, the transmission line, section thereof, or connectors shall be repaired or replaced by a qualified technician to bring the line back into compliance with the accepted transmission level per the manufacturer's recommendations.
c. Supervision	Introduction of a fault in any supervised circuit shall result in a trouble indication at the control unit. One connection shall be opened at not less than 10 percent of the initiating device, notification appliance, and signaling line circuit. Each initiating device, notification appliance, and signaling line circuit shall be tested for correct indication at the control unit. All circuits shall perform as indicated in Table 3-5, Table 3-6, or Table 3-7.
13. Initiating Devices	
a. Electromechanical Releasing Device	
1. Nonrestorable-Type Link	Correct operation shall be verified by removal of the fusible link and operation of the associated device. Any moving parts shall be lubricated as necessary.
2. Restorable-Type Link*	Correct operation shall be verified by removal of the fusible link and operation of the associated device. Any moving parts shall be lubricated as necessary.
b. Fire Extinguishing System(s) or Suppression System(s) Alarm Switch	The switch shall be mechanically or electrically operated and receipt of signal by the control panel shall be verified.
c. Fire-Gas and Other Detectors	Fire-gas detectors and other fire detectors shall be tested as prescribed by the manufacturer and as necessary for the application.
d. Heat Detectors	
1. Fixed-Temperature, Rate-of-Rise, Rate-of Compensation, Restorable Line, Spot Type (excluding Pneumatic Tube Type)	Heat test shall be performed with a heat source per the manufacturer's recommendations for response within 1 minute. A test method shall be used that is recommended by the manufacturer or other method shall be used that will not damage the nonrestorable fixed-temperature element of a combination rate-of-rise/fixed-temperature element.
2. Fixed-Temperature, Nonrestorable Line Type	Heat test shall not be performed. Functionality shall be tested mechanically and electrically. Loop resistance shall be measured and recorded. Changes from acceptance test shall be investigated.
3. Fixed-Temperature, Nonrestorable Spot Type	After 15 years from initial installation, all devices shall be replaced or two detectors per 100 shall be laboratory tested. The two detectors shall be replaced with new devices. If a failure occurs on any of the detectors removed, additional detectors shall be removed and tested to determine either a general problem involving faulty detectors or a localized problem involving one or two defective detectors.

Table 7-2.2 Test Methods *(Continued)*

Device	Method
4. Nonrestorable (General)	<p>If detectors are tested instead of replaced, tests shall be repeated at intervals of 5 years.</p> <p>Heat tests shall not be performed. Functionality shall be tested mechanically and electrically.</p>
5. Restorable Line Type, Pneumatic Tube Only	Heat tests shall be performed (where test chambers are in circuit) or a test with pressure pump shall be conducted.
e. Fire Alarm Boxes	Manual fire alarm boxes shall be operated per the manufacturer's instructions. Key-operated presignal and general alarm manual fire alarm boxes shall both be tested.
f. Radiant Energy Fire Detectors	<p>Flame detectors and spark/ember detectors shall be tested in accordance with the manufacturer's instructions to determine that each detector is operative.</p> <p>Flame detector and spark/ember detector sensitivity shall be determined using any of the following:</p> <ul style="list-style-type: none"> (a) Calibrated test method (b) Manufacturer's calibrated sensitivity test instrument (c) Listed control unit arranged for the purpose (d) Other approved calibrated sensitivity test method that is directly proportional to the input signal from a fire, consistent with the detector listing or approval <p>If designed to be field adjustable, detectors found to be outside of the approved range of sensitivity shall be replaced or adjusted to bring them into the approved range.</p> <p>Flame detector and spark/ember detector sensitivity shall not be determined using a light source that administers an unmeasured quantity of radiation at an undefined distance from the detector.</p>
g. Smoke Detectors	
1. Systems Detectors	<p>The detectors shall be tested in place to ensure smoke entry into the sensing chamber and an alarm response. Testing with smoke or listed aerosol approved by the manufacturer shall be permitted as acceptable test methods. Other methods approved by the manufacturer that ensure smoke entry into the sensing chamber shall be permitted.</p> <p>Any of the following tests shall be performed to ensure that each smoke detector is within its listed and marked sensitivity range:</p> <ul style="list-style-type: none"> (a) Calibrated test method (b) Manufacturer's calibrated sensitivity test instrument (c) Listed control equipment arranged for the purpose (d) Smoke detector/control unit arrangement whereby the detector causes a signal at the control unit when its sensitivity is outside its listed sensitivity range (e) Other calibrated sensitivity test method approved by the authority having jurisdiction
2. Single Station Detectors	The detectors shall be tested in place to ensure smoke entry into the sensing chamber and an alarm response. Testing with smoke or listed aerosol approved by the manufacturer shall be permitted as acceptable test methods. Other methods approved by the manufacturer that ensure smoke entry into the sensing chamber shall be permitted.
3. Air Sampling	Per manufacturer's recommended test methods, detector alarm response shall be verified through the end sampling port on each pipe run; airflow through all other ports shall be verified as well.

Table 7-2.2 Test Methods *(Continued)*

Device	Method
4. Duct Type	Air duct detectors shall be tested or inspected to ensure that the device will sample the airstream. The test shall be made in accordance with the manufacturer's instructions.
5. Projected Beam Type	The detector shall be tested by introducing smoke, other aerosol, or an optical filter into the beam path.
6. Smoke Detector with Built-in Thermal Element	Both portions of the detector shall be operated independently as described for the respective devices.
7. Smoke Detectors with Control Output Functions	It shall be verified that the control capability shall remain operable even if all of the initiating devices connected to the same initiating device circuit or signaling line circuit are in an alarm state.
h. Initiating Devices, Supervisory	
1. Control Valve Switch	Valve shall be operated and signal receipt shall be verified to be within the first two revolutions of the hand wheel or within one-fifth of the travel distance, or per the manufacturer's specifications.
2. High- or Low-Air Pressure Switch	Switch shall be operated. Receipt of signal obtained where the required pressure is increased or decreased a maximum 10 psi (70 kPa) from the required pressure level shall be verified.
3. Room Temperature Switch	Switch shall be operated. Receipt of signal to indicate the decrease in room temperature to 40°F (4.4°C) and its restoration to above 40°F (4.4°C) shall be verified.
4. Water Level Switch	Switch shall be operated. Receipt of signal indicating the water level raised or lowered 3 in. (76.2 mm) from the required level within a pressure tank, or 12 in. (305 mm) from the required level of a nonpressure tank, shall be verified, as shall its restoral to required level.
5. Water Temperature Switch	Switch shall be operated. Receipt of signal to indicate the decrease in water temperature to 40°F (4.4°C) and its restoration to above 40°F (4.4°C) shall be verified.
i. Mechanical, Electrosonic, or Pressure-Type Waterflow Device	Water shall be flowed through an inspector's test connection indicating the flow of water equal to that from a single sprinkler of the smallest orifice size installed in the system for wet-pipe systems, or an alarm test bypass connection for dry-pipe, pre-action, or deluge systems in accordance with NFPA 25, <i>Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems</i> .
14. Alarm Notification Appliances	
a. Audible	Sound pressure level shall be measured with sound level meter meeting ANSI S1.4a, <i>Specifications for Sound Level Meters</i> , Type 2 requirements. Levels throughout protected area shall be measured and recorded.
b. Audible Textural Notification Appliances (Speakers and other Appliances to Convey Voice Messages)	Sound pressure level shall be measured with sound level meter meeting ANSI S1.4a, <i>Specifications for Sound Level Meters</i> , Type 2 requirements. Levels throughout protected area shall be measured and recorded. Audible information shall be verified to be distinguishable and understandable.
c. Visible	Test shall be performed in accordance with the manufacturer's instructions. Device locations shall be verified to be per approved layout and it shall be confirmed that no floor plan changes affect the approved layout.
15. Special Hazard Equipment	
a. Abort Switch (IRI Type)	Abort switch shall be operated. Correct sequence and operation shall be verified.
b. Abort Switch (Recycle Type)	Abort switch shall be operated. Development of correct matrix with each sensor operated shall be verified.
c. Abort Switch (Special Type)	Abort switch shall be operated. Correct sequence and operation in accordance with authority having jurisdiction shall be verified. Sequencing on as-built drawings or in owner's manual shall be observed.

Table 7-2.2 Test Methods (Continued)

Device	Method
d. Cross Zone Detection Circuit	One sensor or detector on each zone shall be operated. Occurrence of correct sequence with operation of first zone and then with operation of second zone shall be verified.
e. Matrix-Type Circuit	All sensors in system shall be operated. Development of correct matrix with each sensor operated shall be verified.
f. Release Solenoid Circuit	Solenoid shall be used with equal current requirements. Operation of solenoid shall be verified.
g. Squibb Release Circuit	AGI flashbulb or other test light approved by the manufacturer shall be used. Operation of flashbulb or light shall be verified.
h. Verified, Sequential, or Counting Zone Circuit	Required sensors at a minimum of four locations in circuit shall be operated. Correct sequence with both the first and second detector in alarm shall be verified.
i. All Above Devices or Circuits or Combinations Thereof	Supervision of circuits by creating an open circuit shall be verified.
16. Supervising Station Fire Alarm Systems — Transmission Equipment	
a. All Equipment	<p>Test shall be performed on all system functions and features in accordance with the equipment manufacturer's instructions for correct operation in conformance with the applicable sections of Chapter 5.</p> <p>Initiating device shall be actuated. Receipt of the correct initiating device signal at the supervising station within 90 seconds shall be verified. Upon completion of the test, the system shall be restored to its functional operating condition.</p> <p>If test jacks are used, the first and last tests shall be made without the use of the test jack.</p>
b. Digital Alarm Communicator Transmitter (DACT)	<p>Connection of the DACT to two separate means of transmission shall be ensured.</p> <p><i>Exception: DACTs that are connected to a telephone line (number) that is also supervised for adverse conditions by a derived local channel.</i></p> <p>DACT shall be tested for line seizure capability by initiating a signal while using the primary line for a telephone call. Receipt of the correct signal at the supervising station shall be verified. Completion of the transmission attempt within 90 seconds from going off-hook to on-hook shall be verified.</p> <p>The primary line from the DACT shall be disconnected. Indication of the DACT trouble signal at the premises shall be verified as well as transmission to the supervising station within 4 minutes of detection of the fault.</p> <p>The secondary means of transmission from the DACT shall be disconnected. Indication of the DACT trouble signal at the premises shall be verified as well as transmission to the supervising station within 4 minutes of detection of the fault.</p> <p>The DACT shall be caused to transmit a signal to the DACR while a fault in the primary telephone number is simulated. Utilization of the secondary telephone number by the DACT to complete the transmission to the DACR shall be verified.</p>
c. Digital Alarm Radio Transmitter (DART)	The primary telephone line shall be disconnected. Transmission of a trouble signal to the supervising station by the DART within 4 minutes shall be verified.
d. McCulloh Transmitter	<p>Initiating device shall be actuated. Production of not less than three complete rounds of not less than three signal impulses each by the McCulloh transmitter shall be verified.</p> <p>If end-to-end metallic continuity is present and with a balanced circuit, each of the following four transmission channel fault conditions shall be caused in turn, and receipt of correct signals at the supervising station shall be verified:</p> <p>(a) Open</p>

Table 7-2.2 Test Methods *(Continued)*

Device	Method
e. Radio Alarm Transmitter (RAT)	(b) Ground
	(c) Wire-to-wire short
	(d) Open and ground
	If end-to-end metallic continuity is not present and with a properly balanced circuit, each of the following three transmission channel fault conditions shall be caused in turn, and receipt of proper signals at the supervising station shall be verified
	(a) Open
	(b) Ground
	(c) Wire-to-wire short
	A fault between elements of the transmitting equipment shall be caused. Indication of the fault at the protected premises shall be verified or it shall be verified that a trouble signal is transmitted to the supervising station.
17. Supervising Station Fire Alarm Systems — Receiving Equipment	
a. All Equipment	Tests shall be performed on all system functions and features in accordance with the equipment manufacturer's instructions for correct operation in conformance with the applicable sections of Chapter 5.
	Initiating device shall be actuated. Receipt of the correct initiating device signal at the supervising station within 90 seconds shall be verified. Upon completion of the test, the system shall be restored to its functional operating condition.
	If test jacks are used, the first and last tests shall be made without the use of the test jack.
b. Digital Alarm Communicator Receiver (DACR)	Each telephone line (number) shall be disconnected in turn from the DACR and audible and visual annunciation of a trouble signal in the supervising station shall be verified.
	A signal shall be caused to be transmitted on each individual incoming DACR line at least once every 24 hours. Receipt of these signals shall be verified.
c. Digital Alarm Radio Receiver (DARR)	The following conditions of all DARRs on all subsidiary and repeater station receiving equipment shall be caused. Receipt at the supervising station of correct signals for each of the following conditions shall be verified:
	(a) AC power failure of the radio equipment
	(b) Receiver malfunction
	(c) Antenna and interconnecting cable failure
	(d) Indication of automatic switchover of the DARR
d. McCulloh Systems	(e) Data transmission line failure between the DARR and the supervising or subsidiary station
	The current on each circuit at each supervising and subsidiary station under the following conditions shall be tested and recorded:
	(a) During functional operation
	(b) On each side of the circuit with the receiving equipment conditioned for an open circuit
	A single break or ground condition shall be caused on each transmission channel. If such a fault prevents the functioning of the circuit, receipt of a trouble signal shall be verified.

Table 7-2.2 Test Methods (Continued)

Device	Method
e. Radio Alarm Supervising Station Receiver (RASSR) and Radio Alarm Repeater Station Receiver (RARSR)	<p>Each of the following conditions at each of the supervising or subsidiary stations and all repeater station radio transmitting and receiving equipment shall be caused; receipt of correct signals at the supervising station shall be verified:</p> <ul style="list-style-type: none"> (a) RF transmitter in use (radiating) (b) AC power failure supplying the radio equipment (c) RF receiver malfunction (d) Indication of automatic switchover
f. Private Microwave Radio Systems	<p>Each of the following conditions at each of the supervising or subsidiary stations and all repeater station radio transmitting and receiving equipment shall be caused; receipt of correct signals at the supervising station shall be verified:</p> <ul style="list-style-type: none"> (a) AC power failure supplying the radio equipment (b) RF receiver malfunction (c) Indication of automatic switchover, if applicable <p>Each of the following conditions at each of the supervising or subsidiary stations and all repeater station radio transmitting and receiving equipment shall be caused; receipt of correct signals at the supervising station shall be verified:</p> <ul style="list-style-type: none"> (a) RF transmitter in use (radiating) (b) AC power failure supplying the radio equipment (c) RF receiver malfunction (d) Indication of automatic switchover
18. Emergency Communications Equipment	
a. Amplifier/Tone Generators	Correct switching and operation of backup equipment shall be verified.
b. Call-in Signal Silence	Function shall be operated and receipt of correct visual and audible signals at control panel shall be verified.
c. Off-hook Indicator (Ring Down)	Phone set shall be installed or phone shall be removed from hook and receipt of signal at control panel shall be verified.
d. Phone Jacks	Phone jack shall be visually inspected and communications path through jack shall be initiated.
e. Phone Set	Each phone set shall be activated and correct operation shall be verified.
f. System Performance	System shall be operated with a minimum of any five handsets simultaneously. Voice quality and clarity shall be verified.
19. Interface Equipment	
Interface equipment connections shall be tested by operating or simulating the equipment being supervised. Signals required to be transmitted shall be verified at the control panel. Test frequency for interface equipment shall be the same as the frequency required by the applicable NFPA standard(s) for the equipment being supervised.	
20. Guard's Tour Equipment	
The device shall be tested in accordance with the manufacturer's specifications.	
21. Special Procedures	
a. Alarm Verification	Time delay and alarm response for smoke detector circuits identified as having alarm verification shall be verified.
b. Multiplex Systems	<p>Communications between sending and receiving units under both primary and secondary power shall be verified.</p> <p>Communications between sending and receiving units under open circuit and short circuit trouble conditions shall be verified.</p>

Table 7-2.2 Test Methods (Continued)

Device	Method
	<p>Communications between sending and receiving units in all directions where multiple communications pathways are provided shall be verified.</p> <p>If redundant central control equipment is provided, switchover and all required functions and operations of secondary control equipment shall be verified.</p> <p>All system functions and features shall be verified in accordance with manufacturer's instructions.</p>
22. Low-Power Radio (Wireless Systems)	<p>The following procedures describe additional acceptance and reacceptance test methods to verify wireless protection system operation:</p> <p>(a) The manufacturer's manual and the as-built drawings provided by the system supplier shall be used to verify correct operation after the initial testing phase has been performed by the supplier or by the supplier's designated representative.</p> <p>(b) Starting from the functional operating condition, the system shall be initialized in accordance with the manufacturer's manual. A test shall be conducted to verify the alternative path, or paths, by turning off or disconnecting the primary wireless repeater. The alternative communications path shall exist between the wireless control panel and peripheral devices used to establish initiation, indicating, control, and annunciation. The system shall be tested for both alarm and trouble conditions.</p> <p>(c) Batteries for all components in the system shall be checked monthly. If the control panel checks all batteries and all components daily, the system shall not require monthly testing of the batteries.</p>

7-3 Inspection and Testing Frequency.

7-3.1* Visual Inspection. Visual inspection shall be performed in accordance with the schedules in Section 7-3 or more often if required by the authority having jurisdiction. The visual inspection shall be made to ensure that there are no changes that affect equipment performance.

Exception No. 1: Devices or equipment that is inaccessible for safety considerations (for example, continuous process operations, energized

electrical equipment, radiation, and excessive height) shall be inspected during scheduled shutdowns if approved by the authority having jurisdiction. Extended intervals shall not exceed 18 months.

Exception No. 2: If automatic inspection is performed at a frequency of not less than weekly by a remotely monitored fire alarm control unit specifically listed for such application, the visual inspection frequency shall be permitted to be annual. Table 7-3.1 shall apply.

Table 7-3.1 Visual Inspection Frequencies

Component	Initial/ Reacceptance	Monthly	Quarterly	Semiannually	Annually
1. Control Equipment: Fire Alarm Systems Monitored for Alarm, Supervisory, Trouble Signals					
a. Fuses	X	—	—	—	X
b. Interfaced Equipment	X	—	—	—	X
c. Lamps and LEDs	X	—	—	—	X
d. Primary (Main) Power Supply	X	—	—	—	X
2. Control Equipment: Fire Alarm Systems Unmonitored for Alarm, Supervisory, Trouble Signals					
a. Fuses	X (weekly)	—	—	—	—
b. Interfaced Equipment	X (weekly)	—	—	—	—
c. Lamps and LEDs	X (weekly)	—	—	—	—
d. Primary (Main) Power Supply	X (weekly)	—	—	—	—

Table 7-3.1 Visual Inspection Frequencies (Continued)

Component	Initial/ Reacceptance	Monthly	Quarterly	Semiannually	Annually
3. Batteries					
a. Lead-Acid	X	X	—	—	—
b. Nickel-Cadmium	X	—	—	X	—
c. Primary (Dry Cell)	X	X	—	—	—
d. Sealed Lead-Acid	X	—	—	X	—
4. Transient Suppressors	X	—	—	X	—
5. Control Panel Trouble Signals	X	—	—	X	—
6. Fiber-Optic Cable Connections	X	—	—	—	X
7. Emergency Voice/Alarm Communications Equipment	X	—	—	X	—
8. Remote Annunciators	X	—	—	X	—
9. Initiating Devices					
a. Air Sampling	X	—	—	X	—
b. Duct Detectors	X	—	—	X	—
c. Electromechanical Releasing Devices	X	—	—	X	—
d. Fire-Extinguishing System(s) or Suppression System(s) Switches	X	—	—	X	—
e. Fire Alarm Boxes	X	—	—	X	—
f. Heat Detectors	X	—	—	X	—
g. Radiant Energy Fire Detectors	X	—	X	—	—
h. Smoke Detectors	X	—	—	X	—
i. Supervisory Signal Devices	X	—	X	—	—
j. Waterflow Devices	X	—	X	—	—
10. Guard's Tour Equipment	X	—	—	X	—
11. Interface Equipment	X	—	—	X	—
12. Alarm Notification Appliances — Supervised	X	—	—	X	—
13. Supervising Station Fire Alarm Systems — Transmitters					
a. DACT	X	—	—	X	—
b. DART	X	—	—	X	—
c. McCulloh	X	—	—	X	—
d. RAT	X	—	—	X	—
14. Special Procedures	X	—	—	X	—
15. Supervising Station Fire Alarm Systems — Receivers					
a. DACR*	X	X	—	—	—
b. DARR*	X	—	—	X	—
c. McCulloh Systems*	X	—	—	X	—
d. Two-Way RF Multiplex*	X	—	—	X	—
e. RASSR*	X	—	—	X	—
f. RARS*	X	—	—	X	—
g. Private Microwave*	X	—	—	X	—

*Reports of automatic signal receipt shall be verified daily.

7-3.2* Testing. Testing shall be performed in accordance with the schedules in Chapter 7 or more often if required by the authority having jurisdiction. If automatic testing is performed at least weekly by a remotely monitored fire alarm control unit specifically listed for the application, the manual testing frequency shall be permitted to be extended to annual. Table 7-3.2 shall apply.

Exception: Devices or equipment that are inaccessible for safety considerations (for example, continuous process operations, energized electrical equipment, radiation, and excessive height) shall be tested during scheduled shutdowns if approved by the authority having jurisdiction but shall not be tested more than every 18 months.

Table 7-3.2 Testing Frequencies

Component	Initial/ Reacceptance	Monthly	Quarterly	Semiannually	Annually	Table 7-2.2 Reference
1. Control Equipment — Building Systems Connected to Supervising Station						1, 7, 16, 17
a. Functions	X	—	—	—	X	—
b. Fuses	X	—	—	—	X	—
c. Interfaced Equipment	X	—	—	—	X	—
d. Lamps and LEDs	X	—	—	—	X	—
e. Primary (Main) Power Supply	X	—	—	—	X	—
f. Transponders	X	—	—	—	X	—
2. Control Equipment — Building Systems — Not Connected to a Supervising Station	—	—	—	—	—	1
a. Functions	X	—	X	—	—	—
b. Fuses	X	—	X	—	—	—
c. Interfaced Equipment	X	—	X	—	—	—
d. Lamps and LEDs	X	—	X	—	—	—
e. Primary (Main) Power Supply	X	—	X	—	—	—
f. Transponders	X	—	X	—	—	—
3. Engine-Driven Generator — Central Station Facilities and Fire Alarm Systems	X	X	—	—	—	—
4. Engine-Driven Generator — Public Fire Alarm Reporting Systems	X	—	—	—	—	—
5. Batteries — Central Station Facilities						
a. Lead-Acid Type	—	—	—	—	—	6b
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (30 minutes)	X	X	—	—	—	—
3. Load Voltage Test	X	X	—	—	—	—
4. Specific Gravity	X	—	—	X	—	—
b. Nickel-Cadmium Type	—	—	—	—	—	6c
1. Charger Test (Replace battery as needed.)	X	—	X	—	—	—
2. Discharge Test (30 minutes)	X	—	—	—	X	—
3. Load Voltage Test	X	—	—	—	X	—
c. Sealed Lead-Acid Type	X	X	—	—	—	6d
1. Charger Test (Replace battery as needed.)	—	X	X	—	—	—
2. Discharge Test (30 minutes)	X	X	—	—	—	—
3. Load Voltage Test	X	X	—	—	—	—

Table 7-3.2 Testing Frequencies (Continued)

Component	Initial/ Reacceptance	Monthly	Quarterly	Semiannually	Annually	Table 7-2.2 Reference
6. Batteries — Fire Alarm Systems						
a. Lead-Acid Type	—	—	—	—	—	6b
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (30 minutes)	X	—	—	X	—	—
3. Load Voltage Test	X	—	—	X	—	—
4. Specific Gravity	X	—	—	X	—	—
b. Nickel-Cadmium Type	—	—	—	—	—	6c
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (30 minutes)	X	—	—	—	X	—
3. Load Voltage Test	X	—	—	X	—	—
c. Primary Type (Dry Cell)	—	—	—	—	—	6a
1. Load Voltage Test	X	X	—	—	—	—
d. Sealed Lead-Acid Type	—	—	—	—	—	6d
1. Charger Test (Replace battery every 4 years.)	X	—	—	—	X	—
2. Discharge Test (30 minutes)	X	—	—	—	X	—
3. Load Voltage Test	X	—	—	X	—	—
7. Batteries — Public Fire Alarm Reporting Systems	X (daily)	—	—	—	—	—
Voltage tests in accordance with Table 7-2.2, item 7(a)–(f)						
a. Lead-Acid Type	—	—	—	—	—	6b
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (2 hours)	X	—	X	—	—	—
3. Load Voltage Test	X	—	X	—	—	—
4. Specific Gravity	X	—	—	X	—	—
b. Nickel-Cadmium Type	—	—	—	—	—	6c
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (2 hours)	X	—	—	—	X	—
3. Load Voltage Test	X	—	X	—	—	—
c. Sealed Lead-Acid Type	—	—	—	—	—	6d
1. Charger Test (Replace battery as needed.)	X	—	—	—	X	—
2. Discharge Test (2 hours)	X	—	—	—	X	—
3. Load Voltage Test	X	—	X	—	—	—
8. Fiber-Optic Cable Power	X	—	—	—	X	12b
9. Control Unit Trouble Signals	X	—	—	—	X	9
10. Conductors — Metallic	X	—	—	—	—	11
11. Conductors — Nonmetallic	X	—	—	—	—	12
12. Emergency Voice/Alarm Communications Equipment	X	—	—	—	X	18
13. Retransmission Equipment (The requirements of 7-3.4 shall apply.)	X	—	—	—	—	—
14. Remote Annunciators	X	—	—	—	X	10

Table 7-3.2 Testing Frequencies (Continued)

Component	Initial/ Reacceptance					Table 7-2.2 Reference
	Monthly	Quarterly	Semiannually	Annually		
15. Initiating Devices	—	—	—	—	—	13
a. Duct Detectors	X	—	—	—	X	—
b. Electromechanical Releasing Device	X	—	—	—	X	—
c. Fire-Extinguishing System(s) or Suppression System(s) Switches	X	—	—	—	X	—
d. Fire-Gas and Other Detectors	X	—	—	—	X	—
e. Heat Detectors (The requirements of 7-3.2.3 shall apply.)	X	—	—	—	X	—
f. Fire Alarm Boxes	X	—	—	—	X	—
g. Radiant Energy Fire Detectors	X	—	—	X	—	—
h. All Smoke Detectors — Functional	X	—	—	—	X	—
i. Smoke Detectors — Sensitivity (The requirements of 7-3.2.1 shall apply.)	—	—	—	—	—	—
j. Supervisory Signal Devices	X	—	X	—	—	—
k. Waterflow Devices (except valve tamper switches)	X	—	—	X	—	—
l. Valve Tamper Switches	X	—	—	X	—	—
16. Guard's Tour Equipment	X	—	—	—	X	—
17. Interface Equipment	X	—	—	—	X	19
18. Special Hazard Equipment	X	—	—	—	X	15
19. Alarm Notification Appliances	—	—	—	—	—	14
a. Audible Devices	X	—	—	—	X	—
b. Audible Textual Notification Appliances	X	—	—	—	X	—
c. Visible Devices	X	—	—	—	X	—
20. Off-Premises Transmission Equipment	X	—	X	—	—	—
21. Supervising Station Fire Alarm Systems — Transmitters	—	—	—	—	—	16
a. DACT	X	—	—	—	X	—
b. DART	X	—	—	—	X	—
c. McCulloh	X	—	—	—	X	—
d. RAT	X	—	—	—	X	—
22. Special Procedures	X	—	—	—	X	21
23. Supervising Station Fire Alarm Systems — Receivers	—	—	—	—	—	17
a. DACR	X	X	—	—	—	—
b. DARR	X	X	—	—	—	—
c. McCulloh Systems	X	X	—	—	—	—
d. Two-Way RF Multiplex	X	X	—	—	—	—
e. RASSR	X	X	—	—	—	—
f. RARSR	X	X	—	—	—	—
g. Private Microwave	X	X	—	—	—	—

7-3.2.1* Detector sensitivity shall be checked within 1 year after installation and every alternate year thereafter. After the second required calibration test, if sensitivity tests indicate that the detector has remained within its listed and marked sensitivity range (or 4 percent obscuration light gray smoke, if not marked), the length of time between calibration tests shall be permitted to be extended to a maximum of 5 years. If the frequency is extended, records of detector-caused nuisance alarms and subsequent trends of these alarms shall be maintained. In zones or in areas where nuisance alarms show any increase over the previous year, calibration tests shall be performed.

To ensure that each smoke detector is within its listed and marked sensitivity range, it shall be tested using any of the following methods:

- (1) Calibrated test method
- (2) Manufacturer's calibrated sensitivity test instrument
- (3) Listed control equipment arranged for the purpose
- (4) Smoke detector/control unit arrangement whereby the detector causes a signal at the control unit where its sensitivity is outside its listed sensitivity range
- (5) Other calibrated sensitivity test methods approved by the authority having jurisdiction

Detectors found to have a sensitivity outside the listed and marked sensitivity range shall be cleaned and recalibrated or be replaced.

Exception No. 1: Detectors listed as field adjustable shall be permitted to be either adjusted within the listed and marked sensitivity range and cleaned and recalibrated, or they shall be replaced.

Exception No. 2: This requirement shall not apply to single station detectors referenced in 7-3.3 and Table 7-2.2.

The detector sensitivity shall not be tested or measured using any device that administers an unmeasured concentration of smoke or other aerosol into the detector.

7-3.2.2 Test frequency of interfaced equipment shall be the same as specified by the applicable NFPA standards for the equipment being supervised.

7-3.2.3 For restorable fixed-temperature, spot-type heat detectors, two or more detectors shall be tested on each initiating circuit annually. Different detectors shall be tested each year, with records kept by the building owner specifying which detectors have been tested. Within 5 years, each detector shall have been tested.

7-3.2.4* For testing addressable and analog-described devices, which are affixed to either a single, molded assembly or a twist-lock type affixed to a base, testing shall be conducted using the signaling style circuits (Styles 0.5 through 7).

Analog-type detectors shall be tested with the same criteria.

7-3.3 Single station smoke detectors installed in one- and two-family dwelling units shall be inspected, tested, and maintained as specified in Chapter 8. Single station detectors installed in other than one- and two-family dwelling units shall be tested and maintained in accordance with Chapter 7.

7-3.4 Test of all circuits extending from the central station shall be made at intervals of not more than 24 hours.

7-3.5 Public Fire Reporting Systems.

7-3.5.1 Emergency power sources other than batteries shall be operated to supply the system for a continuous period of 1 hour at least weekly. This test shall require simulated failure of the normal power source.

7-3.5.2 Testing facilities shall be installed at the communications center and each subsidiary communications center, if used.

Exception: If satisfactory to the authority having jurisdiction, those facilities for systems leased from a nonmunicipal organization that might be located elsewhere.

7-4 Maintenance.

7-4.1 Fire alarm system equipment shall be maintained in accordance with the manufacturer's instructions. The frequency of maintenance shall depend on the type of equipment and the local ambient conditions.

7-4.2 The frequency of cleaning shall depend on the type of equipment and the local ambient conditions.

7-4.3 All apparatus requiring rewinding or resetting to maintain normal operation shall be rewound or reset as promptly as possible after each test and alarm. All test signals received shall be recorded to indicate date, time, and type.

7-4.4 The retransmission means as defined in Section 5-2 shall be tested at intervals of not more than 12 hours. The retransmission signal and the time and date of the retransmission shall be recorded in the central station.

Exception: If the retransmission means is the public switched telephone network, it shall be permitted to be tested weekly to confirm its operation to each public fire service communications center.

7-5 Records.

7-5.1* Permanent Records. After successful completion of acceptance tests approved by the authority having jurisdiction, a set of reproducible as-built installation drawings, operation and maintenance manuals, and a written sequence of operation shall be provided to the building owner or the owner's designated representative. The owner shall be responsible for maintaining these records for the life of the system for examination by any authority having jurisdiction. Paper or electronic media shall be permitted.

7-5.2 Maintenance, Inspection, and Testing Records.

7-5.2.1 Records shall be retained until the next test and for 1 year thereafter.

7-5.2.2 A permanent record of all inspections, testing, and maintenance shall be provided that includes the following information regarding tests and all the applicable information requested in Figure 7-5.2.2.

- (1) Date
- (2) Test frequency
- (3) Name of property
- (4) Address
- (5) Name of person performing inspection, maintenance, tests, or combination thereof, and affiliation, business address, and telephone number
- (6) Name, address, and representative of approving agency(ies)
- (7) Designation of the detector(s) tested, for example, "Tests performed in accordance with Section _____."
- (8) Functional test of detectors
- (9) *Functional test of required sequence of operations
- (10) Check of all smoke detectors
- (11) Loop resistance for all fixed-temperature, line-type heat detectors
- (12) Other tests as required by equipment manufacturers
- (13) Other tests as required by the authority having jurisdiction
- (14) Signatures of tester and approved authority representative
- (15) Disposition of problems identified during test (for example, owner notified, problem corrected/successfully retested, device abandoned in place)

Figure 7-5.2.2 Example of an inspection and testing form.

INSPECTION AND TESTING FORM		
SERVICE ORGANIZATION Name: _____ Address: _____ Representative: _____ License No.: _____ Telephone: _____		DATE: _____ TIME: _____ PROPERTY NAME (USER) Name: _____ Address: _____ Owner Contact: _____ Telephone: _____
MONITORING ENTITY Contact: _____ Telephone: _____ Monitoring Account Ref. No.: _____		APPROVING AGENCY Contact: _____ Telephone: _____
TYPE TRANSMISSION <input type="checkbox"/> McCulloh <input type="checkbox"/> Multiplex <input type="checkbox"/> Digital <input type="checkbox"/> Reverse Priority <input type="checkbox"/> RF <input type="checkbox"/> Other (Specify) _____ _____		SERVICE <input type="checkbox"/> Weekly <input type="checkbox"/> Monthly <input type="checkbox"/> Quarterly <input type="checkbox"/> Semiannually <input type="checkbox"/> Annually <input type="checkbox"/> Other (Specify) _____ _____
Panel Manufacturer: _____ Circuit Styles: _____ Number of Circuits: _____ Software Rev.: _____ Last Date System Had Any Service Performed: _____ Last Date that Any Software or Configuration Was Revised: _____		Model No.: _____
ALARM-INITIATING DEVICES AND CIRCUIT INFORMATION		
Quantity	Circuit Style	Manual Stations Ion Detectors Photo Detectors Duct Detectors Heat Detectors Waterflow Switches Supervisory Switches Other (Specify): _____ _____
_____ _____ _____ _____ _____ _____ _____ _____	_____ _____ _____ _____ _____ _____ _____ _____	

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Figure 7-5.2.2 (Continued)

ALARM NOTIFICATION APPLIANCES AND CIRCUIT INFORMATION		
Quantity	Circuit Style	
		Bells
		Horns
		Chimes
		Strobes
		Speakers
		Other (Specify): _____
No. of alarm indicating circuits: _____		
Are circuits supervised? <input type="checkbox"/> Yes <input type="checkbox"/> No		
SUPERVISORY SIGNAL-INITIATING DEVICES AND CIRCUIT INFORMATION		
Quantity	Circuit Style	
		Building Temp.
		Site Water Temp.
		Site Water Level
		Fire Pump Power
		Fire Pump Running
		Fire Pump Auto Position
		Fire Pump or Pump Controller Trouble
		Fire Pump Running
		Generator In Auto Position
		Generator or Controller Trouble
		Switch Transfer
		Generator Engine Running
		Other: _____

SIGNALING LINE CIRCUITS		
Quantity and style (See NFPA 72, Table 3-6) of signaling line circuits connected to system:		
Quantity _____	Style(s) _____	
SYSTEM POWER SUPPLIES		
a. Primary (Main): Nominal Voltage _____, Amps _____		
Overcurrent Protection: Type _____, Amps _____		
Location (Panel Number): _____		
Disconnecting Means Location: _____		
b. Secondary (Standby):		
_____ Storage Battery: Amp-Hr. Rating _____		
Calculated capacity to operate system, in hours: _____ 24 _____ 60 _____		
_____ Engine-driven generator dedicated to fire alarm system:		
Location of fuel storage: _____		
TYPE BATTERY		
<input type="checkbox"/> Dry Cell		
<input type="checkbox"/> Nickel-Cadmium		
<input type="checkbox"/> Sealed Lead-Acid		
<input type="checkbox"/> Lead-Acid		
<input type="checkbox"/> Other (Specify): _____		
c. Emergency or standby system used as a backup to primary power supply, instead of using a secondary power supply:		
_____ Emergency system described in NFPA 70, Article 700		
_____ Legally required standby described in NFPA 70, Article 701		
_____ Optional standby system described in NFPA 70, Article 702, which also meets the performance requirements of Article 700 or 701.		

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Figure 7-5.2.2 (Continued)

PRIOR TO ANY TESTING				
NOTIFICATIONS ARE MADE	Yes	No	Who	Time
Monitoring Entity	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Building Occupants	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Building Management	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Other (Specify)	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
AHJ (Notified) of Any Impairments	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____

SYSTEM TESTS AND INSPECTIONS			
TYPE	Visual	Functional	Comments
Control Panel	<input type="checkbox"/>	<input type="checkbox"/>	_____
Interface Eq.	<input type="checkbox"/>	<input type="checkbox"/>	_____
Lamps/LEDS	<input type="checkbox"/>	<input type="checkbox"/>	_____
Fuses	<input type="checkbox"/>	<input type="checkbox"/>	_____
Primary Power Supply	<input type="checkbox"/>	<input type="checkbox"/>	_____
Trouble Signals	<input type="checkbox"/>	<input type="checkbox"/>	_____
Disconnect Switches	<input type="checkbox"/>	<input type="checkbox"/>	_____
Ground-Fault Monitoring	<input type="checkbox"/>	<input type="checkbox"/>	_____

SECONDARY POWER			
TYPE	Visual	Functional	Comments
Battery Condition	<input type="checkbox"/>		_____
Load Voltage		<input type="checkbox"/>	_____
Discharge Test		<input type="checkbox"/>	_____
Charger Test		<input type="checkbox"/>	_____
Specific Gravity		<input type="checkbox"/>	_____

TRANSIENT SUPPRESSORS			
	Visual	Functional	Comments
	<input type="checkbox"/>		_____

REMOTE ANNUNCIATORS			
	Visual	Functional	Comments
	<input type="checkbox"/>	<input type="checkbox"/>	_____

NOTIFICATION APPLIANCES			
	Visual	Functional	Comments
Audible	<input type="checkbox"/>	<input type="checkbox"/>	_____
Visual	<input type="checkbox"/>	<input type="checkbox"/>	_____
Speakers	<input type="checkbox"/>	<input type="checkbox"/>	_____
Voice Clarity	<input type="checkbox"/>		_____

INITIATING AND SUPERVISORY DEVICE TESTS AND INSPECTIONS							
Loc. & S/N	Device Type	Visual Check	Functional Test	Factory Setting	Meas. Setting	Pass	Fail
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

(NFPA Inspection and Testing 3 of 4)

Figure 7-5.2.2 (Continued)

EMERGENCY COMMUNICATIONS EQUIPMENT	Visual	Functional	Comments
Phone Set	<input type="checkbox"/>	<input type="checkbox"/>	_____
Phone Jacks	<input type="checkbox"/>	<input type="checkbox"/>	_____
Off-Hook Indicator	<input type="checkbox"/>	<input type="checkbox"/>	_____
Amplifier(s)	<input type="checkbox"/>	<input type="checkbox"/>	_____
Tone Generator(s)	<input type="checkbox"/>	<input type="checkbox"/>	_____
Call-in Signal	<input type="checkbox"/>	<input type="checkbox"/>	_____
System Performance	<input type="checkbox"/>	<input type="checkbox"/>	_____

INTERFACE EQUIPMENT	Visual	Device Operation	Simulated Operation
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SPECIAL HAZARD SYSTEMS	Visual	Device Operation	Simulated Operation
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Specify) _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Special Procedures: _____

Comments: _____

ON/OFF PREMISES MONITORING	Yes	No	Time	Comments
Alarm Signal	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Alarm Restoral	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Trouble Signal	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Supervisory Signal	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Supervisory Restoral	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____

NOTIFICATIONS THAT TESTING IS COMPLETE	Yes	No	Who	Time
Building Management	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Monitoring Agency	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Building Occupants	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Other (Specify)	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____

The following did not operate correctly: _____

System restored to normal operation: Date: _____ Time: _____

THIS TESTING WAS PERFORMED IN ACCORDANCE WITH APPLICABLE NFPA STANDARDS.

Name of Inspector: _____ Date: _____ Time: _____

Signature: _____

Name of Owner or Representative: _____

Date: _____ Time: _____

Signature: _____

(NFPA Inspection and Testing 4 of 4)

7-5.3 For supervising station fire alarm systems, records pertaining to signals received at the supervising station that result from maintenance, inspection, and testing, shall be maintained for not less than 12 months. Upon request, a hard copy record shall be provided to the authority having jurisdiction. Paper or electronic media shall be permitted.

7-5.4 If the operation of a device, circuit, control panel function, or special hazard system interface is simulated, it shall be noted on the certificate that the operation was simulated, and the certificate shall indicate by whom it was simulated.

Chapter 8 Fire Warning Equipment for Dwelling Units

8-1* Primary Function. Fire warning equipment for dwelling units shall provide a reliable means to notify the occupants of a dwelling unit of the presence of a threatening fire and the need to escape to a place of safety before such escape might be impeded by untenable conditions in the normal path of egress.

8-1.1* Limitations.

8-1.1.1 Life safety from fire in residential occupancies shall be based primarily on early notification to occupants of the need to escape, followed by the appropriate egress actions by those occupants. Fire warning systems for dwelling units are capable of protecting about half of the occupants in potentially fatal fires. Victims are often intimate with the fire, too old or too young, or physically or mentally impaired such that they cannot escape even when warned early enough that escape should be possible. For these people, other strategies such as protection-in-place or assisted escape or rescue shall be necessary.

8-1.1.2* The performance of fire warning equipment for dwelling units discussed in Chapter 8 shall depend on such equipment being properly selected, installed, operated, tested, and maintained in accordance with the provisions of this code and with the manufacturer's instructions provided with the equipment.

8-1.2 Performance Criteria.

8-1.2.1* Sufficient initiating devices shall be installed within the dwelling unit so that their operation provides adequate egress time before the occurrence of untenable conditions at any point along the normal path of egress for all design fire scenarios specified in applicable codes and any supplementary fire scenarios specified by the authority having jurisdiction.

8-1.2.2* Fire warning equipment for dwelling units shall provide a sound that is audible in all occupiable dwelling areas. Audible fire alarm signals shall meet the performance requirements of 4-3.4. If the dwelling unit is occupied by people with hearing deficiencies, visible appliances shall be provided in all dwelling areas to meet the requirements of Section 4-4.

8-1.2.3* Newly installed fire warning equipment for dwelling units (including self-contained devices) shall produce the audible emergency signal described in ANSI S3.41, *Audible Emergency Evacuation Signal*, whenever the intended response is to evacuate the building. The same audible signal shall be permitted to be used for other devices as long as the desired response is immediate evacuation.

Exception: Fire warning equipment that is installed in accordance with provisions of this chapter in other than dwelling units, unless required by another chapter.

8-1.2.4* Location of initiating devices shall consider conditions such as high or low temperature, humidity, or sources of smoke that can lead to nuisance alarms.

8-1.3 Verification Methods. The following methods of verifying compliance with the performance criteria of 8-1.2 shall be permitted. Other methods permitted by the authority having jurisdiction shall be accepted if appropriate.

8-1.3.1 Calculation of detector activation times for all fire scenarios shall demonstrate that sufficient time is provided to allow for successful escape of all occupants.

8-1.3.2 Calculation of sound distribution or light intensity levels, or both, shall demonstrate compliance with the performance criteria of 8-1.2.2.

8-1.3.3 Timing the signal to determine that it meets the required temporal pattern shall be permitted.

8-1.4 Acceptable Solutions. Equipment and installations that comply with 8-1.4.1 through 8-1.4.4 shall be considered one way of meeting the performance criteria of 8-1.2. Other means judged by the authority having jurisdiction as providing equivalent performance shall be permitted.

8-1.4.1* Smoke detectors and smoke alarms located in accordance with the requirements of NFPA 101®, *Life Safety Code*®, for the applicable occupancy classification of the building shall be considered in compliance with these requirements.

8-1.4.1.1 New Hotels and Dormitories.

8-1.4.1.1.1 Detection.

8-1.4.1.1.2 A corridor smoke detection system in accordance with Section 7-6 of NFPA 101 shall be provided. (101:16-3.4.4.1)

Exception: Buildings protected throughout by an approved, supervised automatic sprinkler system installed in accordance with 16-3.5.1 of NFPA 101. (101:16-3.4.4.1)

8-1.4.1.1.3 An approved, single-station smoke alarm shall be installed in accordance with 7-6.2.10 of NFPA 101 in every guest room and every living area and sleeping room within a guest suite. (101:16-3.4.4.2)

8-1.4.1.2 Existing Hotels and Dormitories.

8-1.4.1.2.1 Detection.

8-1.4.1.2.2 An approved, single-station smoke alarm shall be installed in accordance with 7-6.2.10 of NFPA 101 in every guest room and every living area and sleeping room within a guest suite. (101:17-3.4.4.2)

Exception No. 1: These alarms shall not be required to be interconnected. (101:17-3.4.4.2)

Exception No. 2: Single-station smoke alarms without a secondary (standby) power source shall be permitted. (101:17-3.4.4.2)

8-1.4.1.3 New Apartment Buildings.

8-1.4.1.3.1 Detection.

8-1.4.1.3.2 Approved, single-station smoke alarms shall be installed in accordance with 7-6.2.10 of NFPA 101 outside every sleeping area in the immediate vicinity of the bedrooms and on all levels of the dwelling unit including basements. (101:18-3.4.4.1)

8-1.4.1.3.3 Approved, single-station smoke alarms shall be installed in accordance with 7-6.2.10 of NFPA 101 in every sleeping room. (101:18-3.4.4.2)

Exception: In buildings protected throughout by an approved, supervised automatic sprinkler system installed in accordance with 18-3.5 of NFPA 101. (101:18-3.4.4.2)

8-1.4.1.4 Existing Apartment Buildings.

8-1.4.1.4.1 Detection.

8-1.4.1.4.2 Approved, single-station smoke alarms shall be installed in accordance with 7-6.2.10 of NFPA 101 outside every sleeping area in the immediate vicinity of the bedrooms and on all levels of the dwelling unit including basements. (101:19-3.4.4.1)

Exception No. 1: The single-station smoke alarm shall not be required where the building is equipped throughout with an existing total automatic smoke detection system. (101:19-3.4.4.1)

Exception No. 2: Single-station smoke alarms without a secondary (standby) power source shall be permitted. (101:19-3.4.4.1)

8-1.4.1.4.3 In buildings using Option 2, a complete automatic fire detection system in accordance with 7-6.1.4 of NFPA 101 shall be required. (101:19-3.4.4.2)

8-1.4.1.5 Lodging or Rooming Houses.

8-1.4.1.5.1 Detection.

8-1.4.1.5.2 Approved single-station smoke alarms shall be installed in accordance with 7-6.2.10 of NFPA 101 in every sleeping room.

Exception No. 1: These detectors shall not be required to be interconnected. (101:20-3.3.4)

Exception No. 2: Existing battery-powered smoke alarms, rather than house electric-powered smoke alarms, shall be permitted where the facility has demonstrated to the authority having jurisdiction that the testing, maintenance, and battery replacement programs will ensure reliability of power to the smoke alarms. (101:30-3.3.4)

8-1.4.1.6 One- and Two-Family Dwellings.

8-1.4.1.6.1 Detection, Alarm, and Communications Systems.

8-1.4.1.6.2 Approved, single-station smoke alarms shall be installed in accordance with 7-6.2.10 of NFPA 101 in the following locations:

- (1) All sleeping rooms

Exception: Smoke alarms shall not be required in sleeping rooms in existing construction.

- (2) Outside of each separate sleeping area, in the immediate vicinity of the sleeping rooms
- (3) On each additional story of the dwelling unit including basements (101:21-3.3.1)

Exception No. 1: Dwelling units protected by an approved smoke detection system installed in accordance with Section 7-6 of NFPA 101, having an approved means of occupant notification.

Exception No. 2: In existing construction, approved smoke alarms powered by batteries shall be permitted.

8-1.4.2* Initiating devices shall be located in areas where ambient conditions are within the limits specified by the manufacturer, and smoke alarms or smoke detectors shall not be closer than 3 ft (1 m) from the door to a bathroom or kitchen. Smoke alarms or smoke detectors that are located within 20 ft

(6.1 m) of a cooking appliance and are equipped with an alarm silencing means or are of the photoelectric type shall be considered acceptable.

8-1.4.3 Smoke alarms conforming to the requirements of ANSI/UL 217, *Standard for Safety Single and Multiple Station Smoke Alarms*, or smoke detectors conforming to ANSI/UL 268, *Standard for Safety Smoke Detectors for Fire Protective Signaling Systems*, shall be considered acceptable. Visible signaling appliances shall conform to the requirements of ANSI/UL 1971, *Signaling Devices for Hearing Impaired*. Smoke alarms and smoke detectors shall be capable of detecting abnormal quantities of smoke and shall alarm prior to a gray smoke level of 4 percent per ft (0.58 dB/m optical density) that can occur in a dwelling unit. Visible notification appliances located on the ceiling over the bed and within 16 ft of a sleeping occupant shall have a light output rating of at least 177 cd. Where a visible notification appliance in a sleeping room is mounted more than 24 in. (610 mm) below the ceiling and within 16 ft of the pillow, a minimum rating of 110 cd shall be permitted.

8-1.4.4 Smoke detectors shall be connected to central controls for power, signal processing, and activation of notification appliances. Smoke alarms shall not be interconnected in numbers that exceed the manufacturer's recommendations, but in no case shall more than 18 initiating devices be interconnected (of which 12 can be smoke alarms) where the interconnecting means is not supervised, nor more than 64 initiating devices be interconnected (of which 42 can be smoke alarms) where the interconnecting means is supervised.

8-2 Optional Functions. The following optional functions of fire warning equipment for dwelling units shall be permitted:

- (1) Notification of the fire department, either directly or through an alarm monitoring service
- (2) Monitoring of other safety systems, such as fire sprinklers for proper operating conditions
- (3) Notification of occupants or others of potentially dangerous conditions, such as the presence of fuel gases or toxic gases such as carbon monoxide
- (4) Notification of occupants or others of the activation of intrusion (burglar alarm) sensors
- (5) Any other function, safety related or not, that may share components or wiring

8-2.1 Performance Criteria.

8-2.1.1* If designed and installed to perform additional functions, fire warning equipment for dwelling units shall operate reliably and without compromise to its primary functions.

8-2.1.2 Fire signals shall take precedence over any other signal or functions, even if a non-fire signal is activated first.

8-2.1.3 Signals shall be distinctive so that a fire signal can be easily distinguished from signals that require different actions by the occupants.

8-2.1.4 Faults in other systems or components shall not affect the operation of the fire warning system.

8-2.2 Verification Methods.

8-2.2.1 The following methods of verifying compliance with the performance criteria of 8-2.1 shall be permitted. Other methods permitted by the authority having jurisdiction shall be accepted if appropriate.

8-2.2.2 Equipment designed and installed such that the required operation is obtained shall be considered acceptable.

8-2.3 Acceptable Solutions.

8-2.3.1 Equipment and installations that comply with the following shall be considered one way of meeting the performance criteria of 8-2.1. Other means judged by the authority having jurisdiction as providing equivalent performance shall be permitted.

8-2.3.2 Fire warning equipment for dwelling units listed for the functions and combinations stated shall be considered acceptable when judged by the authority having jurisdiction as providing equivalent performance.

8-3 Reliability.

8-3.1 Fire warning systems located in dwelling units and having all of the following features shall be considered to have a functional reliability of 95 percent:

- (1) Utilizes a control panel
- (2) Has at least two independent sources of operating power
- (3) Monitors all initiating and notification circuits for integrity
- (4) Transmits alarm signals to a constantly attended, remote monitoring location
- (5) Is tested regularly by the homeowner and at least every 3 years by a qualified service technician

8-3.2 Fire warning systems for dwelling units with all of the features of 8-3.1 except (4) or systems that use low-power wireless transmission from initiating devices within the dwelling units shall be considered to have a functional reliability of 90 percent.

8-3.3 Fire warning systems for dwelling units comprised of interconnected smoke alarms where the interconnecting means is monitored for integrity shall be considered to have a functional reliability of 88 percent. If the interconnecting means is not supervised or the alarms are not interconnected, such systems shall be considered to have a functional reliability of 85 percent.

8-3.4* Fire warning equipment for dwelling units shall be provided with a convenient means for testing its operability by the homeowner.

8-3.5 Unless otherwise recommended by the manufacturer, smoke alarms installed in accordance with Chapters 18, 19, or 21 of NFPA 101, *Life Safety Code*, shall be replaced when they fail to respond to tests conducted in accordance with 8-3.4 but shall not remain in service longer than 10 years from the date of installation.

8-4 Performance Criteria.

8-4.1 The two independent power sources shall consist of a primary source that uses the commercial light and power source and a secondary source that consists of a rechargeable battery or standby generator that can operate the system for at least 24 hours in the normal condition followed by 4 minutes of alarm.

8-4.2 All monitored circuits shall indicate with a distinctive trouble signal the occurrence of a single fault (open or unintentional ground), whether or not such fault affects the system's operation. Circuits interconnecting multiple station alarms shall not be required to be monitored provided a fault

does not prevent an alarm signal from the detector that senses the abnormal condition.

8-4.3 Supervising Stations.

8-4.3.1 Means to transmit alarm signals to a constantly attended, remote monitoring location shall perform as described in Chapter 5 except that the DACT serving the protected premises only requires a single telephone line and only requires a call to a single DACR number. DACT test signals shall be transmitted at least monthly. Such systems shall not be required to be certificated or placarded.

8-4.3.2* Remote monitoring locations shall be permitted to verify residential alarm signals prior to reporting them to the fire service provided that the verification process does not delay the reporting by more than 90 seconds.

8-4.4 Low-power wireless systems shall comply with the performance criteria of Section 3-10.

8-4.5 Smoke alarms shall be powered from the commercial light and power source along with a secondary battery source that is capable of operating the device for at least 7 days in the normal condition followed by 4 minutes of alarm. Alternatively, smoke alarms shall be powered by a non-replaceable primary battery that is capable of operating the device for at least 10 years followed by 4 minutes of alarm, followed by 7 days of trouble.

8-4.6 Smoke alarms powered by a primary battery capable of operating the device for at least 1 year in the normal condition, followed by 4 minutes of alarm, followed by at least 7 days of trouble, shall be used only if specifically permitted.

8-4.7 Verification Methods. The following methods of verifying compliance with the performance criteria of Section 8-4 shall be permitted. Other methods permitted by the authority having jurisdiction shall be accepted if appropriate.

8-4.7.1 Engineering analysis such as fault tree analysis (FTA) or failure modes and effects criticality analysis (FMECA) shall be acceptable methods of determining equipment reliability.

8-4.7.2 Equipment designed and installed such that the required operation is obtained shall be considered acceptable.

8-4.8 Acceptable Solutions.

8-4.8.1 Equipment and installations that comply with 8-4.8.2 shall be considered one way of meeting the performance criteria of Section 8-4. Other means judged by the authority having jurisdiction as providing equivalent performance shall be permitted.

8-4.8.2 Equipment listed and approved to standards that verify the required performance such as ANSI/UL 985, *Standard for Safety Household Fire Warning Control Units*; ANSI/UL 217, *Standard for Safety Single and Multiple Station Smoke Alarms*; or ANSI/UL 268, *Standard for Safety Smoke Detectors for Fire Protective Signaling Systems*, shall be considered acceptable.

Chapter 9 Referenced Publications

9-1 The following documents or portions thereof are referenced within this code as mandatory requirements and shall be considered part of the requirements of this code. The edition indicated for each referenced mandatory document is the

current edition as of the date of the NFPA issuance of this code. Some of these mandatory documents might also be referenced in this code for specific informational purposes and, therefore, are also listed in Appendix C.

9-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*, 1999 edition.

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*, 1999 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 1999 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1998 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1998 edition.

NFPA 54, *National Fuel Gas Code*, 1999 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 1998 edition.

NFPA 70, *National Electrical Code®*, 1999 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1999 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 1999 edition.

NFPA 101®, *Life Safety Code®*, 1997 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 1999 edition.

NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*, 1996 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1997 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 1999 edition.

9-1.2 Other Publications.

9-1.2.1 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI A-58.1, *Building Code Requirements for Minimum Design Loads in Buildings and Other Structures*,

ANSI S1.4a, *Specifications for Sound Level Meters*, 1985.

ANSI S3.41, *Audible Emergency Evacuation Signal*, 1996.

ANSI/ASME A17.1, *Safety Code for Elevators and Escalators*, 1998.

ANSI/IEEE C2, *National Electrical Safety Code*, 1997.

ANSI/UL 217, *Standard for Safety Single and Multiple Station Smoke Alarms*, 1997.

ANSI/UL 268, *Standard for Safety Smoke Detectors for Fire Protective Signaling Systems*, 1999.

ANSI/UL 827, *Standard for Safety Central-Station for Watchman, Fire-Alarm and Supervisory Services*, 1997.

ANSI/UL 985, *Standard for Safety Household Fire Warning Control Units*, 1994.

ANSI/UL 1971, *Signaling Devices for Hearing Impaired*, 1995.

9-1.2.2 EIA Publication. Electronic Industries Alliance, 2500 Wilson Boulevard, Arlington, VA 22201-3834.

EIA Tr 41.3, *Telephones*.

9-1.3 Additional References.

International Municipal Signal Association, P.O. Box 539, Newark, NY 14513.

National Institute for Certification in Engineering Technologies, 1420 King Street, Alexandria, VA 22314-2794.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-2.1 Fire alarm systems intended for life safety should be designed, installed, and maintained to provide indication and warning of abnormal fire conditions. The system should alert building occupants and summon appropriate aid in adequate time to allow for occupants to travel to a safe place and for rescue operations to occur. The fire alarm system should be part of a life safety plan that also includes a combination of prevention, protection, egress, and other features particular to that occupancy.

A-1-4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction. The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Certification of Personnel. This definition of *certification of personnel* applies only to municipal fire alarm systems.

A-1-4 Combination System. Examples of non-fire systems are security, card access control, closed circuit television, sound reinforcement, background music, paging, sound masking, building automation, time, and attendance.

A-1-4 Double Doorway. Refer to Figure 2-10.6.5.3.1 for an illustration of detector location requirements for double doors.

A-1-4 Ember. Class A and Class D combustibles burn as embers under conditions where the flame typically associated with fire does not necessarily exist. This glowing combustion yields radiant emissions in parts of the radiant energy spectrum that are radically different from those parts affected by flaming combustion. Specialized detectors that are specifically designed to detect those emissions should be used in applications where this type of combustion is expected. In general, flame detectors are not intended for the detection of embers.

A-1-4 Evacuation. Evacuation does not include the relocation of occupants within a building.

A-1-4 Fixed-Temperature Detector. The difference between the operating temperature of a fixed-temperature device and the surrounding air temperature is proportional to the rate at which the temperature is rising. The rate is commonly referred to as *thermal lag*. The air temperature is always higher than the operating temperature of the device.

Typical examples of fixed-temperature sensing elements are as follows.

(a) *Bimetallic.* A sensing element comprised of two metals that have different coefficients of thermal expansion arranged so that the effect is deflection in one direction when heated and in the opposite direction when cooled.

(b) *Electrical Conductivity.* A line-type or spot-type sensing element in which resistance varies as a function of temperature.

(c) *Fusible Alloy.* A sensing element of a special composition metal (eutectic) that melts rapidly at the rated temperature.

(d) *Heat-Sensitive Cable.* A line-type device in which the sensing element comprises, in one type, two current-carrying wires separated by heat-sensitive insulation that softens at the rated temperature, thus allowing the wires to make electrical contact. In another type, a single wire is centered in a metallic tube, and the intervening space is filled with a substance that becomes conductive at a critical temperature, thus establishing electrical contact between the tube and the wire.

(e) *Liquid Expansion.* A sensing element comprising a liquid that is capable of marked expansion in volume in response to an increase in temperature.

A-1-4 Flame Detector. Flame detectors are categorized as ultraviolet, single wavelength infrared, ultraviolet infrared, or multiple wavelength infrared.

A-1-4 Ionization Smoke Detection. Ionization smoke detection is more responsive to invisible particles (smaller than 1 micron in size) produced by most flaming fires. It is somewhat less responsive to the larger particles typical of most smoldering fires. Smoke detectors that use the ionization principle are usually of the spot type.

A-1-4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-4 Photoelectric Light Obscuration Smoke Detection. The response of photoelectric light obscuration smoke detectors is usually not affected by the color of smoke.

Smoke detectors that use the light obscuration principle are usually of the line type. These detectors are commonly referred to as "projected beam smoke detectors."

A-1-4 Photoelectric Light-Scattering Smoke Detection. Photoelectric light-scattering smoke detection is more responsive to visible particles (larger than 1 micron in size) produced by most smoldering fires. It is somewhat less responsive to the smaller particles typical of most flaming fires. It is also less responsive to black smoke than to lighter colored smoke. Smoke detectors that use the light-scattering principle are usually of the spot type.

A-1-4 Radio Channel. The width of the channel depends on the type of transmissions and the tolerance for the frequency of emission. Channels normally are allocated for radio transmission in a specified type for service by a specified transmitter.

A-1-4 Rate Compensation Detector. A typical example of a rate compensation detector is a spot-type detector with a tubular casing of a metal that tends to expand lengthwise as it is heated and an associated contact mechanism that closes at a certain point in the elongation. A second metallic element inside the tube exerts an opposing force on the contacts, tending to hold them open. The forces are balanced in such a way that, on a slow rate-of-temperature rise, there is more time for heat to penetrate to the inner element, which inhibits contact closure until the total device has been heated to its rated temperature level. However, on a fast rate-of-temperature rise, there is not as much time for heat to penetrate to the inner element, which exerts less of an inhibiting effect so that contact closure is achieved when the total device has been heated to a lower temperature. This, in effect, compensates for thermal lag.

A-1-4 Rate-of-Rise Detector. Typical examples of rate-of-rise detectors are as follows.

(a) *Pneumatic Rate-of-Rise Tubing.* A line-type detector comprising small-diameter tubing, usually copper, that is installed on the ceiling or high on the walls throughout the protected area. The tubing is terminated in a detector unit that contains diaphragms and associated contacts set to actuate at a predetermined pressure. The system is sealed except for calibrated vents that compensate for normal changes in temperature.

(b) *Spot-Type Pneumatic Rate-of-Rise Detector.* A device consisting of an air chamber, a diaphragm, contacts, and a compensating vent in a single enclosure. The principle of operation is the same as that described for pneumatic rate-of-rise tubing.

(c) *Electrical Conductivity—Type Rate-of-Rise Detector.* A line-type or spot-type sensing element in which resistance changes due to a change in temperature. The rate of change of resistance is monitored by associated control equipment, and an alarm is initiated when the rate of temperature increase exceeds a preset value.

A-1-4 Sloping Peaked-Type Ceiling. Refer to Figure A-2-2.4.4.1 for an illustration of smoke or heat detector spacing on peaked-type sloped ceilings.

A-1-4 Sloping Shed-Type Ceiling. Refer to Figure A-2-2.4.4.2 for an illustration of smoke or heat detector spacing on shed-type sloped ceilings.

A-1-4 Smooth Ceiling. Open truss constructions are not considered to impede the flow of fire products unless the upper member, in continuous contact with the ceiling, projects below the ceiling more than 4 in. (100 mm).

A-1-4 Spark. The overwhelming majority of applications involving the detection of Class A and Class D combustibles with radiant energy-sensing detectors involve the transport of particulate solid materials through pneumatic conveyor ducts

or mechanical conveyors. It is common in the industries that include such hazards to refer to a moving piece of burning material as a *spark* and to systems for the detection of such fires as *spark detection systems*.

A-1-4 Voice Intelligibility. As used in this code, intelligibility and intelligible are both applied to the description of voice communications systems intended to reproduce human speech. When a human being can clearly distinguish and understand human speech reproduced by such a system, the system is said to be intelligible. Satisfactory intelligibility requires adequate audibility and adequate clarity. Clarity is defined as freedom from distortion of all kinds (IEC 60849, *Sound Systems for Emergency Purposes*, Section 3.6). The following are three kinds of distortion responsible for the reduction of speech clarity in an electroacoustic system:

- (1) Amplitude distortion, due to non-linearity in electronic equipment and transducers
- (2) Frequency distortion, due to non-uniform frequency response of transducers and selective absorption of various frequencies in acoustic transmission
- (3) Time domain distortion, due to reflections and reverberation in the acoustic domain

Of these three kinds of distortion, frequency distortion is partially, and time domain distortion is totally, a function of the environment in which the system is installed (size, shape, and surface characteristics of walls, floors, and ceilings) and the character and placement of the loudspeakers (transducers).

A-1-4 Wavelength. The concept of wavelength is extremely important in selecting the proper detector for a particular application. There is a precise interrelation between the wavelength of light being emitted from a flame and the combustion chemistry producing the flame. Specific subatomic, atomic, and molecular events yield radiant energy of specific wavelengths. For example, ultraviolet photons are emitted as the result of the complete loss of electrons or very large changes in electron energy levels. During combustion, molecules are violently torn apart by the chemical reactivity of oxygen, and electrons are released in the process, recombining at drastically lower energy levels, thus giving rise to ultraviolet radiation. Visible radiation is generally the result of smaller changes in electron energy levels within the molecules of fuel, flame intermediates, and products of combustion. Infrared radiation comes from the vibration of molecules or parts of molecules when they are in the superheated state associated with combustion. Each chemical compound exhibits a group of wavelengths at which it is resonant. These wavelengths constitute the chemical's infrared spectrum, which is usually unique to that chemical.

This interrelationship between wavelength and combustion chemistry affects the relative performance of various types of detectors with respect to various fires.

A-1-5.1.3 Examples of qualified personnel include individuals who can demonstrate experience on similar systems and have the following qualifications:

- (1) Factory trained and certified in fire alarm system design
- (2) National Institute of Certification in Engineering Technologies (NICET) fire alarm certified — minimum level III
- (3) Licensed or certified by a state or local authority

A-1-5.2.3 The term *fire alarm systems* includes all equipment, regardless of location, that requires power but does not receive all power directly from the main control unit. Examples of fire alarm equipment that require power include, but are not limited to,

the following multiple control units, remote power supplies, amplifiers, transponders, and required computer equipment.

A-1-5.2.7(c) An engine-driven generator without standby battery supplement should not be assumed to be capable of a reliable power transfer within 30 seconds of a primary power loss.

A-1-5.2.7(d) UPS equipment often contains an internal bypass arrangement to supply the load directly from the line. These internal bypass arrangements are a potential source of failure. UPS equipment also requires periodic maintenance. It is, therefore, necessary to provide a means of promptly and safely bypassing and isolating the UPS equipment from all power sources while maintaining continuity of power supply to the equipment normally supplied by the UPS.

A-1-5.2.9 Rechargeable-Type Batteries, or Storage Batteries. The following newer types of rechargeable batteries are normally used in protected premises applications.

(a) *Vented Lead-Acid, Gelled, or Starved Electrolyte Battery.* This rechargeable-type battery is generally used in place of primary batteries in applications that have a relatively high current drain or that require the extended standby capability of much lower currents. The nominal voltage of a single cell is 2 volts, and the battery is available in multiples of 2 volts (e.g., 2, 4, 6, 12). Batteries should be stored according to the manufacturer's recommendations.

(b) *Nickel-Cadmium Battery.* The sealed-type nickel-cadmium battery generally used in applications where the battery current drain during a power outage is low to moderate (typically up to a few hundred milliamperes) and is fairly constant. Nickel-cadmium batteries are also available in much larger capacities for other applications. The nominal voltage per cell is 1.42 volts, with batteries available in multiples of 1.42 (e.g., 12.78, 25.56). Batteries in storage can be stored in any state of charge for indefinite periods. However, a battery in storage will lose capacity (will self-discharge), depending on storage time and temperature. Typically, batteries stored for more than 1 month require an 8-hour to 14-hour charge period to restore capacity. In service, the battery should receive a continuous, constant-charging current that is sufficient to keep it fully charged. (Typically, the charge rate equals $1/10$ to $1/20$ of the ampere-hour rating of the battery.) Because batteries are made up of individual cells connected in series, the possibility exists that, during deep discharge, one or more cells that are low in capacity will reach complete discharge prior to other cells. The cells with remaining life tend to charge the depleted cells, causing a polarity reversal resulting in permanent battery damage. This condition can be determined by measuring the open cell voltage of a fully charged battery (voltage should be a minimum of 1.28 volts per cell multiplied by the number of cells). Voltage depression effect is a minor change in discharge voltage level caused by constant current charging below the system discharge rate.

In some applications of nickel-cadmium batteries, for example, battery-powered shavers, a memory characteristic also exists. Specifically, if the battery is discharged daily for 1 minute, followed by a recharge, operation for 5 minutes will not result in the rated ampere-hour output because the battery has developed a 1-minute discharge memory.

(c) *Sealed Lead-Acid Battery.* In a sealed lead-acid battery, the electrolyte is totally absorbed by the separators, and no venting normally occurs. Gas evolved during recharge is internally recombined, resulting in minimal loss of capacity life. A

high-pressure vent, however, is provided to avoid damage under abnormal conditions.

A-1-5.2.9.2.3 Batteries are trickle-charged if they are off-line and waiting to be put under load in the event of a loss of power.

Float-charged batteries are fully charged and connected across the output of the rectifiers to smooth the output and to serve as a standby source of power in the event of a loss of line power.

A-1-5.4.1.2 It is not the intent of this paragraph to dictate the time frame for the local fire safety devices to complete their function, such as fan wind-down time, door closure time, or elevator travel time.

A-1-5.4.2.1 Coded Alarm Signal Designations. The recommended coded signal designations for buildings that have four floors and multiple basements are provided in Table A-1-5.4.2.1.

Table A-1-5.4.2.1 Recommended Coded Signal Designations

Location	Coded Signal
Fourth floor	2-4
Third floor	2-3
Second floor	2-2
First floor	2-1
Basement	3-1
Sub-basement	3-2

A-1-5.4.2.2 Actuation of an initiating device is usually the instant at which a complete digital signal is achieved at the device, such as a contact closure. For smoke detectors or other automatic initiating devices, which may involve signal processing and analysis of the signature of fire phenomena, actuation means the instant when the signal analysis requirements are completed by the device or control unit software.

A separate control unit contemplates a network of control units forming a single large system as defined in Section 3-8.

For some analog initiating devices, actuation is the moment that the fire alarm control unit interprets that the signal from an initiating device has exceeded the alarm threshold programmed into the control unit.

For smoke detectors working on a system with alarm verification, where the verification function is performed in the fire alarm control unit, the moment of actuation of smoke detectors is sometimes determined by the fire alarm control unit.

A-1-5.4.5.2 The operability of controlled mechanical equipment (e.g., smoke and fire dampers, elevator recall arrangements, and door holders) should be verified by periodic testing. Failure to test and properly maintain controlled mechanical equipment can result in operational failure during an emergency, with potential consequences up to and including loss of life.

A-1-5.4.6.3.3 The purposes for automatic trouble re-sound is to remind owners, or those responsible for the system, that the system remains in a fault condition. A secondary benefit is to possibly alert occupants of the building that the fire alarm system is in a fault condition.

A-1-5.4.6.3.4 In large, campus-style arrangements with proprietary supervising stations monitoring protected premises systems, and in other situations where off-premises monitoring achieves the desired result, the authority having jurisdiction is permitted to allow the re-sound to occur only at the supervising station. Approval by the authority having jurisdiction is required so it can consider all fire safety issues and make a determination that there are procedures in place to ensure that the intent is met, in other words, someone is available to take action to correct the problem.

A-1-5.4.7(b) A valve supervisory, low-pressure switch or other device intended to cause a supervisory signal when actuated should not be connected in series with the end-of-line supervisory device of initiating device circuits, unless a distinctive signal, different from a trouble signal, is indicated.

A-1-5.4.10 A system provided with an alarm verification feature as permitted by 3-8.3.2.3.1 is not considered a presignal system, since the delay in the signal produced is 60 seconds or less and requires no human intervention.

A-1-5.4.11.4 The bypass means is intended to enable automatic or manual day and night and weekend operation.

A-1-5.5.1(1) The requirement of 1-5.5.1(1) does not preclude transfer to secondary supply at less than 85 percent of nominal primary voltage, provided the requirements of 1-5.2.5 are met.

A-1-5.5.2.1 Fire alarm specifications can include some or all of the following:

- (1) Address of the protected premises
- (2) Owner of the protected premises
- (3) Authority having jurisdiction
- (4) Applicable codes, standards, and other design criteria to which the system is required to comply
- (5) Type of building construction and occupancy
- (6) Fire department response point(s) and annunciator location(s)
- (7) Type of fire alarm system to be provided
- (8) Calculations, for example, secondary supply and voltage drop calculations
- (9) Type(s) of fire alarm-initiating devices, supervisory alarm-initiating devices, and evacuation notification appliances to be provided
- (10) Intended area(s) of coverage
- (11) Complete list of detection, evacuation signaling, and annunciator zones
- (12) Complete list of fire safety control functions
- (13) Complete sequence of operations detailing all inputs and outputs

A-1-5.5.4 The installation of all fire alarm system wiring should take into account the fire alarm system manufacturer's published installation instructions and the limitations of the applicable product listings or approvals.

A-1-5.6 The intent of 1-5.6 is to have the fire alarm system respond before it is incapacitated by fire. There have been several fatal fires where the origin and path of the fire resulted in destruction of the control unit before a detector responded.

CAUTION

The exception to 1-5.6 permits use of a heat detector if ambient conditions are not suitable for smoke detection. It is important to also evaluate whether the area is suitable for the control unit.

The code intends that only one smoke detector is required at the control unit even when the area of the room would require more than one detector if installed according to the spacing rules in Chapter 2.

A-1-5.7.1.2 Fire alarm system annunciation should, as a minimum, be sufficiently specific to identify the origin of a fire alarm signal in accordance with the following.

(a) If a floor exceeds 20,000 ft² (1860 m²) in area, the floor should be subdivided into detection zones of 20,000 ft² (1860 m²) or less, consistent with the existing smoke and fire barriers on the floor.

(b) If a floor exceeds 20,000 ft² (1860 m²) in area and is undivided by smoke or fire barriers, detection zoning should be determined on a case-by-case basis in consultation with the authority having jurisdiction.

(c) Waterflow switches on sprinkler systems that serve multiple floors, areas exceeding 20,000 ft² (1860 m²), or areas inconsistent with the established detection system zoning should be annunciated individually.

(d) In-duct smoke detectors on air-handling systems that serve multiple floors, areas exceeding 20,000 ft² (1860 m²), or areas inconsistent with the established detection system zoning should be annunciated individually.

(e) If a floor area exceeds 20,000 ft² (1860 m²), additional zoning should be provided. The length of any zone should not exceed 300 ft (91 m) in any direction. If the building is provided with automatic sprinklers throughout, the area of the alarm zone should be permitted to coincide with the allowable area of the sprinkler zone.

A-1-5.8.1 The provision of a double loop or other multiple path conductor or circuit to avoid electrical monitoring is not acceptable.

A-1-5.8.1 Exception No. 7 This code does not have jurisdiction over the monitoring integrity of conductors within equipment, devices, or appliances.

A-1-5.8.6.1 Backup amplifying and evacuation signal-generating equipment is recommended with automatic transfer upon primary equipment failure to ensure prompt restoration of service in the event of equipment failure.

A-1-5.8.7.2 Because digital alarm communicator systems establish communications channels between the protected premises and the central station via the public switched telephone network, the requirement to supervise circuits between the protected premises and the central station (*refer to 1-5.8.1*) is considered to be met if the communications channel is periodically tested in accordance with 5-5.3.2.1.10.

A-1-6.1.3 Protected premises fire alarm systems are often installed under construction or remodeling contracts and subsequently connected to a supervising station fire alarm system under a separate contract. All contractors should complete the portions of the record of completion form for the portions

of the connected systems for which they are responsible. Several partially completed forms might be accepted by the authority having jurisdiction provided that all portions of the connected systems are covered in the set of forms.

A-1-6.2.1 The requirements of Chapter 7 should be used to perform the installation wiring and operational acceptance tests required when completing the record of completion.

The record of completion form shall be permitted to be used to record decisions reached prior to installation regarding intended system type(s), circuit designations, device types, notification appliance type, power sources, and the means of transmission to the supervising station.

A-1-6.2.2(1) The owner's manual should include the following:

(a) A detailed narrative description of the system inputs, evacuation signaling, ancillary functions, annunciation, intended sequence of operations, expansion capability, application considerations, and limitations

(b) Operator instructions for basic system operations, including alarm acknowledgment, system reset, interpretation of system output (LEDs, CRT display, and printout), operation of manual evacuation signaling and ancillary function controls, and change of printer paper

(c) A detailed description of routine maintenance and testing as required and recommended and as would be provided under a maintenance contract, including testing and maintenance instructions for each type of device installed. This information should include the following:

(1) Listing of the individual system components that require periodic testing and maintenance

(2) Step-by-step instructions detailing the requisite testing and maintenance procedures, and the intervals at which these procedures shall be performed, for each type of device installed

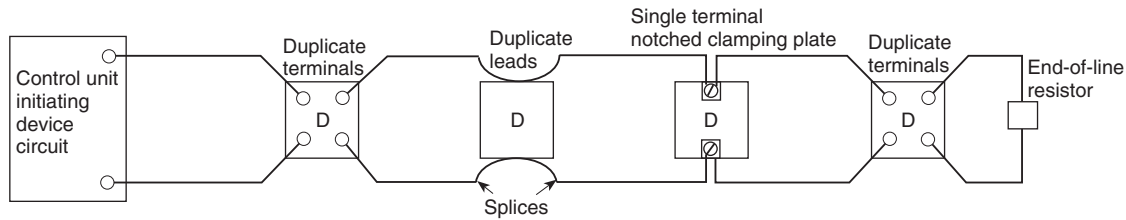
(3) A schedule that correlates the testing and maintenance procedures recommended by A-1-6.2.2(c)(2) with the listing recommended by A-1-6.2.2(c)(1)

(d) Detailed troubleshooting instructions for each trouble condition generated from the monitored field wiring, including opens, grounds, and loop failures [These instructions should include a list of all trouble signals annunciated by the system, a description of the condition(s) that causes such trouble signals, and step-by-step instructions describing how to isolate such problems and correct them (or how to call for service, as appropriate).]

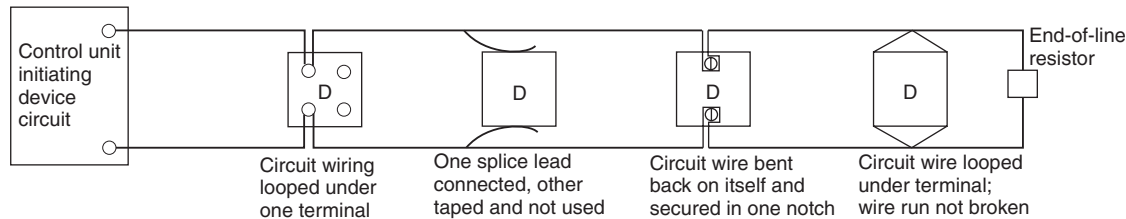
(e) A service directory, including a list of names and telephone numbers of those who provide service for the system

A-2-1.3.4 The monitoring of circuit integrity relies on the interruption of the wiring continuity when the connection to the initiating device is lost. Terminals and leads, as illustrated in Figures A-2-1.3.4(a) and (b) monitor the presence of the device on the initiating device circuit.

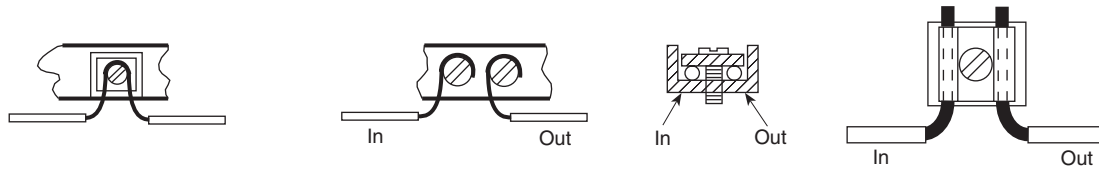
Figure A-2-1.3.4(a) Correct wiring methods — four-wire detectors with separate power supply.



Correct wiring method — two-wire detectors



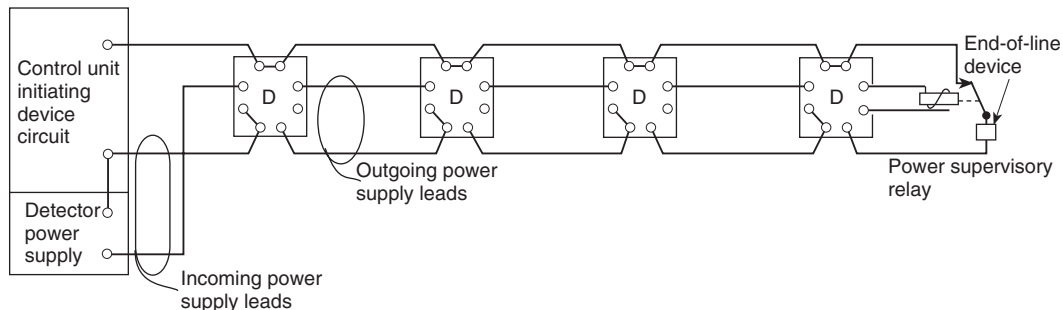
Incorrect wiring method — two-wire detectors



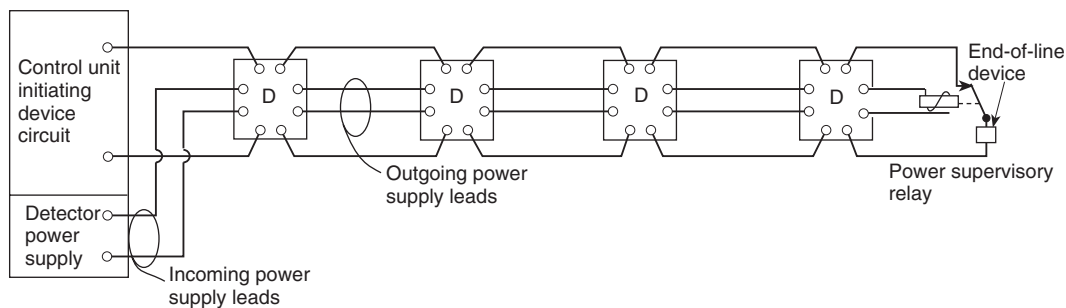
Incorrect

Correct — separate incoming and outgoing conductors

Figure A-2-1.3.4(b) Wiring arrangements for three- and four-wire detectors.



Illustrates four-wire smoke detector employing a three-wire connecting arrangement. One side of power supply is connected to one side of initiating device circuit. Wire run broken at each connection to smoke detector to provide supervision.



Illustrates four-wire smoke detector employing a four-wire connecting arrangement. Incoming and outgoing leads or terminals for both initiating device and power supply connections. Wire run broken at each connection to provide supervision.

D = Detector

A-2-1.4.2 The requirement of 2-1.4.2 recognizes that there are several different types of detector coverage.

A-2-1.4.2.2 If there are no detectors in the room or area of fire origin, the fire could exceed the design objectives before being detected by remotely located detectors.

A-2-1.4.2.3 If there are no detectors in the room or area of fire origin, the fire could exceed the design objectives before being detected by remotely located detectors.

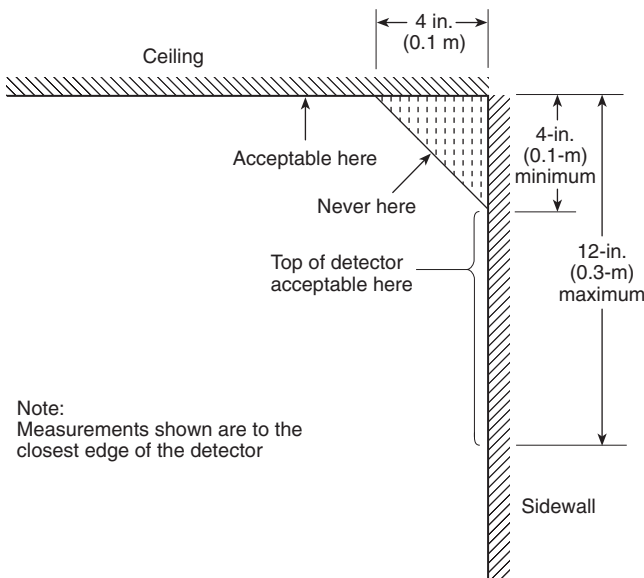
A-2-1.4.2.4 The requirement of 2-1.4.2.4 recognizes there will be instances where, for example, a facility owner would want to apply detection to meet certain performance goals and to address a particular hazard or need, but that detection is not required. Once installed, of course, acceptance testing, annual testing, and ongoing maintenance in accordance with this code is anticipated.

A-2-2.1.2 The linear space rating is the maximum allowable distance between heat detectors. The linear space rating is also a measure of the heat detector response time to a standard test fire where tested at the same distance. The higher the rating, the faster the response time. This code recognizes only those heat detectors with ratings of 50 ft (15 m) or more.

A-2-2.1.3 In order to predict the response of a heat detector using current fire modeling programs and currently published equations describing plume dynamics, two parameters must be known: operating temperature and thermal response coefficient. The thermal response coefficient is the quantification of the rate of heat transfer from the ceiling jet to the detector sensing element per unit of time, expressed as a function of ceiling jet temperature, ceiling jet velocity, and time. Response time index is a commonly used thermal response coefficient for sprinklers.

A-2-2.2.1 Figure A-2-2.2.1 illustrates the proper mounting placement for detectors.

Figure A-2-2.2.1 Example of proper mounting for detectors.



A-2-2.3 Detectors should be selected to minimize this temperature difference in order to minimize response time. However, a heat detector with a temperature rating that is somewhat in excess of the highest normally expected ambient temperature is specified in order to avoid the possibility of premature operation of the heat detector to non-fire conditions.

A-2-2.4 In addition to the special requirements for heat detectors that are installed on ceilings with exposed joists, reduced spacing also might be required due to other structural characteristics of the protected area, such as possible drafts or other conditions that could affect detector operation.

A-2-2.4.1 Maximum linear spacings on smooth ceilings for spot-type heat detectors are determined by full-scale fire tests. [See Figure A-2-2.4.1(c).] These tests assume that the detectors are to be installed in a pattern of one or more squares, each side of which equals the maximum spacing as determined in the test, as illustrated in Figure A-2-2.4.1(a). The detector to be tested is placed at a corner of the square so that it is positioned at the farthest possible distance from the fire while remaining within the square. Thus, the distance from the detector to the fire is always the test spacing multiplied by 0.7 and can be calculated as shown in Table A-2-2.4.1.

Table A-2-2.4.1 Test Spacing for Spot-Type Heat Detectors

Test Spacing		Maximum Test Distance from Fire to Detector (0.7 × D)	
ft	m	ft	m
50 × 50	15.24 × 15.24	35.0	10.67
40 × 40	12.19 × 12.19	28.0	8.53
30 × 30	9.10 × 9.10	21.0	6.40
25 × 25	7.62 × 7.62	17.5	5.33
20 × 20	6.10 × 6.10	14.0	4.27
15 × 15	4.57 × 4.57	10.5	3.20

Once the correct maximum test distance has been determined, it is valid to interchange the positions of the fire and the detector. The detector is now in the middle of the square, and the listing specifies that the detector is adequate to detect a fire that occurs anywhere within that square — even out to the farthest corner.

In laying out detector installations, designers work in terms of rectangles, as building areas are generally rectangular in shape. The pattern of heat spread from a fire source, however, is not rectangular in shape. On a smooth ceiling, heat spreads out in all directions in an ever-expanding circle. Thus, the coverage of a detector is not, in fact, a square, but rather a circle whose radius is the linear spacing multiplied by 0.7. [See also Figure A-2-2.4.1(b).]

This is graphically illustrated in Figure A-2-2.4.1(d). With the detector at the center, by rotating the square, an infinite number of squares can be laid out, the corners of which create the plot of a circle whose radius is 0.7 times the listed spacing. The detector will cover any of these squares and, consequently, any point within the confines of the circle.

So far this explanation has considered squares and circles. In practical applications, very few areas turn out to be exactly square, and circular areas are extremely rare. Designers deal generally with rectangles of odd dimensions and corners of rooms or areas formed by wall intercepts, where spacing to one wall is less than one-half the listed spacing. To simplify the rest of this explanation, the use of a detector with a listed spacing of 30 ft \times 30 ft (9.1 m \times 9.1 m) should be considered. The principles derived are equally applicable to other types.

Figure A-2-2.4.1 (f) illustrates the derivation of this concept. In Figure A-2-2.4.1 (f), a detector is placed in the center of a circle with a radius of 21 ft (0.7 \times 30 ft) [6.4 m (0.7 \times 9.1 m)]. A series of rectangles with one dimension less than the permitted maximum of 30 ft (9.1 m) is constructed within the circle. The following conclusions can be drawn.

(a) As the smaller dimension decreases, the longer dimension can be increased beyond the linear maximum spacing of the detector with no loss in detection efficiency.

(b) A single detector covers any area that fits within the circle. For a rectangle, a single, properly located detector may be permitted, provided the diagonal of the rectangle does not exceed the diameter of the circle.

(c) Relative detector efficiency actually is increased, because the area coverage in square feet is always less than the 900 ft² (83.6 m²) permitted if the full 30 ft \times 30 ft (9.1 m \times 9.1 m) square were to be utilized. The principle illustrated here allows equal linear spacing between the detector and the fire, with no recognition for the effect of reflection from walls or partitions, which in narrow rooms or corridors is of additional benefit. For detectors that are not centered, the longer dimension should always be used in laying out the radius of coverage.

Areas so large that they exceed the rectangular dimensions given in Figure A-2-2.4.1 (f) require additional detectors. Often proper placement of detectors can be facilitated by breaking down the area into multiple rectangles of the dimensions that fit most appropriately. For example, refer to Figure A-2-2.4.1 (e). A corridor 10 ft (3 m) wide and up to 82 ft (25 m) long can be covered with two 30-ft (9.1-m) spot-type detectors. An area 40 ft (12.2 m) wide and up to 74 ft (22.6 m) long can be covered with four spot-type detectors. Irregular areas need more careful planning to make certain that no spot on the ceiling is more than 21 ft (6.4 m) away from a detector. These points can be determined by striking arcs from the remote corner. Where any part of the area lies beyond the circle with a radius of 0.7 times the listed spacings, additional detectors are required.

Figure A-2-2.4.1(a) Spot-type heat detectors.

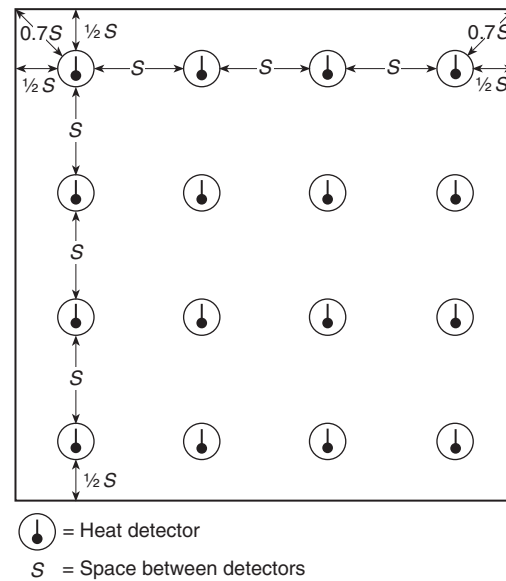


Figure A-2-2.4.1(b) Line-type detectors — spacing layouts, smooth ceiling.

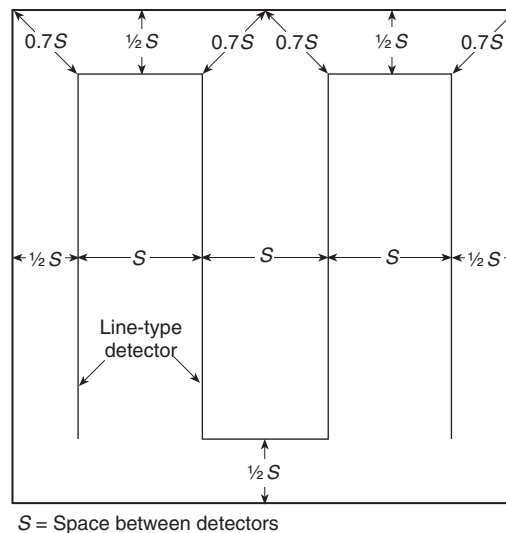


Figure A-2.2.4.1(c) Fire test layout.

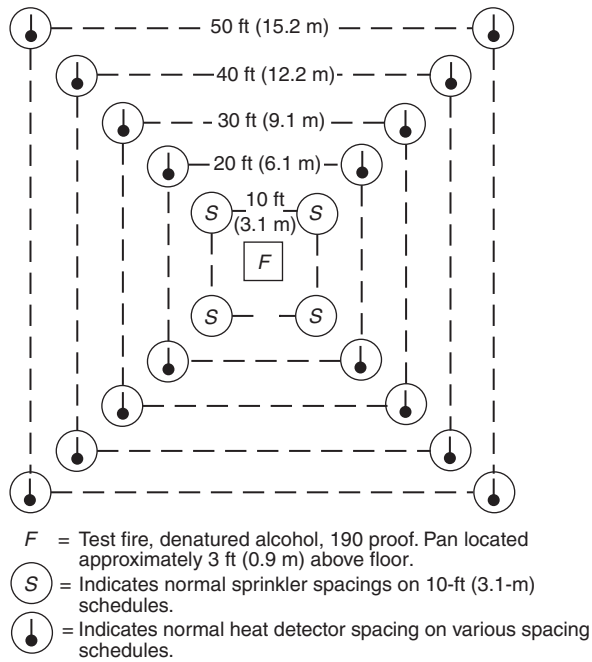


Figure A-2.2.4.1(d) Detector covering any square laid out in the confines of a circle in which the radius is 0.7 times the listed spacing.

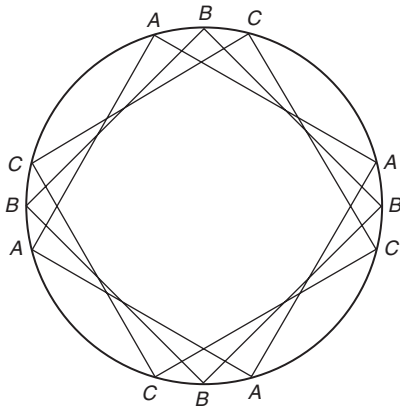


Figure A-2.2.4.1(e) Typical rectangles for detector curves of 15 ft to 50 ft (4.57 m to 15.24 m).

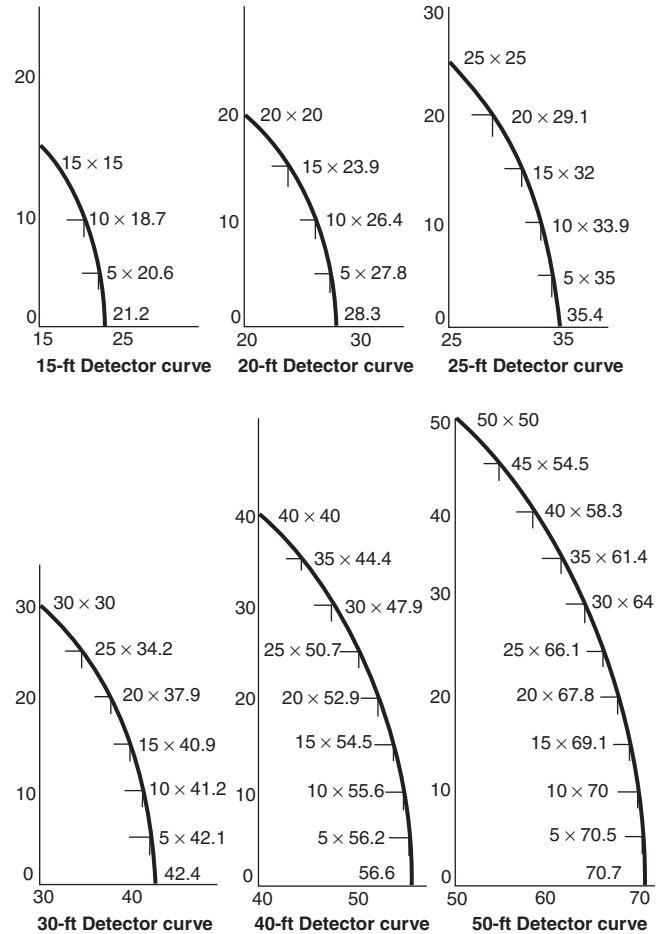
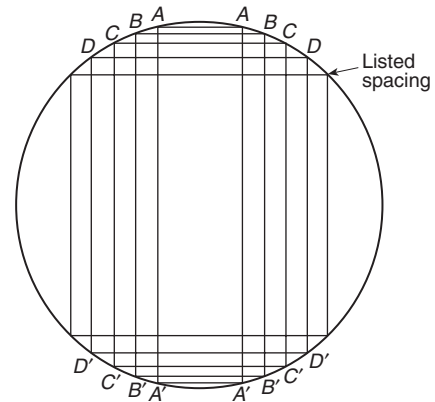


Figure A-2.2.4.1(f) Detector spacing, rectangular areas.

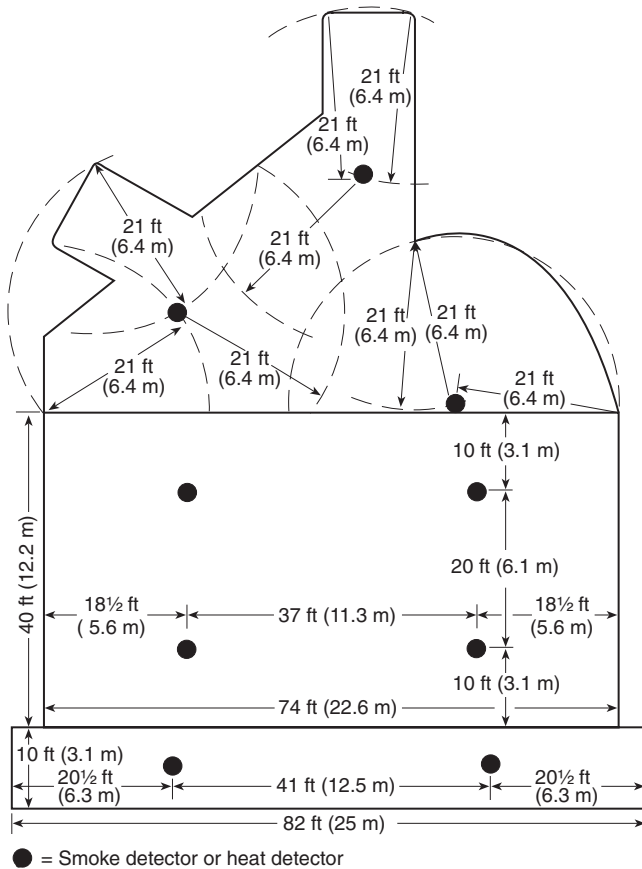


Rectangles

$A = 10 \text{ ft} \times 41 \text{ ft} = 410 \text{ ft}^2$	$(3.1 \text{ m} \times 12.5 \text{ m} = 38.1 \text{ m}^2)$
$B = 15 \text{ ft} \times 39 \text{ ft} = 585 \text{ ft}^2$	$(4.6 \text{ m} \times 11.9 \text{ m} = 54.3 \text{ m}^2)$
$C = 20 \text{ ft} \times 37 \text{ ft} = 740 \text{ ft}^2$	$(6.1 \text{ m} \times 11.3 \text{ m} = 68.8 \text{ m}^2)$
$D = 25 \text{ ft} \times 34 \text{ ft} = 850 \text{ ft}^2$	$(7.6 \text{ m} \times 10.4 \text{ m} = 78.9 \text{ m}^2)$
Listed spacing = $30 \text{ ft} \times 30 \text{ ft} = 900 \text{ ft}^2$	$(9.1 \text{ m} \times 9.1 \text{ m} = 83.6 \text{ m}^2)$

A-2-2.4.1.2 Figure A-2-2.4.1.2 illustrates smoke or heat detector spacing layouts in irregular areas.

Figure A-2-2.4.1.2 Smoke or heat detector spacing layout in irregular areas.



A-2-2.4.3 The location and spacing of heat detectors should consider beam depth, ceiling height, beam spacing, and fire size.

If the ratio of beam depth (D) to ceiling height (H), (D/H), is greater than 0.10 and the ratio of beam spacing (W) to ceiling height (H), (W/H), is greater than 0.40, heat detectors should be located in each beam pocket.

If either the ratio of beam depth to ceiling height (D/H) is less than 0.10 or the ratio of beam spacing to ceiling height (W/H) is less than 0.40, heat detectors should be installed on the bottom of the beams.

A-2-2.4.4.1 Figure A-2-2.4.4.1 illustrates smoke or heat detector spacing for peaked-type sloped ceilings.

A-2-2.4.4.2 Figure A-2-2.4.4.2 illustrates smoke or heat detector spacing for shed-type sloped ceilings.

A-2-2.4.5.1 Both 2-2.4.5.1 and Table 2-2.4.5.1 are constructed to provide detector performance on higher ceilings [to 30 ft (9.1 m) high] that is essentially equivalent to that which would exist with detectors on a 10-ft (3-m) ceiling.

The Fire Detection Institute Fire Test Report (*refer to Appendix C*) is used as a basis for Table 2-2.4.5.1. The report does not include data on integration-type detectors. Pending development of such data, the manufacturer's recommendations will provide guidance. (*Refer to Figure A-2-2.4.5.1.*)

Table 2-2.4.5.1 provides for spacing modification to take into account different ceiling heights for generalized fire conditions. Information regarding a design method that allows the designer to take into account ceiling height, fire size, and ambient temperatures is provided in Appendix B.

Figure A-2-2.4.4.1 Smoke or heat detector spacing layout, sloped ceilings (peaked type).

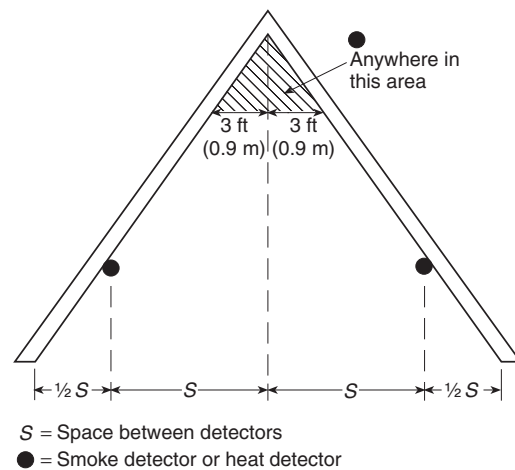


Figure A-2-2.4.4.2 Smoke or heat detector spacing layout, sloped ceilings (shed type).

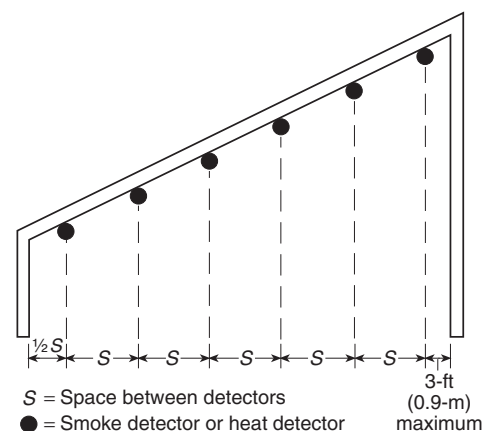
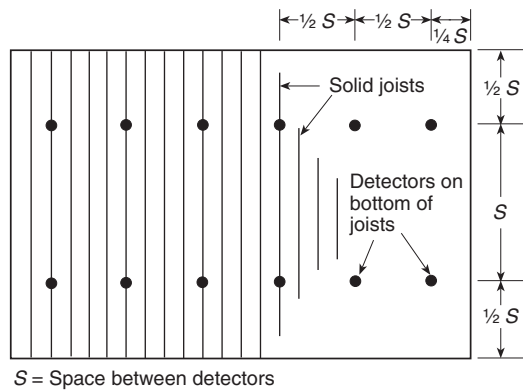


Figure A-2.2.4.5.1 Detector spacing layout, solid joist construction.

A-2-2.4.5.2 The width of uniform temperature of the plume when it impinges on the ceiling is approximately 0.4 times the height above the fire, so reducing spacing below this level will not increase response time. For example, a detector with a listed spacing of 15 ft (4.6 m) or 225 ft² (21 m²) need not be spaced closer than 12 ft (3.7 m) on a 30-ft (9.1-m) ceiling, even though Table 2-2.4.5.1 states that the spacing should be 0.34×15 , which equals 5.1 ft (1.6 m).

A-2-3.1.1 The addition of a heat detector to a smoke detector does not enhance its performance as an early warning device.

A-2-3.2 The person designing an installation should keep in mind that in order for a smoke detector to respond the smoke has to travel from the point of origin to the detector. In evaluating any particular building or location, likely fire locations should be determined first. From each of these points of origin, paths of smoke travel should be determined. Wherever

practicable, actual field tests should be conducted. The most desired locations for smoke detectors are the common points of intersection of smoke travel from fire locations throughout the building.

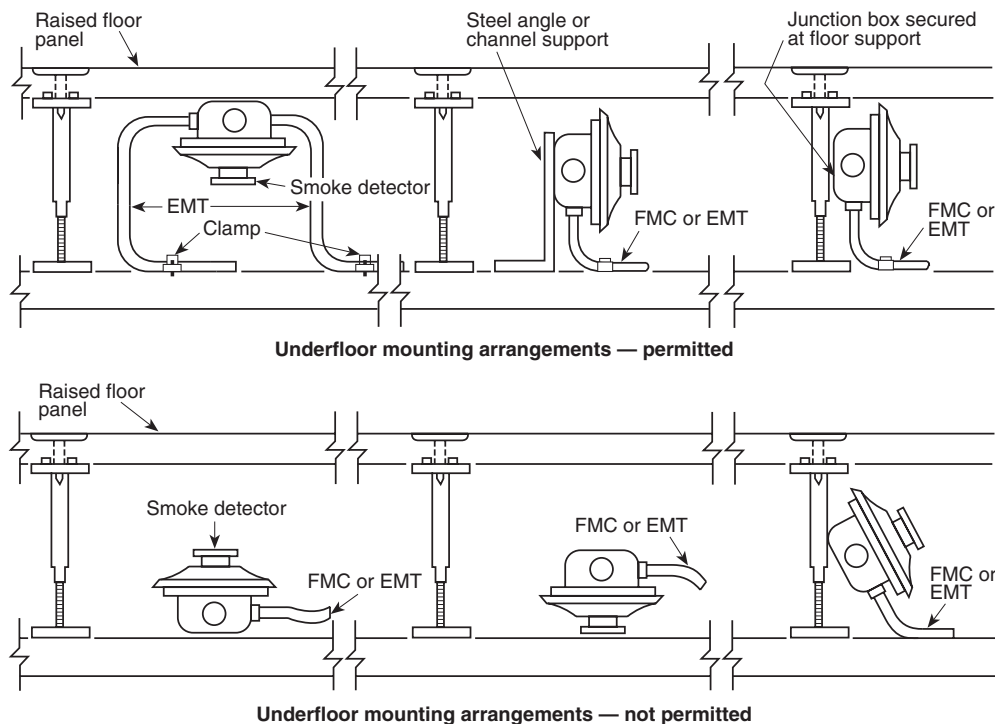
NOTE: This is one of the reasons that specific spacing is not assigned to smoke detectors by the testing laboratories.

A-2-3.3 Throughout this code, smoke detector sensitivity is referred to in terms of the percent obscuration required to alarm or produce a signal. Smoke detectors are tested using various smoke sources that have different characteristics (for example, color, particle size, number of particles, particle shape). Unless otherwise specified, this code, the manufacturers, and the listing agencies report and use the percent obscuration produced using a specific type of gray smoke. Actual detector response will vary when the characteristics of the smoke reaching the detector is different from the smoke used in testing and reporting detector sensitivity.

A-2-3.4.1 For operation, all types of smoke detectors depend on smoke entering the sensing chamber or light beam. If sufficient concentration is present, operation is obtained. Since the detectors are usually mounted on the ceiling, response time depends on the nature of the fire. A hot fire rapidly drives the smoke up to the ceiling. A smoldering fire, such as in a sofa, produces little heat; therefore, the time for smoke to reach the detector is increased.

A-2-3.4.3 In high-ceiling areas, such as atriums, where spot-type smoke detectors are not accessible for periodic maintenance and testing, projected beam-type or air sampling-type detectors should be considered where access can be provided.

A-2-3.4.3.2 Figure A-2-3.4.3.2 illustrates under-floor mounting installations.

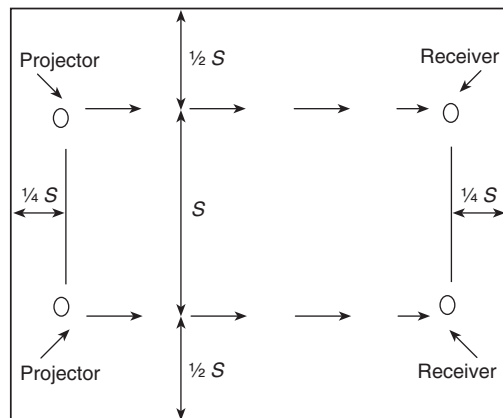
Figure A-2-3.4.3.2 Mounting installations permitted (top) and not permitted (bottom).

A-2-3.4.5.1.2 This is useful in calculating locations in corridors or irregular areas (*refer to A-2-2.4.1 and Figure A-2-2.4.1.2*). For irregularly shaped areas, the spacing between detectors can be greater than the selected spacing, provided the maximum spacing from a detector to the farthest point of a sidewall or corner within its zone of protection is not greater than 0.7 times the selected spacing (0.7S).

A-2-3.4.5.2 On smooth ceilings, a spacing of not more than 60 ft (18.3 m) between projected beams and not more than one-half that spacing between a projected beam and a side-wall (wall parallel to the beam travel) should be used as a guide. Other spacing should be determined based on ceiling height, airflow characteristics, and response requirements.

In some cases, the light beam projector is mounted on one end wall, with the light beam receiver mounted on the opposite wall. However, it is also permitted to suspend the projector and receiver from the ceiling at a distance from the end walls not exceeding one-quarter the selected spacing (S). (*Refer to Figure A-2-3.4.5.2.*)

Figure A-2-3.4.5.2 Maximum distance at which ceiling-suspended light beam projector and receiver can be positioned from end wall is one-quarter selected spacing (S).



S = Selected detector spacing

A-2-3.4.6 Detectors are placed at reduced spacings at right angles to joists or beams in an attempt to ensure that detection time is equivalent to that which would be experienced on a flat ceiling. It takes longer for the combustion products (smoke or heat) to travel at right angles to beams or joists because of the phenomenon wherein a plume from a relatively hot fire with significant thermal lift tends to fill the pocket between each beam or joist before moving to the next beam or joist.

Though it is true that this phenomenon might not be significant in a small smoldering fire where there is only enough thermal lift to cause stratification at the bottom of the joists, reduced spacing is still recommended to ensure that detection time is equivalent to that which would exist on a flat ceiling, even in the case of a hotter type of fire.

A-2-3.4.6.1 The spacing guidelines in 2-3.4.6.1 are based on a detection design fire of 100 kW. For detection at a larger 1-MW fire and ceiling heights of 28 ft (8.53 m) or less,

smooth ceiling spacings should be used and the detectors may be located on the ceiling or the bottom of the beams.

A-2-3.4.6.2 The spacing guidelines in 2-3.4.6.2 are based on a detection design fire of 100 kW. For detection at a larger 1-MW fire, the following spacings should be used.

(a) For beamed ceilings with beams running parallel to (up) the slope, with slopes 10 degrees or less, spacing for flat-beamed ceilings should be used. For ceilings with slopes greater than 10 degrees, twice the smooth ceiling spacing should be used in the direction parallel to (up) the slopes, and one-half the spacing should be used in the direction perpendicular to (across) the slope. For slopes greater than 10 degrees, the detectors located at a distance of one-half the spacing from the low end are not required. Spacing should be measured along the horizontal projection of the ceiling.

(b) For beamed ceilings with beams running perpendicular to (across) the slope, for any slope, smooth ceiling spacing should be used in the direction parallel to the beams (across the slope), and one-half the smooth ceiling spacing should be used in the direction perpendicular to the beams (up the slope).

A-2-3.4.7 Refer to Figure A-2-2.4.4.1.

A-2-3.4.8 Refer to Figure A-2-2.4.4.2.

A-2-3.5.1 Detectors should not be located in a direct airflow nor closer than 3 ft (1 m) from an air supply diffuser or return air opening. Supply or return sources larger than those commonly found in residential and small commercial establishments can require greater clearance to smoke detectors. Similarly, smoke detectors should be located farther away from high velocity air supplies.

A-2-3.5.2.2 Smoke might not be drawn into the duct or plenums when the ventilating system is shut down. Furthermore, when the ventilating system is operating, the detector(s) can be less responsive to a fire condition in the room of fire origin due to dilution by clean air.

A-2-3.6.1.1 Product-listing standards include tests for temporary excursions beyond normal limits. In addition to temperature, humidity, and velocity variations, smoke detectors should operate reliably under such common environmental conditions as mechanical vibration, electrical interference, and other environmental influences. Tests for these conditions are also conducted by the testing laboratories in their listing program. In those cases in which environmental conditions approach the limits shown in Table A-2-3.6.1.1, the detector manufacturer should be consulted for additional information and recommendations.

A-2-3.6.1.2 Smoke detectors can be affected by electrical and mechanical influences and by aerosols and particulate matter found in protected spaces. The location of detectors should be such that the influences of aerosols and particulate matter from sources such as those in Table A-2-3.6.1.2(a) are minimized. Similarly, the influences of electrical and mechanical factors shown in Table A-2-3.6.1.2(b) should be minimized. While it might not be possible to isolate environmental factors totally, an awareness of these factors during system layout and design favorably affects detector performance.

Table A-2-3.6.1.1 Environmental Conditions That Influence Smoke Detector Response

Detection Protection	Air Velocity >300 ft (>91.44 m)/min	Altitude >3000 ft (>914.4 m)	Humidity >93% RH	Temp. <32°F >100°F (<0°C >37.8°C)	Color of Smoke
Ion	X	X	X	X	O
Photo	O	O	X	X	X
Beam	O	O	X	X	O
Air Sampling	O	O	X	X	O

X = Can affect detector response.

O = Generally does not affect detector response.

Table A-2-3.6.1.2(a) Common Sources of Aerosols and Particulate Matter Moisture

Moisture
Humid outside air
Humidifiers
Live steam
Showers
Slop sink
Steam tables
Water spray
Combustion Products and Fumes
Chemical fumes
Cleaning fluids
Cooking equipment
Curing
Cutting, welding, and brazing
Dryers
Exhaust hoods
Fireplaces
Machining
Ovens
Paint spray
Atmospheric Contaminants
Corrosive atmospheres
Dust or lint
Excessive tobacco smoke
Heat treating
Linen and bedding handling

Table A-2-3.6.1.2(a) Common Sources of Aerosols and Particulate Matter Moisture (Continued)

Pneumatic transport
Sawing, drilling, and grinding
Textile and agricultural processing
Engine Exhaust
Diesel trucks and locomotives
Engines not vented to the outside
Gasoline forklift trucks
Heating Element with Abnormal Conditions
Dust accumulations
Improper exhaust
Incomplete combustion

Table A-2-3.6.1.2(b) Sources of Electrical and Mechanical Influences on Smoke Detectors

Electrical Noise and Transients	Airflow
Vibration or shock	Gusts
Radiation	Excessive velocity
Radio frequency	
Intense light	
Lightning	
Electrostatic discharge	
Power supply	

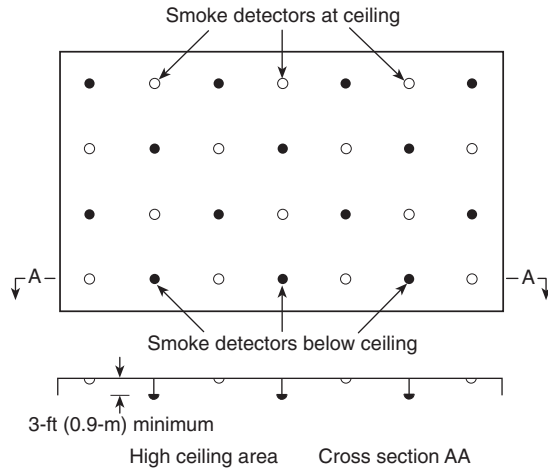
A-2-3.6.1.4 Stratification of air in a room can hinder air containing smoke particles or gaseous combustion products from reaching ceiling-mounted smoke detectors or fire-gas detectors.

Stratification occurs when air containing smoke particles or gaseous combustion products is heated by smoldering or burning material and, becoming less dense than the surrounding cooler air, rises until it reaches a level at which there is no longer a difference in temperature between it and the surrounding air.

Stratification also can occur when evaporative coolers are used, because moisture introduced by these devices can condense on smoke, causing it to fall toward the floor. Therefore, to ensure rapid response, it might be necessary to install smoke detectors on sidewalls or at locations below the ceiling.

In installations where detection of smoldering or small fires is desired and where the possibility of stratification exists, consideration should be given to mounting a portion of the detectors below the ceiling. In high-ceiling areas, projected beam-type or air sampling-type detectors at different levels also should be considered. (Refer to Figure A-2-3.6.1.4.)

Figure A-2-3.6.1.4 Smoke detector layout accounting for stratification.



A-2-3.6.2.2 Airflow through holes in the rear of a smoke detector can interfere with smoke entry to the sensing chamber. Similarly, air from the conduit system can flow around the outside edges of the detector and interfere with smoke reaching the sensing chamber. Additionally, holes in the rear of a detector provide a means for entry of dust, dirt, and insects, each of which can adversely affect the detector’s performance.

A-2-3.6.3.2 Where the light path of a projected beam-type detector is abruptly interrupted or obscured, the unit should not initiate an alarm. It should give a trouble signal after verification of blockage.

A-2-3.6.4.1 A single-pipe network has a shorter transport time than a multiple-pipe network of similar length pipe; however,

a multiple-pipe system provides a faster smoke transport time than a single-pipe system of the same total length. As the number of sampling holes in a pipe increases, the smoke transport time increases. Where practicable, pipe run lengths in a multiple-pipe system should be nearly equal, or the system should be otherwise pneumatically balanced.

A-2-3.6.4.2 The air sampling-type detector system should be able to withstand dusty environments by either air filtering or electronic discrimination of particle size. The detector should be capable of providing optimal time delays of alarm outputs to eliminate nuisance alarms due to transient smoke conditions. The detector should also provide facilities for the connection of monitoring equipment for the recording of background smoke level information necessary in setting alert and alarm levels and delays.

A-2-3.6.5 For the most effective detection of fire in high-rack storage areas, detectors should be located on the ceiling above each aisle and at intermediate levels in the racks. This is necessary to detect smoke that is trapped in the racks at an early stage of fire development when insufficient thermal energy is released to carry the smoke to the ceiling. Earliest detection of smoke is achieved by locating the intermediate level detectors adjacent to alternate pallet sections as shown in Figures A-2-3.6.5(a) and (b). The detector manufacturer’s recommendations and engineering judgment should be followed for specific installations.

A projected beam-type detector can be permitted to be used in lieu of a single row of individual spot-type smoke detectors.

Sampling ports of an air sampling-type detector can be permitted to be located above each aisle to provide coverage that is equivalent to the location of spot-type detectors. The manufacturer’s recommendations and engineering judgment should be followed for the specific installation.

A-2-3.6.6.3 Smoke detector spacing depends on the movement of air within the room.

A-2-4.1 For the purpose of this code, radiant energy includes the electromagnetic radiation emitted as a by-product of the combustion reaction, which obeys the laws of optics. This includes radiation in the ultraviolet, visible, and infrared portions of the spectrum emitted by flames or glowing embers. These portions of the spectrum are distinguished by wavelengths as shown in Table A-2-4.1.

Table A-2-4.1 Spectrum Wavelength Ranges

Radiant Energy	μm
Ultraviolet	0.1–0.35
Visible	0.36–0.75
Infrared	0.76–220

Conversion Factors: 1.0 μm = 1000 nM = 10,000 Å.

Figure A-2-3.6.5(a) Detector location for solid storage (closed rack) in which transverse and longitudinal flue spaces are irregular or non-existent, as for slatted or solid shelved storage.

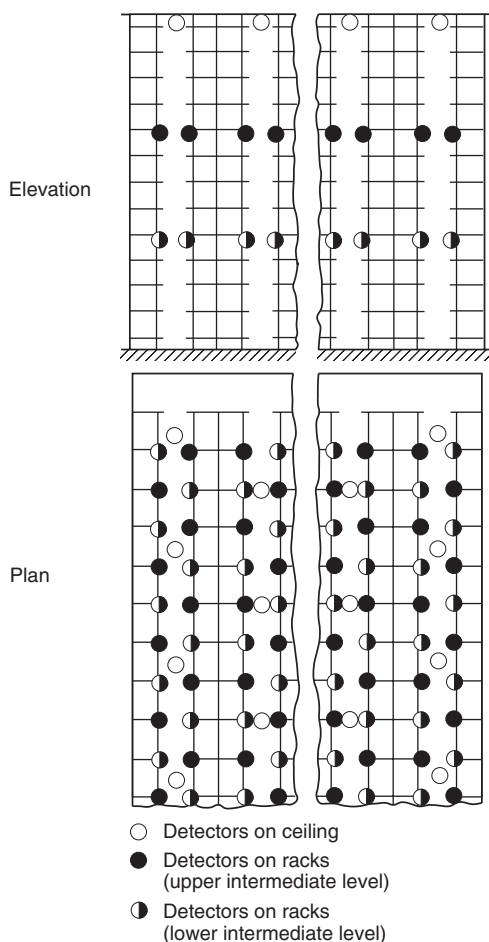
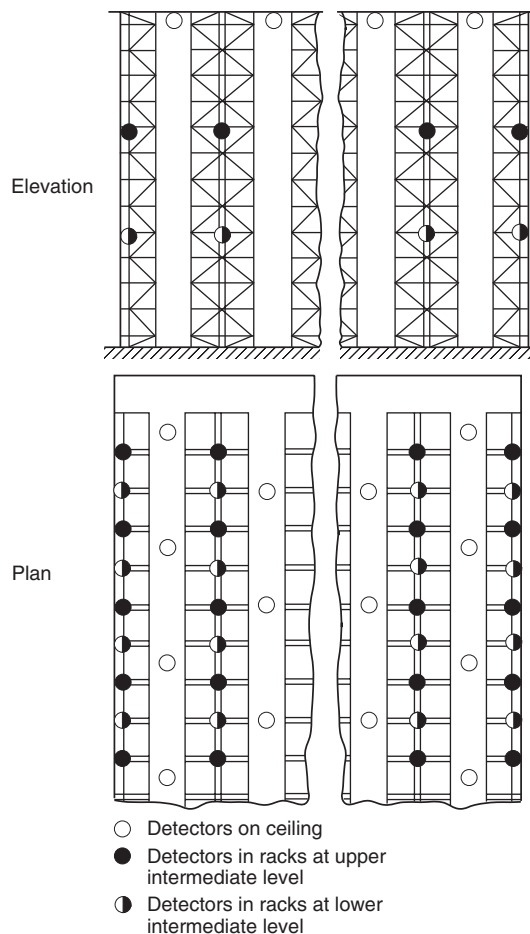


Figure A-2-3.6.5(b) Detector location for palletized storage (open rack) or no shelved storage in which regular transverse and longitudinal flue spaces are maintained.



A-2-4.2 Following are operating principles for two types of detectors.

(a) *Flame Detectors.* Ultraviolet flame detectors typically use a vacuum photodiode Geiger-Muller tube to detect the ultraviolet radiation that is produced by a flame. The photodiode allows a burst of current to flow for each ultraviolet photon that hits the active area of the tube. When the number of current bursts per unit time reaches a predetermined level, the detector initiates an alarm.

A single wavelength infrared flame detector uses one of several different photocell types to detect the infrared emissions in a single wavelength band that are produced by a flame. These detectors generally include provisions to minimize alarms from commonly occurring infrared sources such as incandescent lighting or sunlight.

An ultraviolet/infrared (UV/IR) flame detector senses ultraviolet radiation with a vacuum photodiode tube and a selected wavelength of infrared radiation with a photocell and uses the combined signal to indicate a fire. These detectors need exposure to both types of radiation before an alarm signal can be initiated.

A multiple wavelength infrared (IR/IR) flame detector senses radiation at two or more narrow bands of wavelengths in the infrared spectrum. These detectors electronically compare the emissions between the bands and initiate a signal where the relationship between the two bands indicates a fire.

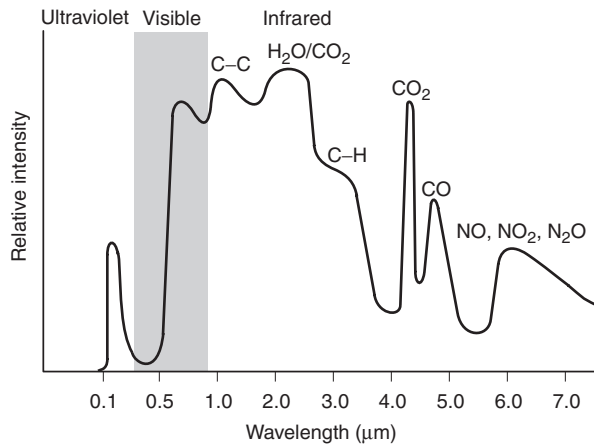
(b) *Spark/Ember Detectors.* A spark/ember-sensing detector usually uses a solid state photodiode or phototransistor to sense the radiant energy emitted by embers, typically between 0.5 microns and 2.0 microns in normally dark environments. These detectors can be made extremely sensitive (micro-watts), and their response times can be made very short (microseconds).

A-2-4.2.1 The radiant energy from a flame or spark/ember is comprised of emissions in various bands of the ultraviolet, visible, and infrared portions of the spectrum. The relative quantities of radiation emitted in each part of the spectrum are determined by the fuel chemistry, the temperature, and the rate of combustion. The detector should be matched to the characteristics of the fire.

Almost all materials that participate in flaming combustion emit ultraviolet radiation to some degree during flaming combustion, whereas only carbon-containing fuels emit significant

radiation at the 4.35-micron (carbon dioxide) band used by many detector types to detect a flame. (Refer to Figure A-2-4.2.1.)

Figure A-2-4.2.1 Spectrum of a typical flame (free-burning gasoline).



The radiant energy emitted from an ember is determined primarily by the fuel temperature (Planck's Law Emissions) and the emissivity of the fuel. Radiant energy from an ember is primarily infrared and, to a lesser degree, visible in wavelength. In general, embers do not emit ultraviolet energy in significant quantities (0.1 percent of total emissions) until the ember achieves temperatures of 2000 K (1727°C or 3240°F). In most cases, the emissions are included in the band of 0.8 microns to 2.0 microns, corresponding to temperatures of approximately 750°F to 1830°F (398°C to 1000°C).

Most radiant energy detectors have some form of qualification circuitry within them that uses time to help distinguish between spurious, transient signals and legitimate fire alarms. These circuits become very important where the anticipated fire scenario and the ability of the detector to respond to that anticipated fire are considered. For example, a detector that uses an integration circuit or a timing circuit to respond to the flickering light from a fire might not respond well to a deflagration resulting from the ignition of accumulated combustible vapors and gases, or where the fire is a spark that is traveling up to 328 ft/sec (100 m/sec) past the detector. Under these circumstances, a detector that has a high-speed response capability is most appropriate. On the other hand, in applications where the development of the fire is slower, a detector that uses time for the confirmation of repetitive signals is appropriate. Consequently, the fire growth rate should be considered in selecting the detector. The detector performance should be selected to respond to the anticipated fire.

The radiant emissions are not the only criteria to be considered. The medium between the anticipated fire and the detector is also very important. Different wavelengths of radiant energy are absorbed with varying degrees of efficiency by materials that are suspended in the air or that accumulate on the optical surfaces of the detector. Generally, aerosols and surface deposits reduce the sensitivity of the detector. The detection technology used should take into account those normally occurring aerosols and surface deposits to minimize the reduction of system response between maintenance intervals. It should be noted that the smoke evolved from the combustion of middle and heavy fraction petroleum distillates is highly absorptive in the ultraviolet end of the spectrum. If using this type of detection, the system should be designed to

minimize the effect of smoke interference on the response of the detection system.

The environment and ambient conditions anticipated in the area to be protected impact the choice of detector. All detectors have limitations on the range of ambient temperatures over which they will respond, consistent with their tested or approved sensitivities. The designer should make certain that the detector is compatible with the range of ambient temperatures anticipated in the area in which it is installed. In addition, rain, snow, and ice attenuate both ultraviolet and infrared radiation to varying degrees. Where anticipated, provisions should be made to protect the detector from accumulations of these materials on its optical surfaces.

A-2-4.2.2 Normal radiant emissions that are not from a fire can be present in the hazard area. When selecting a detector for an area other potential sources of radiant emissions should be evaluated. Refer to A-2-4.2.1 for additional information.

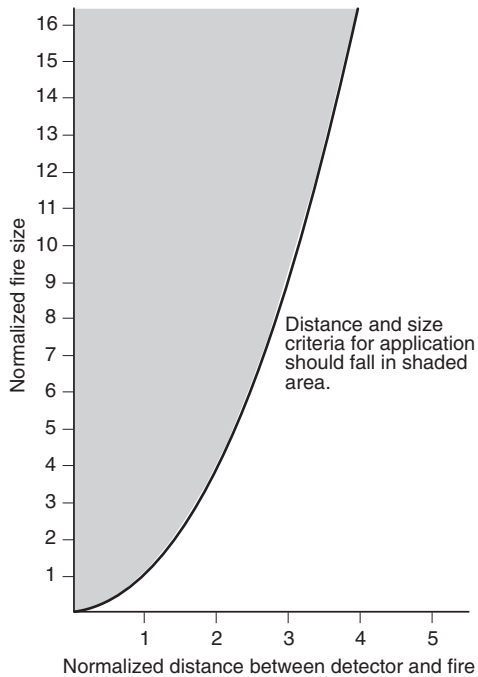
A-2-4.3.1.1 All optical detectors respond according to the following theoretical equation:

$$S = \frac{kpe^{\zeta}d}{d^2}$$

where:

- k = proportionality constant for the detector
- p = radiant power emitted by the fire
- e = Naperian logarithm base (2.7183)
- ζ = extinction coefficient of air
- d = distance between the fire and the detector
- S = radiant power reaching the detector

The sensitivity (S) typically is measured in nanowatts. This equation yields a family of curves similar to the one shown in Figure A-2-4.3.1.1.

Figure A-2-4.3.1.1 Normalized fire size vs. distance.

The curve defines the maximum distance at which the detector consistently detects a fire of defined size and fuel. Detectors should be employed only in the shaded area above the curve.

Under the best of conditions, with no atmospheric absorption, the radiant power reaching the detector is reduced by a factor of 4 if the distance between the detector and the fire is doubled. For the consumption of the atmospheric extinction, the exponential term *Zeta* (ζ) is added to the equation. *Zeta* is a measure of the clarity of the air at the wavelength under consideration. *Zeta* is affected by humidity, dust, and any other contaminants in the air that are absorbent at the wavelength in question. *Zeta* generally has values between -0.001 and -0.1 for normal ambient air.

A-2-4.3.2.1 The following are types of application for which flame detectors are suitable:

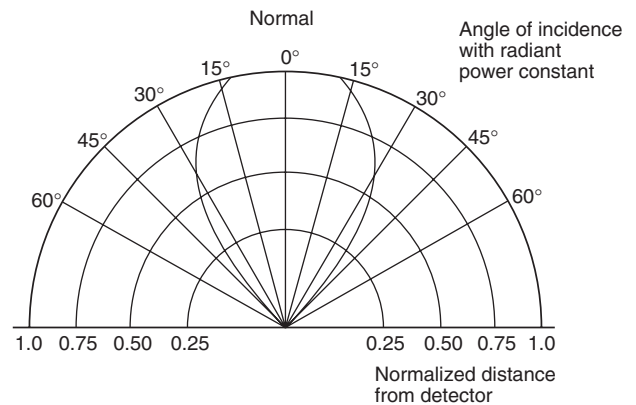
- (1) High-ceiling, open-spaced buildings such as warehouses and aircraft hangers
- (2) Outdoor or semioutdoor areas where winds or draughts can prevent smoke from reaching a heat or smoke detector
- (3) Areas where rapidly developing flaming fires can occur, such as aircraft hangars, petrochemical production areas, storage and transfer areas, natural gas installations, paint shops, or solvent areas
- (4) Areas needing high fire risk machinery or installations, often coupled with an automatic gas extinguishing system
- (5) Environments that are unsuitable for other types of detectors

Some extraneous sources of radiant emissions that have been identified as interfering with the stability of flame detectors include the following:

- (1) Sunlight
- (2) Lightning
- (3) X-rays
- (4) Gamma rays
- (5) Cosmic rays

- (6) Ultraviolet radiation from arc welding
- (7) Electromagnetic interference (EMI, RFI)
- (8) Hot objects
- (9) Artificial lighting

A-2-4.3.2.3 The greater the angular displacement of the fire from the optical axis of the detector, the larger the fire must become before it is detected. This phenomenon establishes the field of view of the detector. Figure A-2-4.3.2.3 shows an example of the effective sensitivity versus angular displacement of a flame detector.

Figure A-2-4.3.2.3 Normalized sensitivity vs. angular displacement.

A-2-4.3.2.4 Virtually all radiant energy-sensing detectors exhibit some kind of fuel specificity. If burned at uniform rates [J/sec (W)], different fuels emit different levels of radiant power in the ultraviolet, visible, and infrared portions of the spectrum. Under free-burn conditions, a fire of given surface area but of different fuels burns at different rates [J/sec (W)] and emits varying levels of radiation in each of the major portions of the spectrum. Most radiant energy detectors designed to detect flame are qualified based on a defined fire under specific conditions. If employing these detectors for fuels other than the defined fire, the designer should make certain that the appropriate adjustments to the maximum distance between the detector and the fire are made consistent with the fuel specificity of the detector.

A-2-4.3.2.6 This requirement has been satisfied by the following means:

- (1) Lens clarity monitoring and cleaning where a contaminated lens signal is rendered
- (2) Lens air purge

The need to clean detector windows can be reduced by the provision of air purge devices. These devices are not fool-proof, however, and are not a replacement for regular inspection and testing. Radiant energy-sensing detectors should not be placed in protective housings (for example, behind glass) to keep them clean, unless such housings are listed for the purpose. Some optical materials are absorptive at the wavelengths used by the detector.

A-2-4.3.3.1 Spark/ember detectors are installed primarily to detect sparks and embers that could, if allowed to continue to burn, precipitate a much larger fire or explosion. Spark/ember detectors are typically mounted on some form of duct or conveyor, monitoring the fuel as it passes by. Usually, it is necessary to enclose the portion of the conveyor where the detectors are located, as these devices generally require a dark

environment. Extraneous sources of radiant emissions that have been identified as interfering with the stability of spark/ember detectors include the following:

- (1) Ambient light
- (2) Electromagnetic interference (EMI, RFI)
- (3) Electrostatic discharge in the fuel stream

A-2-4.3.3.2 There is a minimum ignition power (watts) for all combustible dusts. If the spark or ember is incapable of delivering that quantity of power to the adjacent combustible material (dust), an expanding dust fire cannot occur. The minimum ignition power is determined by the fuel chemistry, fuel particle size, fuel concentration in air, and ambient conditions such as temperature and humidity.

A-2-4.3.3.4 As the distance between the fire and the detector increases, the radiant power reaching the detector decreases. Refer to A-2-4.3.1.1 for additional information.

A-2-4.3.3.5 The greater the angular displacement of the fire from the optical axis of the detector, the larger the fire must become before it is detected. This phenomenon establishes the field of view of the detector. Figure A-2-4.3.2.3 shows an example of the effective sensitivity versus angular displacement of a flame detector.

A-2-4.3.3.6 This requirement has been satisfied by the following means:

- (1) Lens clarity monitoring and cleaning where a contaminated lens signal is rendered
- (2) Lens air purge

A-2-5.3 The performance characteristics of the detector and the area into which it is to be installed should be evaluated to minimize nuisance alarms or conditions that would interfere with operation.

A-2-6.2 The waterflow device should be field adjusted so that an alarm is initiated no more than 90 seconds after a sustained flow of at least 10 gpm (40 L/min).

Features that should be investigated to minimize alarm response time include the following:

- (1) Elimination of trapped air in the sprinkler system piping
- (2) Use of an excess pressure pump,
- (3) Use of pressure drop alarm-initiating devices
- (4) A combination thereof

Care should be used when choosing waterflow alarm-initiating devices for hydraulically calculated looped systems and those systems using small orifice sprinklers. Such systems might incorporate a single point flow of significantly less than 10 gpm (40 L/min). In such cases, additional waterflow alarm-initiating devices or the use of pressure drop-type waterflow alarm-initiating devices might be necessary.

Care should be used when choosing waterflow alarm-initiating devices for sprinkler systems that use on-off sprinklers to ensure that an alarm is initiated in the event of a waterflow condition. On-off sprinklers open at a predetermined temperature and close when the temperature reaches a predetermined lower temperature. With certain types of fires, waterflow might occur in a series of short bursts of a duration of 10 seconds to 30 seconds each. An alarm-initiating device with retard might not detect waterflow under these conditions. An excess pressure system or a system that operates on pressure drop should be considered to facilitate waterflow detection on sprinkler systems that use on-off sprinklers.

Excess pressure systems can be used with or without alarm valves. The following is a description of one type of excess pressure system with an alarm valve.

An excess pressure system with an alarm valve consists of an excess pressure pump with pressure switches to control the operation of the pump. The inlet of the pump is connected to the supply side of the alarm valve, and the outlet is connected to the sprinkler system. The pump control pressure switch is of the differential type, maintaining the sprinkler system pressure above the main pressure by a constant amount. Another switch monitors low sprinkler system pressure to initiate a supervisory signal in the event of a failure of the pump or other malfunction. An additional pressure switch can be used to stop pump operation in the event of a deficiency in water supply. Another pressure switch is connected to the alarm outlet of the alarm valve to initiate a waterflow alarm signal when waterflow exists. This type of system also inherently prevents false alarms due to water surges. The sprinkler retard chamber should be eliminated to enhance the detection capability of the system for short duration flows.

A-2-7 Alarm initiation can be accomplished by devices that detect the following:

- (1) Flow of water in foam systems
- (2) Pump activation
- (3) Differential pressure
- (4) Pressure (for example, clean agent systems, carbon dioxide systems, and wet/dry chemical systems)
- (5) Mechanical operation of a release mechanism

A-2-8.2.4 It is not the intent of 2-8.2.4 to require manual fire alarm boxes to be attached to moveable partitions or to equipment, nor to require the installation of permanent structures for mounting purposes only.

A-2-8.3 Recommended coded signal designations for buildings that have four floors and multiple basements are provided in Table A-2-8.3.

Table A-2-8.3 Recommended Coded Signal Designations

Location	Coded Signal
Fourth floor	2-4
Third floor	2-3
Second floor	2-2
First floor	2-1
Basement	3-1
Sub-basement	3-2

A-2-10 Refer to NFPA 101®, *Life Safety Code*®, for the definition of *smoke compartment*; NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, for the definition of *duct systems*; and NFPA 92A, *Recommended Practice for Smoke-Control Systems*, for the definition of *smoke zone*.

A-2-10.1 Smoke detectors located in an open area(s) should be used rather than duct-type detectors because of the dilution effect in air ducts. Active smoke management systems installed in accordance with NFPA 92A, *Recommended Practice for Smoke-Control Systems*, or NFPA 92B, *Guide for Smoke Manage-*

ment Systems in Malls, Atria, and Large Areas, should be controlled by total coverage open area detection.

A-2-10.2 Dilution of smoke-laden air by clean air from other parts of the building or dilution by outside air intakes can allow high densities of smoke in a single room with no appreciable smoke in the air duct at the detector location. Smoke might not be drawn from open areas if air-conditioning systems or ventilating systems are shut down.

A-2-10.3 Smoke detectors can be applied in order to initiate control of smoke spread for the following purposes:

- (1) Prevention of the recirculation of dangerous quantities of smoke within a building
- (2) Selective operation of equipment to exhaust smoke from a building
- (3) Selective operation of equipment to pressurize smoke compartments
- (4) Operation of doors and dampers to close the openings in smoke compartments

A-2-10.4.2 Smoke detectors are designed to sense the presence of particles of combustion, but depending on the sensing technology and other design factors, different detectors respond to different types of particles. Detectors based on ionization detection technology are most responsive to smaller, invisible sub-micron sized particles. Detectors based on photoelectric technology, by contrast, are most responsive to larger visible particles.

It is generally accepted that particle size distribution varies from sub-micron diameter particles predominant in the proximity of the flame of a flaming fire to particles one or more orders of magnitude larger, which are characteristic of smoke from a smoldering fire. The actual particle size distribution depends on a host of other variables including the fuel and its physical make-up, the availability of oxygen including air supply and fire gas discharge, and other ambient conditions, especially humidity. Moreover, the particle size distribution is not constant, but as the fire gases cool, the sub-micron particles agglomerate and the very large ones precipitate. In other words, as smoke travels away from the fire source, the particle size distribution shows a relative decrease in smaller particles. Water vapor, which is abundantly present in most fires, when cooled sufficiently will condense to form fog particles — an effect frequently seen above tall chimneys. Because water condensation is basically clear in color, when it is mixed with other smoke particles, it can be expected to lighten the color of the mixture.

In almost every fire scenario in an air-handling system, the point of detection will be some distance from the fire source, therefore, the smoke will be cooler and more visible because of the growth of sub-micron particles into larger particles due to agglomeration and recombination. For these reasons, photoelectric detection technology has advantages over ionization detection technology in air duct system applications.

A-2-10.4.2.2 Detectors listed for the air velocity present can be permitted to be installed at the opening where the return air enters the common return air system. The detectors should be installed up to 12 in. (0.3 m) in front of or behind the opening and spaced according to the following opening dimensions [refer to Figures A-2-10.4.2.2(a), (b), and (c)]:

(a) *Width.*

- (1) Up to 36 in. (914 mm) — One detector centered in opening

- (2) Up to 72 in. (1829 mm) — Two detectors located at the one-quarter points of the opening
- (3) Over 72 in. (1829 mm) — One additional detector for each full 24 in. (610 mm) of opening

(b) *Depth.* The number and spacing of the detector(s) in the depth (vertical) of the opening should be the same as those given for the width (horizontal) above.

(c) *Orientation.* Detectors should be oriented in the most favorable position for smoke entry with respect to the direction of airflow. The path of a projected beam-type detector across the return air openings should be considered equivalent in coverage to a row of individual detectors.

Figure A-2-10.4.2.2(a) Location of a smoke detector(s) in return air system openings for selective operation of equipment.

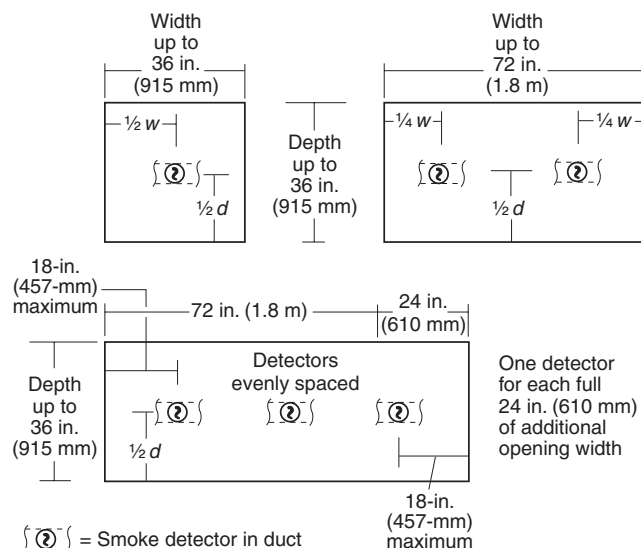


Figure A-2-10.4.2.2(b) Location of a smoke detector(s) in return air systems for selective operation of equipment.

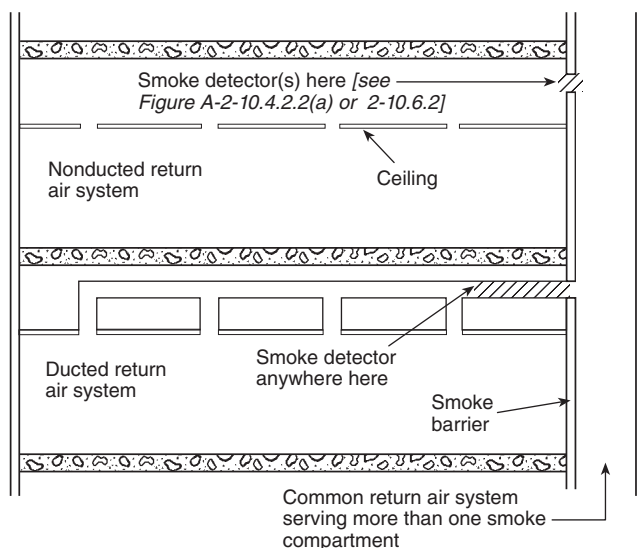
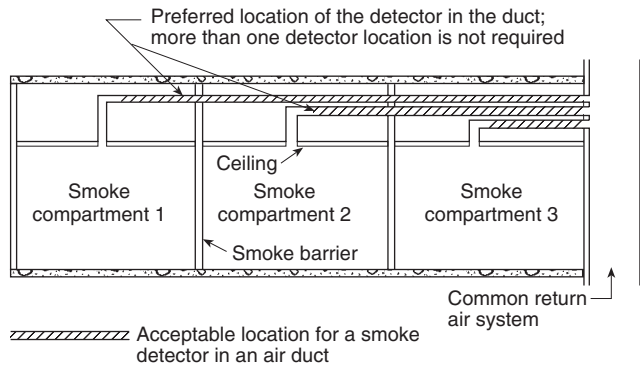


Figure A-2-10.4.2.2(c) Detector location in a duct that passes through smoke compartments not served by the duct.



A-2-10.5.2 If duct detectors are used to initiate the operation of smoke dampers, they should be located so that the detector is between the last inlet or outlet upstream of the damper and the first inlet or outlet downstream of the damper.

In order to obtain a representative sample, stratification and dead air space should be avoided. Such conditions could be caused by return duct openings, sharp turns, or connections, as well as by long, uninterrupted straight runs. For this reason, duct smoke detectors should be located in the zone between 6 and 10 duct-equivalent diameters of straight, uninterrupted run. In return air systems, the requirements of 2-10.4.2.2 take precedence over these considerations. [Refer to Figures A-2-10.5.2(a), (b), and (c).]

A-2-10.6.5.1.2 If the depth of wall section above the door is 60 in. (1520 mm) or greater, additional detectors might be required as indicated by an engineering evaluation.

A-3-2.3.3 A commonly used method of protecting against unauthorized changes can be described as follows (in ascending levels of access):

(a) *Access level 1:* Access by persons who have a general responsibility for safety supervision, who might be expected to investigate and initially respond to a fire alarm or trouble signal

(b) *Access level 2:* Access by persons who have a specific responsibility for safety, and who are trained to operate the control unit

(c) *Access level 3:* Access by persons who are trained and authorized to do the following:

- (1) Reconfigure the site specific data held within the control unit, or controlled by it
- (2) Maintain the control unit in accordance with the manufacturer's published instructions and data

(d) *Access level 4:* Access by persons who are trained and authorized either to repair the control unit or to alter its site specific data or operating system program, thereby changing its basic mode of operation

A-3-4.2 Class A circuits are considered to be more reliable than Class B circuits because they remain fully operational during the occurrence of a single open or a single ground fault, while Class B circuits remain operational only up to the location of an open fault. However, neither Class A nor Class B circuits remain operational during a wire-to-wire short.

Figure A-2-10.5.2(a) Pendant-mounted air duct installation.

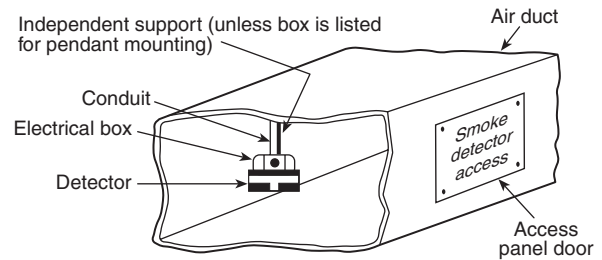


Figure A-2-10.5.2(b) Typical duct detector placement.

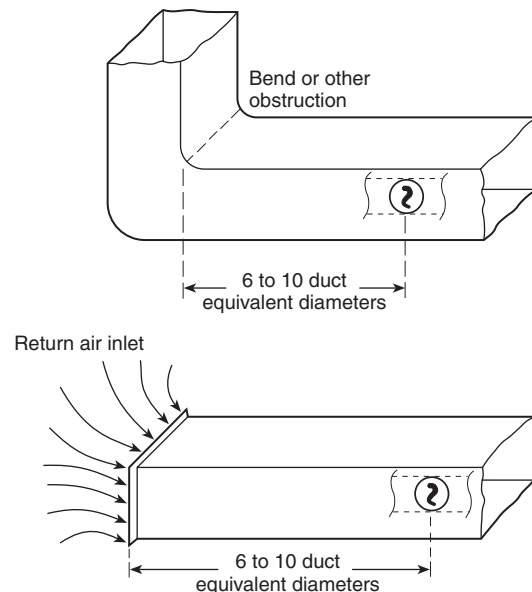
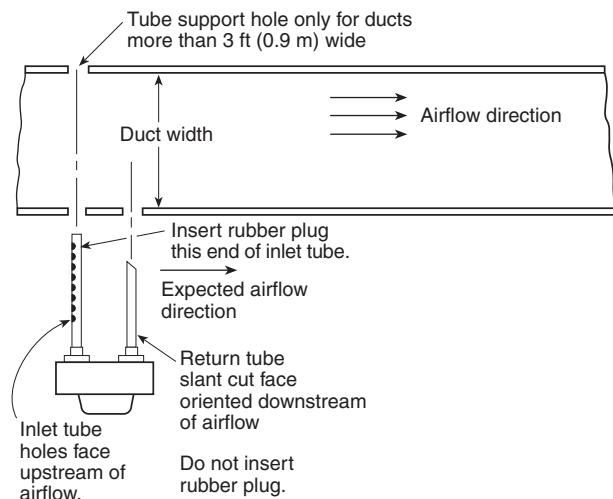


Figure A-2-10.5.2(c) Inlet tube orientation.



For both Class A and Class B initiating device circuits, a wire-to-wire short is permitted to cause an alarm on the system

based on the rationale that a wire-to-wire short is the result of a double fault (for example, both circuit conductors have become grounded), while the code only considers the consequences of single faults. For many applications, an alarm caused by a wire-to-wire short is not permitted, and limitation to a simple Class A designation is not adequate. Introducing the style designation has made it possible to specify the exact performance required during a variety of possible fault conditions.

Limitation to Class A and Class B circuits only poses a more serious problem for signaling line circuits. Though a Class A signaling line circuit remains fully operational during the occurrence of a single open or single ground fault, a wire-to-wire short disables the entire circuit. The risk of such a catastrophic failure is unacceptable to many system designers, users, and authorities having jurisdiction. Once again, using the style designation makes it possible to specify either full system operation during a wire-to-wire short (Style 7) or a level of performance in between that of a Style 7 and a minimum function Class A circuit (Style 2).

A specifier can specify a circuit as either Class A or Class B where system performance during wire-to-wire shorts is of no concern, or it can specify, by the appropriate style designation, where the system performance during a wire-to-wire short and other multiple fault conditions *is* of concern.

A-3-4.2.2.2 A goal of 3-4.2.2.2 is to provide adequate separation between the outgoing and return cables. This separation is required to help ensure protection of the cables from physical damage. The recommended minimum separation to prevent physical damage is 1 ft (0.305 m) where the cable is installed vertically and 4 ft (1.22 m) where the cable is installed horizontally.

A-3-5 Table 3-5 and Table 3-6 should be used as follows.

(a) It should be determined if the initiating devices are directly connected as follows:

- (1) To the initiating device circuit
- (2) To a signaling line circuit interface on a signaling line circuit
- (3) To an initiating device circuit, which in turn is connected to a signaling line circuit interface on a signaling line circuit

(b) Tables 3-5 and 3-6 of signaling performance required should be determined. The columns marked A through E α in Table 3-5, and 0.5 through 7 α in Table 3-6 are arranged in ascending order of performance.

(c) The prime purpose of the tables is to enable identification of minimum performance for styles of initiating device circuits and signaling line circuits. It is not the intention that the styles be construed as grades. That is, a Style 3 system is not superior to a Style 2 system, or vice versa. In fact, a particular style might better provide adequate and reliable signaling for an installation than a more complex style.

(d) Tables 3-5 and 3-6 allow users, designers, manufacturers, and the authority having jurisdiction to identify minimum performance of present and future systems by determining the trouble and alarm signals received at the control unit for the specified abnormal conditions.

(e) The number of automatic fire detectors connected to an initiating device circuit is limited by good engineering practice and the listing of the detectors. If a large number of detectors are connected to an initiating device circuit, locating the detector in alarm or locating a faulty detector becomes difficult and time consuming.

On certain types of detectors, a trouble signal results from faults in the detector. When this occurs where there are large

numbers of detectors on an initiating device circuit, locating the faulty detector also becomes difficult and time consuming.

A-3-6 Refer to A-3-5.

A-3-8.1 This code addresses field installations that interconnect two or more listed control units, possibly from different manufacturers, that together fulfill the requirements of this code.

Such an arrangement should preserve the reliability, adequacy, and integrity of all alarm, supervisory, and trouble signals and interconnecting circuits intended to be in accordance with the provisions of this code.

Where interconnected control units are in separate buildings, consideration should be given to protecting the interconnecting wiring from electrical and radio frequency interference.

A-3-8.2.1 The provisions of 3-8.2.1 apply to the types of equipment used in common for fire alarm systems, such as fire alarm, sprinkler supervisory, or guard's tour service, and for other systems, such as burglar alarm or coded paging systems, and to methods of circuit wiring common to both types of systems.

A-3-8.2.4 Exception No. 1 If the building paging system can be controlled by personnel at the fire command center, and if permitted by the authority having jurisdiction, the building paging system can be used as a supplementary notification system to provide selective and all-call fire alarm evacuation voice messages and messages for occupants to relocate to safe areas in a building.

A-3-8.2.4 Exception No. 2 An emergency voice/alarm communications system can be used for nonemergency purposes provided the performance and supervision requirements of an emergency voice/alarm communications system are still complied with. The building operator, system designer, and authority having jurisdiction should be aware that in some situations such a system could be subject to deliberate tampering. Tampering is usually attempted to reduce the output of a sound system that is in constant use as a music or paging system and is a source of annoyance to employees. The likelihood of tampering can be reduced through proper consideration of loudspeaker accessibility and system operation. Access can be reduced through the use of hidden or non-adjustable transformer taps (which can reduce playback levels), use of vandal resistant listed loudspeakers, and placement in areas that are difficult to access, such as high ceilings (any ceiling higher than could be reached by standing on a desk or chair). Nonemergency operation of the system should always consider that an audio system that annoys an employee potentially reduces employee productivity and can also annoy the public in a commercial environment. Most motivations for tampering can be eliminated through appropriate use of the system and employee discipline. Access to amplification equipment and controls should be limited to those in authority to make adjustments to such equipment. It is common practice to install such equipment in a manner that allows adjustment of nonemergency audio signal levels while defaulting to a fixed, preset level of playback when operating in emergency mode. Under extreme circumstances, certain zones of a protected area might require a dedicated emergency voice/alarm communications zone.

A-3-8.3.2.3.1 The alarm verification feature should not be used as a substitute for proper detector location/applications or regular system maintenance. Alarm verification features are intended to reduce the frequency of false alarms caused by

transient conditions. They are not intended to compensate for design errors or lack of maintenance.

A-3-8.3.3.1.2 Supervisory systems are not intended to provide indication of design, installation, or functional defects in the supervised systems or system components and are not a substitute for regular testing of those systems in accordance with the applicable standard.

Supervised conditions should include, but should not be limited to the following:

- (1) Size of control valves [$1\frac{1}{2}$ in. (38.1 mm) or larger]
- (2) Pressure, including dry-pipe system air, pressure tank air, pre-action system supervisory air, steam for flooding systems, and public water
- (3) Water tanks, including water level and temperature
- (4) Building temperature, including areas such as valve closet and fire pump house
- (5) Electric fire pumps, including running (alarm or supervisory), power failure, and phase reversal
- (6) Engine-driven fire pumps, including running (alarm or supervisory), failure to start, controller off "automatic," and trouble (for example, low oil, high temperature, overspeed)
- (7) Steam turbine fire pumps, including running (alarm or supervisory), steam pressure, and steam control valves
- (8) Fire suppression systems appropriate to the system employed

A-3-8.3.3.1.3 Cancellation of the off-normal signal can be permitted as a restoration signal, unless separate recording of all changes of state is a specific requirement. (*Refer to Chapter 5.*)

A-3-8.3.3.3.2 Sealing or locking such a valve in the open position, or removing the handle from the valve, does not meet the intent of the supervision requirement.

A-3-8.4.1.1.3 Paragraph 3-8.4.1.1.3 requires that the equipment used operate in a certain manner during fault conditions. For example, it is necessary that a fault such as a short circuit does not open a fuse or damage components common to other circuits.

A-3-8.4.1.1.4 Paragraph 3-8.4.1.1.4 requires the protection of circuits as they pass through fire areas other than the one served. This is to delay possible damage to the circuits from fires in areas other than those served by the circuits. This is done to increase the likelihood that circuits serving areas remote from the original fire will have the opportunity to be activated and serve their purpose. Note that the protection requirement would also apply to a signaling line circuit that extends from a master fire alarm control unit to another remote fire alarm control unit where notification appliance circuits might originate.

A-3-8.4.1.2 Paragraph 1-5.4.7 requires that fire alarm signals be distinctive in sound from other signals and that this sound not be used for any other purpose. The use of the distinctive three-pulse temporal pattern fire alarm evacuation signal required by 3-8.4.1.2.2 became effective July 1, 1996, for new systems installed after that date. It had been previously recommended for this purpose by this code since 1979. It has since been adopted as both an American National Standard (ANSI S3.41, *Audible Emergency Evacuation Signal*) and an International Standard (ISO 8201, *Audible Emergency Evacuation Signal*).

Copies of both of these standards are available from the Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, NY 10017-3483.

The standard fire alarm evacuation signal is a three-pulse temporal pattern using any appropriate sound. The pattern consists of the following in this order:

- (a) An on phase lasting 0.5 seconds \pm 10 percent
- (b) An off phase lasting 0.5 seconds \pm 10 percent, for three successive on periods
- (c) An off phase lasting 1.5 seconds \pm 10 percent [*refer to Figures A-3-8.4.1.2(a) and A-3-8.4.1.2(b)*]. The signal should be repeated for a period that is appropriate for the purposes of evacuation of the building, but for not less than 180 seconds. A single-stroke bell or chime sounded at "on" intervals lasting 1 second \pm 10 percent, with a 2-second \pm 10 percent "off" interval after each third "on" stroke, is permitted [*refer to Figure A-3-8.4.1.2(c)*].

The minimum repetition time is permitted to be manually interrupted.

Figure A-3-8.4.1.2(a) Temporal pattern parameters.

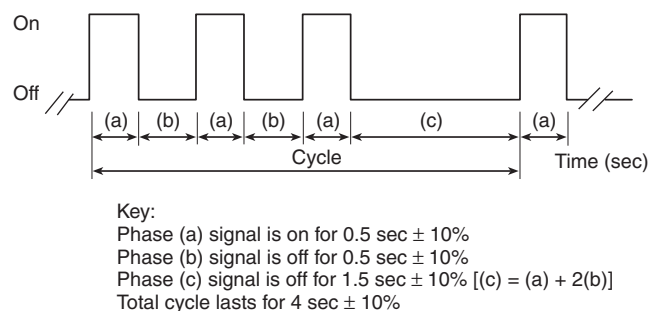


Figure A-3-8.4.1.2(b) Temporal pattern imposed on audible notification appliances that otherwise emit a continuous signal while energized.

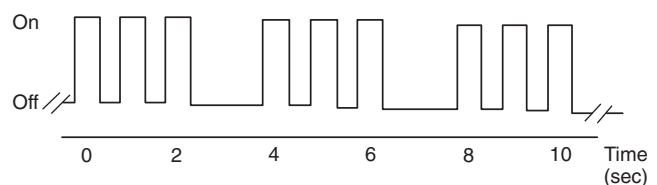


Figure A-3-8.4.1.2(c) Temporal pattern imposed on a single-stroke bell or chime.



A-3-8.4.1.2.3 Coordination or synchronization of the audible signal within a notification zone is needed to preserve the temporal pattern. It is unlikely that the audible signal in one evacuation/notification zone will be heard in another at a level that will destroy the temporal pattern. Thus, it would not normally be necessary to provide coordination/synchronization for an entire system. Caution should be used in spaces such as atriums where the sounds produced in one notification zone can be sufficient to cause confusion regarding the temporal pattern.

A-3-8.4.1.3.5.1 It is not the intention that emergency voice/alarm communications service be limited to English-speaking populations. Emergency messages should be provided in the language of the predominant building population. If there is a possibility of isolated groups that do not speak the predominant language, multilingual messages should be provided. It is expected that small groups of transients unfamiliar with the predominant language will be picked up in the traffic flow in the event of an emergency and are not likely to be in an isolated situation.

A-3-8.4.1.3.5.5.1 The choice of the location(s) for the fire command center should also take into consideration the ability of the fire alarm system to operate and function during any probable single event.

A-3-8.4.1.3.5.5.3 The operation of a fire command center in systems with multiple fire command centers should also consider visible indications at all locations to assist operators in understanding that manual system operation has been established by the fire command center in use.

A-3-8.4.1.3.5.6.2 The design and layout of the loudspeaker audible notification appliances should be arranged such that they do not interfere with the operations of the emergency response personnel. Speakers located in the vicinity of the fire command center should be arranged so they do not cause audio feedback when the system microphone is used. Speakers installed in the area of two-way telephone stations should be arranged so that the sound pressure level emitted does not preclude the effective use of the two-way telephone system. Circuits for paging zones and telephone zones should be separated, shielded, or otherwise arranged to prevent audio cross-talk between circuits.

A-3-8.4.1.3.6.1 Paragraph 3-8.4.1.3.6.1 does not prohibit the provision of multiple notification appliance circuits within an evacuation zone.

A-3-8.4.1.3.7.3 Consideration should be given to the type of telephone handset that fire fighters use in areas where high ambient noise levels exist or areas where high noise levels could exist during a fire condition. Push-to-talk handsets, handsets that contain directional microphones, or handsets that contain other suitable noise-canceling features can be used.

A-3-8.4.2 Embossed plastic tape, pencil, ink, or crayon should not be considered to be a permanently attached placard.

A-3-8.4.3.6 Automatic fire suppression systems referred to in 3-8.4.3.6 include, but are not limited to, preaction and deluge sprinkler systems, carbon dioxide systems, halon systems, and dry chemical systems.

A-3-9.3.1 In facilities without a building alarm system, dedicated fire alarm system control units are required by 3-9.3.1 for elevator recall in order that the elevator recall systems be monitored for integrity and have primary and secondary power meeting the requirements of this code.

The control unit used for this purpose should be located in an area that is normally occupied and should have audible and visible indicators to annunciate supervisory (elevator recall) and trouble conditions; however, no form of general occupant notification or evacuation signal is required or intended by 3-9.3.1.

A-3-9.3.7 It is recommended that the installation be in accordance with Figures A-3-9.3.7(a) and (b). Figure A-3-9.3.7(a) should be used where the elevator is installed at the same time as the building fire alarm system. Figure A-3-9.3.7(b) should

be used where the elevator is installed after the building fire alarm system.

Figure A-3-9.3.7(a) Elevator zone — elevator and fire alarm system installed at same time.

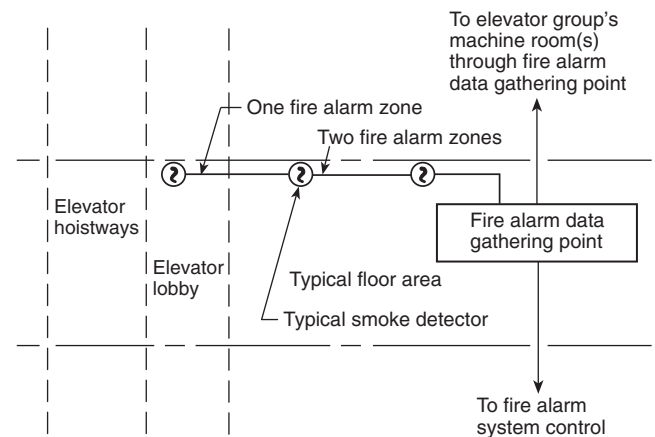
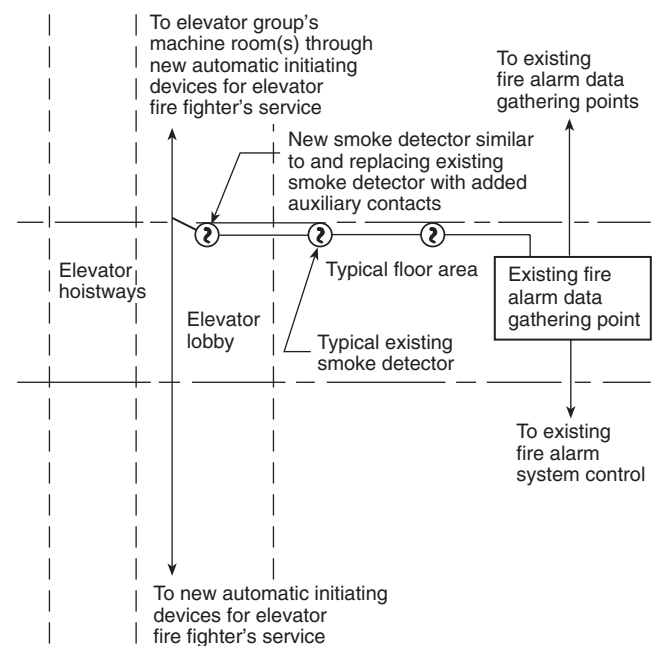


Figure A-3-9.3.7(b) Elevator zone — elevator installed after fire alarm system.



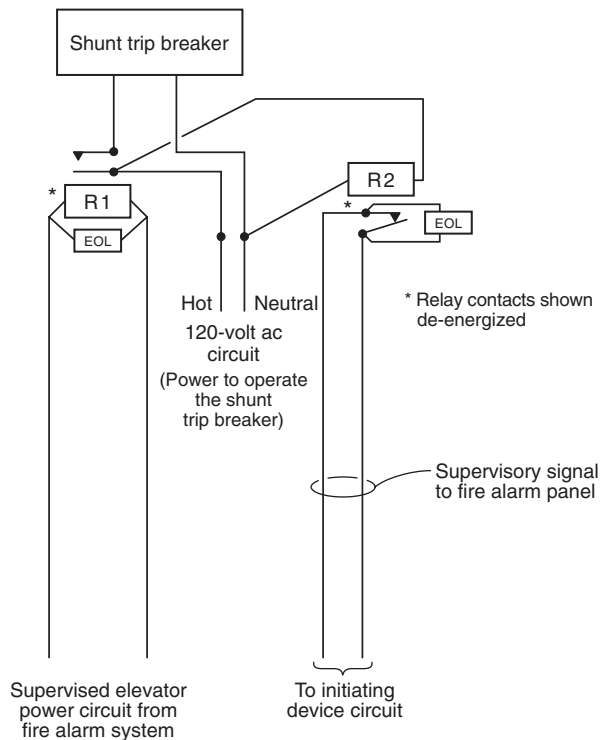
A-3-9.4.1 A lower response time index is intended to provide detector response prior to the sprinkler response, because a lower temperature rating alone might not provide earlier response. The listed spacing rating of the heat detector should be 25 ft (7.6 m) or greater.

A-3-9.4.3 Care should be taken to ensure that elevator power cannot be interrupted due to water pressure surges in the sprinkler system. The intent of the code is to ensure that the switch and the system as a whole do not have the capability of introducing a time delay into the sequence. The use of a switch with a time delay mechanism set to zero does not meet the intent of the code, because it is possible to introduce a time delay after the system has been accepted. This might

occur in response to unwanted alarms caused by surges or water movement, rather than addressing the underlying cause of the surges or water movement (often due to air in the piping). Permanently disabling the delay in accordance with the manufacturer's printed instructions should be considered acceptable. Systems that have software that can introduce a delay in the sequence should be programmed to require a security password to make such a change.

A-3-9.4.4 Figure A-3-9.4.4 illustrates one method of monitoring elevator shunt trip control power for integrity.

Figure A-3-9.4.4 Typical method of providing elevator power shunt trip supervisory signal.



A-3-9.7.3 A problem could exist when batteries are used as a secondary power source if a control unit having 24 hours of standby operating power were to lose primary power and be operated for more than 24 hours from the secondary power source (batteries). It is possible that sufficient voltage would be available to keep the doors locked but not enough voltage available to operate the fire alarm system to release the locks. For systems requiring primary power that meets the requirements of 1-5.2.3, such as a hospital system, door locking would not be an issue even with batteries provided in the fire alarm control unit, because the primary power (emergency generator) would operate the fire alarm control unit and secondary power would not be required.

A-3-10 The term *wireless* has been replaced with the term *low-power radio* to eliminate potential confusion with other transmission media such as optical fiber cables.

Low-power radio devices are required to comply with the applicable low-power requirements of Title 47, *Code of Federal Regulations*, Part 15.

A-3-10.1 Equipment listed solely for dwelling unit use would not comply with this requirement.

A-3-10.3.1 This requirement is not intended to preclude verification and local test intervals prior to alarm transmission.

A-4-1 Notification appliances should be sufficient in quantity, audibility, intelligibility, and visibility so as to reliably convey the intended information to the intended building occupants in a fire emergency.

Notification appliances in conventional commercial and industrial applications should be installed in accordance with the specific requirements of Sections 4-3 and 4-4.

The code recognizes that it is not possible to identify specific criteria sufficient to ensure effective occupant notification in every conceivable application. If the specific criteria of Sections 4-3 and 4-4 are determined to be inadequate or inappropriate to provide the performance recommended above, approved alternative approaches or methods or are permitted to be used.

A-4-2.3 Situations exist where supplemental enclosures are necessary to protect the physical integrity of a notification appliance. Protective enclosures should not interfere with the performance characteristics of the appliance. If the enclosure degrades the performance, methods should be detailed in the installation instructions of the enclosure that clearly identify the degradation. For example, where the appliance signal is attenuated, it might be necessary to adjust the appliance spacings or appliance output.

A-4-2.5 For hardwired appliances, terminals or leads, as described in 4-2.5, are necessary to ensure that the wire run is broken and that the individual connections are made to the leads or other terminals for signaling and power.

A common terminal can be used for connection of incoming and outgoing wires. However, the design and construction of the terminal should not permit an uninsulated section of a single conductor to be looped around the terminal and to serve as two separate connections. For example, a notched clamping plate under a single securing screw is acceptable only if separate conductors of a notification circuit are intended to be inserted in each notch.

A-4.3.1.1 The code does not require that all audible notification appliances within a building be of the same type. However, a mixture of different types of audible notification appliances within a space is not the desired method. Audible notification appliances that convey a similar audible signal are preferred. For example, a space that uses mechanical horns and bells might not be desirable. A space that is provided with mechanical horns and electronic horns with similar audible signal output is preferred.

However, the cost of replacing all existing appliances to match new appliances can impose substantial economic impact where other methods can be used to avoid occupant confusion of signals and signal content. Examples of other methods used to avoid confusion include, but are not limited to, training of occupants, signage, consistent use of temporal code signal pattern, and fire drills.

A-4.3.1.4 In determining maximum ambient sound levels, it is not necessary to include temporary or abnormal sources. For example, in a typical office environment, sound sources that should be considered include air-handling equipment, office cleaning equipment (vacuum cleaners), and background music. Examples of temporary or abnormal sound sources that can be excluded would be sound from internal or external construction activities, that is, office rearrangements and construction equipment.

A4-3.1.5 Voice intelligibility should be measured in accordance with the guidelines in Annex A of IEC 60849, Second Edition: 1998, *Sound Systems for Emergency Purposes*. When tested in accordance with Annex B, Clause B1, of IEC 60849, the system should exceed the equivalent of a common intelligibility scale (CIS) score of 0.70. Intelligibility is achieved when the quantity I_{av-s} , as specified in B3 of IEC 60849, exceeds this value. I_s is the arithmetical average of the measured intelligibility values on the CIS and σ (sigma) is the standard deviation of the results.

Objective means of determining intelligibility are found in IEC 60268, Part 16, Second Edition: 1998, *The Objective Rating of Speech Intelligibility by Speech Transmission Index*. Subject-based techniques for measuring intelligibility are defined by ANSI S3.2-1989, *Method for Measuring the Intelligibility of Speech Over Communications Systems*. ANSI S3.2-1989 should be considered an acceptable alternative to ISO TR 4870, where referenced in IEC 60268, Part 16, Second Edition: 1998, *The Objective Rating of Speech Intelligibility by Speech Transmission Index*.

A4-3.2 The typical average ambient sound level for the occupancies specified in Table A-4-3.2 are intended only for design guidance purposes.

The typical average ambient sound levels specified should not be used in lieu of actual sound level measurements.

Table A-4-3.2 Average Ambient Sound Level According to Location

Location	Average Ambient Sound Level (dBA)
Business occupancies	55
Educational occupancies	45
Industrial occupancies	80
Institutional occupancies	50
Mercantile occupancies	
Piers and water-surrounded structures	40
Places of assembly	55
Residential occupancies	35
Storage occupancies	30
Thoroughfares, high density urban	70
Thoroughfares, medium density urban	55
Thoroughfares, rural and suburban	40
Tower occupancies	35
Underground structures and windowless buildings	40
Vehicles and vessels	50

A4-3.2.2 In areas where the background noise is generated by machinery and is fairly constant, a frequency analysis can be warranted. It might be found that the high sound levels are predominately in one or two frequency bandwidths — often lower frequencies. Fire alarm notification appliances producing sound in one or two other frequency bandwidths can adequately penetrate the background noise and provide notification. The system would still be designed to produce or have a sound level at the particular frequency or frequency bandwidth of at least 15 dB above the average ambient sound level or 5 dB above the maximum sound level having a duration of at least 60 seconds, whichever is greater.

In very high noise areas, such as theaters, dance halls, nightclubs, and machine shops, sound levels during occupied times can be 100 dBA and higher. Peak sounds might be 110 dBA or greater. At other occupied times, the sound level might be below 50 dBA. A system designed to have a sound level of at least 15 dBA above the average ambient sound level or 5 dBA above the maximum sound level having a duration of at least 60 seconds might result in a required fire alarm level in excess of the maximum of 115 dBA. A viable option is to reduce or eliminate the background noise. Professional theaters or other entertainment venues can have road show connection panels (refer to NFPA 70, *National Electrical Code, Section 520-50*) for troupes to connect their light and sound systems to. These power sources can be controlled by the fire alarm system. In less formal applications, such as many nightclubs, designated power circuits could be controlled. Diligence needs to be exercised to ensure that the controlled circuits are used.

Also, in occupancies such as machine shops or other production facilities, care must be exercised in the design to ensure that the removal of power to the noise source does not create some other hazard. As with other fire safety functions, control circuits and relays would be monitored for integrity in accordance with Chapters 1 and 3.

Appropriate audible signaling in high ambient noise areas is often difficult. Areas such as automotive assembly areas, machining areas, paint spray areas, and so on, where the ambient noise is caused by the manufacturing process itself require special consideration. Adding additional audible notification appliances that merely contribute to the already noisy environment might not be appropriate. Other alerting techniques such as visible notification appliances, for example, could be more effectively used.

A4-4 The mounting height of the appliances affects the distribution pattern and level of illumination produced by an appliance on adjacent surfaces. It is this pattern, or effect, that provides occupant notification by visible appliances. If mounted too high, the pattern is larger, but at a lower level of illumination (measured in lumens per square foot or foot-candles). If mounted too low, the illumination is greater (brighter), but the pattern is smaller and might not overlap correctly with that of adjacent appliances.

A qualified designer could choose to present calculations to an authority having jurisdiction showing that it is possible to use a mounting height greater than 96 in. or less than 80 in. provided an equivalent level of illumination is achieved on the adjacent surfaces. This can be accomplished by using listed higher intensity appliances or closer spacing, or both.

Engineering calculations should be prepared by qualified persons and should be submitted to the authority having jurisdiction showing how the proposed variation achieves the same or greater level of illumination provided by the prescriptive requirements of Section 4-4.

The calculations require knowledge of calculation methods for high intensity strobes. In addition, the calculations require knowledge of the test standards used to evaluate and list the appliance.

A-4.4.1 One method of determining compliance with Section 4-4 is that the product be listed in accordance with UL 1971, *Standard for Safety Signaling Devices for the Hearing Impaired*.

A-4.4.2.2 Effective intensity is the conventional method of equating the brightness of a flashing light to that of a steady-burning light as seen by a human observer. The units of effective intensity are expressed in candelas (or candlepower, which is equivalent to candelas). For example, a flashing light that has an effective intensity of 15 cd has the same apparent brightness to an observer as a 15-cd steady-burning light source.

Measurement of effective intensity is usually done in a laboratory using specialized photometric equipment. Accurate field measurement of effective intensity is not practical. Other units of measure for the intensity of flashing lights, such as peak candela or flash energy, do not correlate directly to effective intensity and are not used in this standard.

A-4.4.3 The prescriptive requirements of Section 4-4 assume the use of appliances having very specific characteristics of light color, intensity, distribution, and so on. The appliance and application requirements are based on extensive research. However, the research was limited to typical residential and commercial applications such as school classrooms, offices, hallways, and hotel rooms. While these specific appliances and applications will likely work in other spaces, their use might not be the most effective solution and might not be as reliable as other visible notification methods.

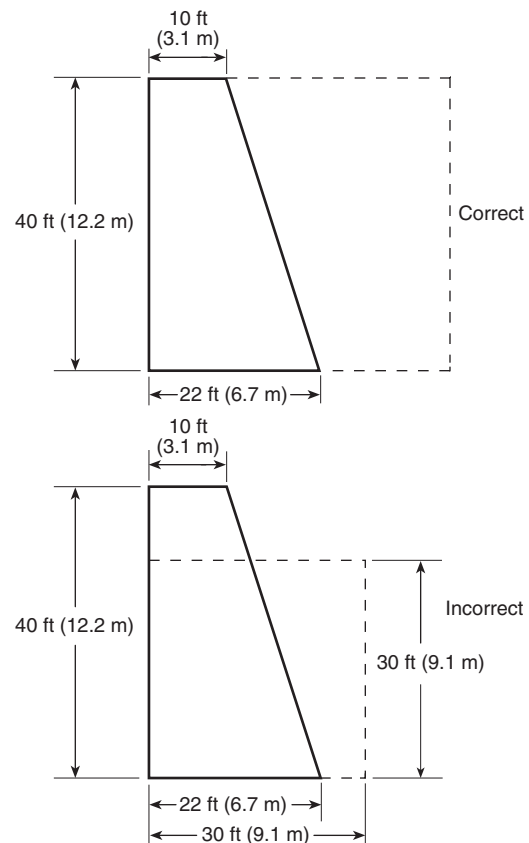
For example, in large warehouse spaces and large distribution spaces such as super stores, it is possible to provide visible signaling using the appliances and applications of this chapter. However, mounting strobe lights at a height of 80 in. to 96 in. along aisles with rack storage subjects the lights to frequent mechanical damage by fork lift trucks and stock. Also, the number of appliances required would be very high. It might be possible to use other appliances and applications not specifically addressed by this chapter at this time. Alternative applications must be carefully engineered for reliability and function and would require permission of the authority having jurisdiction.

Visible notification using the methods contained in 4-4.4.1 is achieved by indirect signaling. This means the viewer need not actually see the appliance, just the effect of the appliance. This can be achieved by producing minimum illumination on surfaces near the appliance such as the floor, walls, and desks. There must be a sufficient change in illumination to be noticeable. The tables and charts in Section 4-4 specify a certain candela effective light intensity for certain size spaces. The data were based on extensive research and testing. Appliances do not typically produce the same light intensity when measured off-axis. To ensure that the appliance produces the desired

illumination (effect), it must have some distribution of light intensity to the areas surrounding the appliance. UL 1971, *Standard for Safety Signaling Devices for the Hearing Impaired*, specifies the distribution of light shown to provide effective notification by indirect visible signaling.

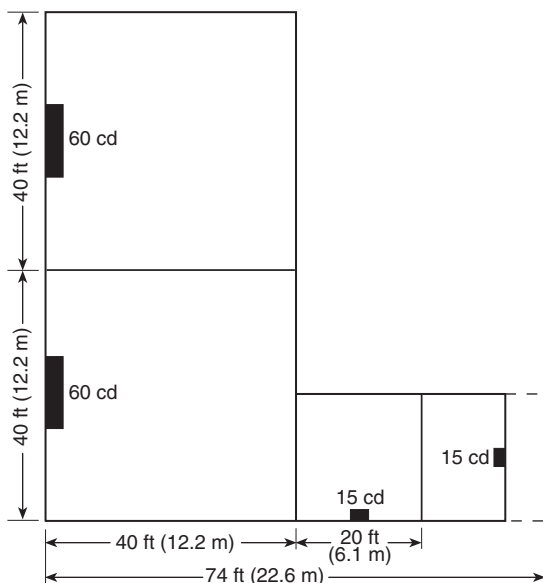
A-4.4.4.1 Areas large enough to exceed the rectangular dimensions given in Figures A-4.4.4.1(a), (b), and (c) require additional appliances. Often, proper placement of appliances can be facilitated by breaking down the area into multiple squares and dimensions that fit most appropriately [refer to Figures A-4.4.4.1(a), (b), (c), and (d)]. An area that is 40 ft (12.2 m) wide and 74 ft (22.6 m) long can be covered with two 60-cd appliances. Irregular areas and areas with dividers or partitions need more careful planning to make certain that at least one 15-cd appliance is installed for each 20-ft \times 20-ft (6.09-m \times 6.09-m) area and that light from the appliance is not blocked.

Figure A-4.4.4.1(a) Irregular area spacing.



Note: Broken lines represent imaginary walls.

Figure A-4.4.1(b) Spacing of wall-mounted visible appliances in rooms.



Note: Broken lines represent imaginary walls.

Figure A-4.4.1(c) Room spacing allocation — correct.

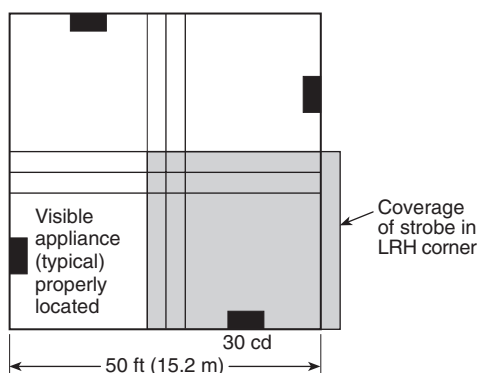
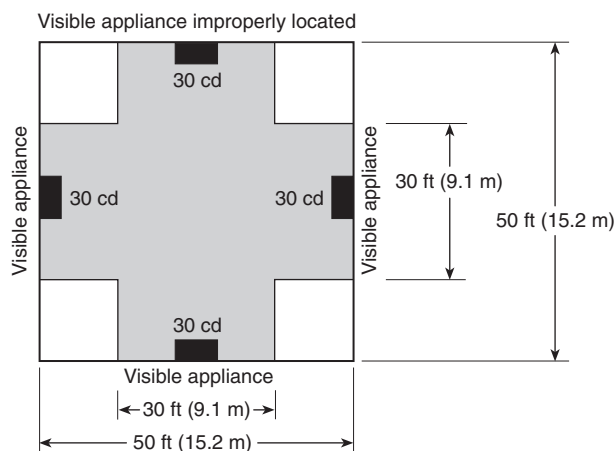


Figure A-4.4.1(d) Room spacing allocation — incorrect.



A-4.4.4.1.1(1) A design that delivers a minimum illumination of 0.0375 lumens/ft² (footcandles) or 0.4037 lumens/m² (lux) to all occupiable spaces where visible notification is required is considered to meet the minimum light intensity requirements of 4-4.4.1.1(1). This level of illumination has been shown to alert people by indirect viewing (reflected light) in a large variety of rooms with a wide range of ambient lighting conditions.

The illumination from a visible notification appliance at a particular distance is equal to the effective intensity of the appliance divided by the distance squared (the inverse square law). Tables 4-4.4.1.1(a) and (b) are based on applying the inverse square law to provide an illumination of at least 0.0375 lumens/ft² throughout each room size. For example, a 60-cd effective intensity appliance in a 40-ft × 40-ft room produces 0.0375 lumens/ft² on the opposite wall 40 ft away ($60 \div 40^2$). This same 60-cd effective intensity appliance produces 0.0375 lumens/ft² on the adjacent wall 20 ft away ($60 \div 20^2$) where the minimum light output of the appliance at 90 degrees off-axis is 25 percent of rated output per ANSI/UL 1971, *Standard for Safety Signaling Devices for the Hearing Impaired*. Similarly, a 110-cd strobe will produce at least 0.0375 lumens/ft² in a 54-ft × 54-ft room. Calculated intensities in Tables 4-4.4.1.1(a) and (b) have been adjusted to standardize the intensity options of presently available products and take into account additional reflections in room corners and higher direct viewing probability when there is more than one appliance in a room.

The application of visible notification appliances in outdoor areas has not been tested and is not addressed in this standard. Visible appliances that are mounted outdoors should be listed for outdoor use (under ANSI/UL 1638, *Visual Signaling Appliances — Private Mode Emergency and General Utility Signaling*, for example) and should be located for direct viewing because reflected light will usually be greatly reduced.

A-4.4.4.1.1(3) The field of view is based on the focusing capability of the human eye specified as 120 degrees in the Illuminating Engineering Society (IES) *Lighting Handbook Reference and Application*. The apex of this angle is the viewer's eye. In order to ensure compliance with the requirements of 4-4.4.1.1, this angle should be increased to approximately 135 degrees.

Testing has shown that high flash rates of high intensity strobe lights can pose a potential risk of seizure to people with photosensitive epilepsy. To reduce this risk, more than two visible appliances are not permitted in any field of view unless they are separated by at least 55 ft (16.8 m) or unless their flashes are synchronized.

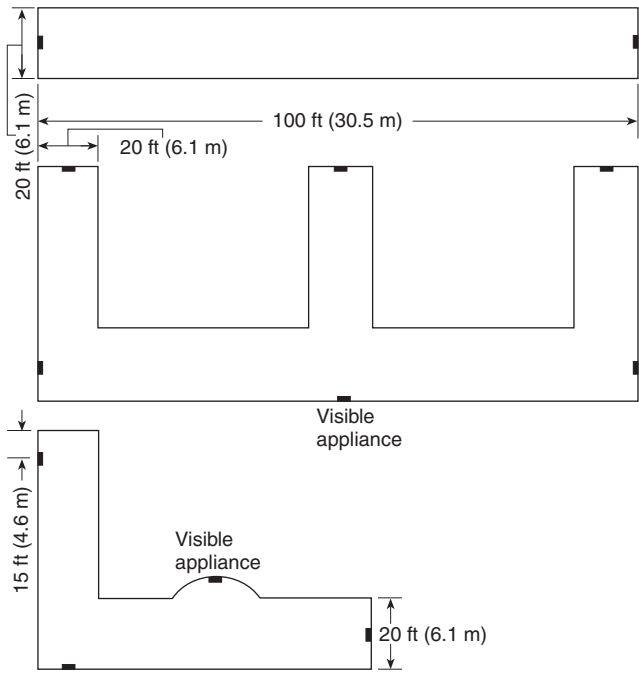
A-4.4.4.2 See Figure A-4.4.2 for corridor and elevator spacing allocation.

A-4.4.4.2.2 Visible appliances in corridors are permitted to be mounted on walls or on ceilings in accordance with 4-4.4.2.2. When there are more than two appliances in a field of view, they need to be at least 55 ft (16.8 m) apart or they need to be synchronized.

A-4.4.4.3.2 For sleeping areas, the use of lights with other intensities at distances different than within 16 ft (4.9 m) has not been researched and is not addressed in this code.

A-4.4.4.4 Examples of rooms where there are concentrated viewing areas include classrooms and theater stages.

Figure A-4.4.2 Corridor and elevator area spacing allocation.



A-4-7.1.2 The evacuation tone signal is used to evaluate the audibility produced by fire alarm speaker appliances because of the fluctuating sound pressure level of voice or recorded messages.

A-4-8 Textual visible appliances are selected and installed to provide temporary text, permanent text, or symbols. Textual visible appliances are most commonly used in the private mode. The use of microprocessors with computer monitors and printers has resulted in the ability to provide detailed fire alarm system information in the form of text and graphics to persons charged with directing emergency response and evacuation. Textual visible appliances are also used in the public mode to communicate emergency response and evacuation information directly to the occupants or inhabitants of the area protected by the fire alarm system. Because textual visible appliances do not necessarily have the ability to alert, they should only be used to supplement audible or visible notification appliances.

Textual visible information should be of a size and visual quality that is easily read. Many factors influence the readability of textual visible appliances, including the following:

- (1) Size and color of the text or graphic
- (2) Distance from the point of observation
- (3) Observation time
- (4) Contrast
- (5) Background luminance
- (6) Lighting
- (7) Stray lighting (glare)
- (8) Shadows
- (9) Physiological factors

While many of these factors can be influenced by the fire alarm equipment manufacturer and by the building designers, there is no readily available method to measure readability.

A-5-1 Table A-5-1 provides a tool for users of the code to easily and systematically look-up requirements for protected premises, central station service, remote supervising station, and proprietary supervising station fire alarm systems.

Table A-5-1 Supervising Station Performance Criteria

System	Protected Premises	Central Station Service	Remote Supervising Station	Proprietary Supervising Station
Qualify	All fire alarm systems	Supervising station service provided by a prime contractor. There is a subscriber (5-2.2.2 and 5-2.2.3).	Where central station service is neither required nor elected, properties under various ownership monitored by a remote supervising station (5-4.1)	Supervising station service monitoring contiguous or non-contiguous properties under one ownership and responsible to the owner of the protected property (5-3.2 et al)
Listed	Equipment listed for the use intended (1-5.1.2)	Service listed or placarded as well as local equipment for intended use (5-1.2.1 and 5-1.2.2)	Equipment listed for use intended (1-5.1.2)	Equipment listed for use intended (1-5.1.2)
Design	According to code by experienced persons (1-5.1.3)	According to code by experienced persons (1-5.1.3)	According to code by experienced persons (1-5.1.3)	According to code by experienced persons (1-5.1.3)
Compatibility	Detector devices pulling power from initiating or signaling circuits listed for control panel (1-5.3)	Detector devices pulling power from initiating or signaling circuits listed for control panel (1-5.3)	Detector devices pulling power from initiating or signaling circuits listed for control panel (1-5.3)	Detector devices pulling power from initiating or signaling circuits listed for control panel (1-5.3)

Table A-5-1 Supervising Station Performance Criteria (Continued)

System	Protected Premises	Central Station Service	Remote Supervising Station	Proprietary Supervising Station
Performance and Limitations	85 percent and 110 percent of the nameplate rated input voltage, 32°F (0°C) and 120°F (49°C) ambient temperature, 85 percent relative humidity at 85°F (29.4°C)	85 percent and 110 percent of the nameplate rated input voltage, 32°F (0°C) and 120°F (49°C) ambient temperature, 85 percent relative humidity at 85°F (29.4°C)	85 percent and 110 percent of the nameplate rated input voltage, 32°F (0°C) and 120°F (49°C) ambient temperature, 85 percent relative humidity at 85°F (29.4°C)	85 percent and 110 percent of the nameplate rated input voltage, 32°F (0°C) and 120°F (49°C) ambient temperature, 85 percent relative humidity at 85°F (29.4°C)
Documentation	Authority having jurisdiction notified of new or changed specifications, wiring diagrams, battery calculations. Floor plans approval statement from contractor meets manufacturer's specifications and NFPA requirements. Record of completion (1-6.2.1 and 1-6.2.2). Results of evaluation required in 3-4.3.3.	Authority having jurisdiction notified of new or changed specifications, wiring diagrams, battery calculations. Floor plans approval statement from contractor meets manufacturer's specifications and NFPA requirements. Record of completion (1-6.2.1 and 1-6.2.2). Results of evaluation required in 3-4.3.3.	Authority having jurisdiction notified of new or changed specifications, wiring diagrams, battery calculations. Floor plans approval statement from contractor meets manufacturer's specifications and NFPA requirements. Record of completion (1-6.2.1 and 1-6.2.2). Results of evaluation required in 3-4.3.3.	Authority having jurisdiction notified of new or changed specifications, wiring diagrams, battery calculations. Floor plans approval statement from contractor meets manufacturer's specifications and NFPA requirements. Record of completion (1-6.2.1 and 1-6.2.2). Results of evaluation required in 3-4.3.3.
Supervising Station Facilities	None	UL 827 compliant for both the supervising station and subsidiary station (5-1.2.1 and 5-1.2.2)	Access restricted, retransmit to public fire or governmental agency. Trouble and supervisory can be received elsewhere at a continuously attended station (5-4.3 et al).	Fire resistive, detached building or cut-off room not near or exposed to hazards. Access restricted, NFPA 10, 26-hour emergency lighting (5-3.3 et al)
Testing and Maintenance	Chapter 7	Chapter 7	Chapter 7	Chapter 7
Runner Service	No	Yes — Alarm arrive at the protected premises within 1 hour where equipment needs to be reset, guard signal — 30 minutes, supervisory — 1 hour, trouble — 4 hour (5-2.6.1 et al)	No	Yes — alarm — 1 hour, guard alarm — 30 minutes, supervisory — 1 hour, trouble — 1 hour (5-3.6.6 et al)
Operations and Management Requirements	None	Central station provides all but test, maintenance, installation and runner service provided by local alarm service. Local alarm service prime contractor provides above and central station provides remainder (5-2.2.2).	None	See Qualify
Staff	None	Minimum of two persons on duty at supervising station. Operation and supervision primary task (5-2.5).	Sufficient to receive alarms. Other duties permitted per the authority having jurisdiction.	Two operators of which one may be the runner, when runner is not in attendance at station contact not to exceed 15 minutes. Primary duties are monitoring alarms and operations of station (5-3.5 et al).

Table A-5-1 Supervising Station Performance Criteria *(Continued)*

System	Protected Premises	Central Station Service	Remote Supervising Station	Proprietary Supervising Station
Monitor Signals	Control unit, fire command center and supervising station if sent to supervising station (1-5.4.3.2.2)	Control unit, fire command center and supervising station if sent to supervising station (1-5.4.3.2.2)	Control unit, fire command center and supervising station if sent to supervising station (1-5.4.3.2.2)	Control unit, fire command center and supervising station if sent to supervising station (1-5.4.3.2.2)
Retransmission	None — Local	Alarm — public fire service communications center, subscriber, dispatch runner provide notice to subscriber and authority having jurisdiction if required. Supervisory, trouble, and guard service similar but not same (5-2.6.1.2 – 5-2.6.1.5).	(1) Alarm to fire department or governmental agency, if not available to another approved location. By dedicated phone circuit or one-way phone, private radio, or other methods acceptable. (2) Supervisory and trouble can go elsewhere (5-4.4.4).	Alarm — public fire department or plant brigade or other parties as required. Guard-protected premises, supervisory-designated person to find problem, others as required. Trouble-designated person to find problem and others as required (5-3.6.7.2 – 5-3.6.7.4).
Records	Current year and 1 year after (1-6.3)	Complete records of all signals received must be retained for at least 1 year. Reports provided of signals received to authority having jurisdiction in a form it finds acceptable (5-2.6.2).	At least 1 year (5-4.6.3).	Complete records of all signals received shall be retained for at least 1 year. Reports provided of signals received to authority having jurisdiction in a form it finds acceptable (5-3.6.7).
Alarm Type	Audible — fire zone. Audible and visual control unit and fire command center (1-5.7.1)	Audible — fire zone. Audible and visual control unit and fire command center (1-5.7.1)	Audible — fire zone. Audible and visual control unit and fire command center (1-5.7.1)	Audible — fire zone. Audible and visual control unit and fire command center (1-5.7.1)
Time/Retransmit	20 seconds (1-5.4.2.2/None)	20 seconds (1-5.4.2.2) Immediate — public fire “maximum” 90 seconds (5-2.6.1.1)	Same/immediate — public fire or owner designate (5-4.6.2)	90 seconds (5-3.4.7) Immediate — public fire plant brigade or others (5-3.6.6.1)
Supervisory Type	Audible — covered zone. Audible and visual at the control panel and fire control center (1-5.7.1)	Audible — covered zone. Audible and visual at the control panel and fire control center (1-5.7.1)	Audible — covered zone. Audible and visual at the control panel and fire control center (1-5.7.1)	Audible — covered zone. Audible and visual at the control panel and fire control center (1-5.7.1)
Time/Retransmit	20 seconds (1-5.4.2.2/None)	20 seconds (1-5.4.2.2) Immediate person designated by subscriber maximum 4 minimum (5-2.6.1.3)	20 seconds (1-5.4.2.2) Immediate — public fire or owner designate (5-4.6.2)	90 seconds (5-3.4.7) Where required immediate person designated (5-3.6.6.3)
Trouble Type	Audible and visual at the control panel and fire control panel (1-5.7.1)	Audible and visual at the control panel and fire control panel (1-5.7.1)	Audible and visual at the control panel and fire control panel (1-5.7.1)	Audible and visual at the control panel and fire control panel (1-5.7.1)
Silence/Reset	Can be silenced, can be intermittent every 10 seconds for 1/2 second, can have a switch secured. Re-sound every 24 hours if silenced, if restored and still silenced tone resounds (1-5.4.8).	Can be silenced, can be intermittent every 10 seconds for 1/2 second, can have a switch secured. Re-sound every 24 hours if silenced, if restored and still silenced tone resounds (1-5.4.8).	Can be silenced, can be intermittent every 10 seconds for 1/2 second, can have a switch secured. Re-sound every 24 hours if silenced, if restored and still silenced tone resounds (1-5.4.8).	Can be silenced, can be intermittent every 10 seconds for 1/2 second, can have a switch secured. Re-sound every 24 hours if silenced, if restored and still silenced tone resounds (1-5.4.8).

Table A-5-1 Supervising Station Performance Criteria (Continued)

System	Protected Premises	Central Station Service	Remote Supervising Station	Proprietary Supervising Station
Time/Retransmit	200 seconds (1-5.4.6/ <i>None</i>)	200 seconds (1-5.4.6) Immediate — person designated by sub- scriber. Maximum 4 minutes (5-2.6.1.4)	200 seconds (1-5.4.6) Immediate — public fire or owner designate (5-4.6.2)	200 seconds (5-3.4.7) Where required immedi- ate person designated (5-3.6.6.4)
Primary Source	Light and power service or engine-driven genera- tor with trained opera- tor (1-5.2.4). Low-power radio and DACT increased.	Same low-power radio and DACT increased	Same low-power radio and DACT increased	Same low-power radio and DACT increased
Capacity	Direct-current voltages not to exceed 350 volts above earth ground (1-5.2.3)	Direct-current voltages not to exceed 350 volts above earth ground (1-5.2.3)	Direct-current voltages not to exceed 350 volts above earth ground (1-5.2.3)	Direct-current voltages not to exceed 350 volts above earth ground (1-5.2.3)
Duration	Constant	Constant	Constant	Constant
Type	2-wire ac, 3-wire ac or dc with continuous unfused neutral conductor or polyphase ac with unfused neutral, dedi- cated branch circuits marked and overcur- rent protection (1-5.2.4)	2-wire ac, 3-wire ac or dc with continuous unfused neutral conductor or polyphase ac with unfused neutral, dedi- cated branch circuits marked and overcur- rent protection (1-5.2.4)	2-wire ac, 3-wire ac or dc with continuous unfused neutral conductor or polyphase ac with unfused neutral, dedi- cated branch circuits marked and overcur- rent protection (1-5.2.4)	2-wire ac, 3-wire ac or dc with continuous unfused neutral conductor or polyphase ac with unfused neutral, dedi- cated branch circuits marked and overcur- rent protection (1-5.2.4)
Secondary	(1) Storage battery. (2) Auto-starting engine generator and storage batteries with 4-hour capacity. (3) Multiple engine- driven generators, one auto starting and capa- ble of largest generator being out of service. Does not cause loss of signal (1-5.2.5)	(1) Storage battery. (2) Auto-starting engine generator and storage batteries with 4-hour capacity. (3) Multiple engine- driven generators, one auto starting and capa- ble of largest generator being out of service. Does not cause loss of signal (1-5.2.5)	(1) Storage battery. (2) Auto-starting engine generator and storage batteries with 4-hour capacity. (3) Multiple engine- driven generators, one auto starting and capa- ble of largest generator being out of service. Does not cause loss of signal (1-5.2.5)	(1) Storage battery. (2) Auto-starting engine generator and storage batteries with 4-hour capacity. (3) Multiple engine- driven generators, one auto starting and capa- ble of largest generator being out of service. Does not cause loss of signal (1-5.2.5)
Capacity	Direct-current voltages not to exceed 360 volts above earth ground (1-5.2.4)	Direct-current voltages not to exceed 360 volts above earth ground (1-5.2.4)	Direct-current voltages not to exceed 360 volts above earth ground (1-5.2.4)	Direct-current voltages not to exceed 360 volts above earth ground (1-5.2.4)
Duration	Automatic without sig- nal loss for 30 seconds and then for 24 hours on protected premises (1-5.2.5)	Automatic without sig- nal loss for 30 seconds and then for 24 hours on protected premises and central station (1-5.2.5)	Automatic without sig- nal loss for 30 seconds and then for 60 hours on remote station (1-5.2.5)	Automatic without sig- nal loss for 30 seconds and then for 24 hours on protected premises and proprietary station (1-5.2.5)
Switch	Automatic but see the different configurations for exception (1-5.2.6)	Automatic but see the different configurations for exception (1-5.2.6)	Automatic but see the different configurations for exception (1-5.2.6)	Automatic but see the different configurations for exception (1-5.2.6)
Type	Automatic (1-5.2.6)	Automatic (1-5.2.6)	Automatic (1-5.2.6)	Automatic (1-5.2.6)

A-5-2.2.2 There are related types of contract service that often are provided from, or controlled by, a central station but that are neither anticipated by, nor consistent with, the provisions of 5-2.2.2. Although 5-2.2.2 does not preclude such arrangements, a central station company is expected to recognize, provide for, and preserve the reliability, adequacy, and integrity of those supervisory and alarm services intended to be in accordance with the provisions of 5-2.2.2.

A-5-2.2.4 It is the prime contractor's responsibility to remove all compliance markings (certification markings or placards) when a service contract goes into effect that conflicts in any way with the requirements of 5-2.2.3.

A-5-2.2.5 The prime contractor should be aware of statutes, public agency regulations, or certifications regarding fire alarm systems that might be binding on the subscriber. The prime contractor should identify for the subscriber which agencies could be an authority having jurisdiction and, if possible, advise the subscriber of any requirements or approvals being mandated by these agencies.

The subscriber has the responsibility for notifying the prime contractor of those private organizations that are being designated as an authority having jurisdiction. The subscriber also has the responsibility to notify the prime contractor of changes in the authority having jurisdiction, such as where there is a change in insurance companies. Although the responsibility is primarily the subscriber's, the prime contractor should also take responsibility for seeking out these private authorities having jurisdiction through the subscriber. The prime contractor is responsible for maintaining current records on the authority(ies) having jurisdiction for each protected premises.

The most prevalent public agency involved as an authority having jurisdiction with regard to fire alarm systems is the local fire department or fire prevention bureau. These are normally city or county agencies with statutory authority, and their approval of fire alarm system installations might be required. At the state level, the fire marshal's office is most likely to serve as the public regulatory agency.

The most prevalent private organizations involved as authorities having jurisdiction are insurance companies. Others include insurance rating bureaus, insurance brokers and agents, and private consultants. It is important to note that these organizations have no statutory authority and become authorities having jurisdiction only when designated by the subscriber.

With both public and private concerns to satisfy, it is not uncommon to find multiple authorities having jurisdiction involved with a particular protected premises. It is necessary to identify all authorities having jurisdiction in order to obtain all the necessary approvals for a central station fire alarm system installation.

A-5-2.4.4 Two telephone lines (numbers) at the central station connected to the public switched telephone network, each having its own telephone instrument connected, and two telephone lines (numbers) available at the public fire service communications center to which a central station operator can retransmit an alarm meet the intent of this requirement.

A-5-2.4.4.3 The following methods have been used successfully for supervising retransmission circuits (channels).

(a) An electrically supervised circuit (channel) provided with suitable code sending and automatic recording equipment.

(b) A supervised circuit (channel) providing suitable voice transmitting, receiving, and automatic recording equipment. The circuit can be permitted to be a telephone circuit with the following stipulations:

- (1) It cannot be used for any other purpose.
- (2) It is provided with a two-way ring-down feature for supervision between the fire department communications center and the central station.
- (3) It is provided with terminal equipment located on the premises at each end.
- (4) It is provided with 24-hour standby power.

NOTE: Local on-premises circuits are not required to be supervised.

(c) Radio facilities using transmissions over a supervised channel with supervised transmitting and receiving equipment. Circuit continuity ensured by any means at intervals not exceeding 8 hours is satisfactory.

A-5-2.6.1.1(1) The term *immediately* in this context is intended to mean "without unreasonable delay." Routine handling should take a maximum of 90 seconds from receipt of an alarm signal by the central station until the initiation of retransmission to the public fire service communications center.

A-5-2.6.1.3 It is anticipated that the central station will first attempt to notify designated personnel at the protected premises. When such notification cannot be made, it might be appropriate to notify law enforcement or the fire department, or both. For example, if a valve supervisory signal is received where protected premises are not occupied, it is appropriate to notify the police.

A-5-2.6.1.3(1) The term *immediately* in this context is intended to mean "without unreasonable delay." Routine handling should take a maximum of 4 minutes from receipt of a supervisory signal by the central station until the initiation of communications with a person(s) designated by the subscriber.

A-5-2.6.1.4(1) The term *immediately* in this context is intended to mean "without unreasonable delay." Routine handling should take a maximum of 4 minutes from receipt of a trouble signal by the central station until initiation of the investigation by telephone.

A-5-2.6.1.5.2 The term *immediately* in this context is intended to mean "without unreasonable delay." Routine handling should take a maximum of 4 minutes from receipt of a trouble signal by the central station until initiation of the investigation by telephone.

A-5-3.2.4 The following functions are included in Appendix A to provide guidelines for utilizing building systems and equipment in addition to proprietary fire alarm equipment in order to provide life safety and property protection.

Building functions that should be initiated or controlled during a fire alarm condition include, but should not be limited to, the following:

- (1) Elevator operation consistent with ANSI A17.1, *Safety Code for Elevators and Escalators*
- (2) Unlocking of stairwell and exit doors (*refer to NFPA 80, Standard for Fire Doors and Fire Windows, and NFPA 101, Life Safety Code*)
- (3) Release of fire and smoke dampers (*refer to NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, and NFPA 90B, Standard for the Installation of Warm Air Heating and Air Conditioning Systems*)

- (4) Monitoring and initiating of self-contained automatic fire extinguishing system(s) or suppression system(s) and equipment (*refer to NFPA 11, Standard for Low-Expansion Foam; NFPA 11A, Standard for Medium- and High-Expansion Foam Systems; NFPA 12, Standard on Carbon Dioxide Extinguishing Systems; NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems; NFPA 13, Standard for the Installation of Sprinkler Systems; NFPA 14, Standard for the Installation of Standpipe and Hose Systems; NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection; and NFPA 17, Standard for Dry Chemical Extinguishing Systems*)
- (5) Lighting control necessary to provide essential illumination during fire alarm conditions (*refer to NFPA 70, National Electrical Code, and NFPA 101, Life Safety Code*)
- (6) Emergency shutoff of hazardous gas
- (7) Control of building environmental heating, ventilating, and air-conditioning equipment to provide smoke control (*refer to NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems*)
- (8) Control of process, data processing, and similar equipment as necessary during fire alarm conditions

A-5-3.6.4 It is the intent of this code that the operator within the proprietary supervising station should have a secure

means of immediately retransmitting any signal indicative of a fire to the public fire department communications center. Automatic retransmission using an approved method installed in accordance with Sections 5-2, 5-3, 5-4, and Chapter 6 is the best method for proper retransmission. However, a manual means can be permitted to be used, consisting of either a manual connection following the requirements of Sections 5-2, 5-4, and Chapter 6, or, for proprietary supervising stations serving only contiguous properties, a means in the form of a municipal fire alarm box installed within 50 ft (15 m) of the proprietary supervising station in accordance with Chapter 6 can be permitted.

A-5-3.6.5 Regardless of the type of retransmission facility used, telephone communications between the proprietary supervising station and the fire department should be available at all times and should not depend on a switchboard operator.

A-5-4.3 As a minimum, the room or rooms containing the remote supervising station equipment should have a 1-hour fire rating, and the entire structure should be protected by an alarm system complying with Chapter 3.

A-5-5.1 Refer to Table A-5-5.1 for communications methods.

Table A-5-5.1 Communications Methods for Supervising Stations

Criteria	5-5.3.1 Active Multiplex	5-5.3.2 Digital Alarm Communicator Systems	5-5.3.3 McCulloh Systems	5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems	5-5.3.5 One-Way Private Radio Alarm Systems	5-5.3.6 Directly Connected Noncoded Systems	5-5.3.7 Private Microwave Radio Systems	5-5.4 Other Transmission Technologies
FCC approval when applicable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Conform to NFPA 70, <i>National Electrical Code</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monitoring for integrity of the transmission and communications channel	Systems are periodically polled for end-to-end communications integrity	Both the premises unit and the system unit monitor for integrity in a manner approved for the means of transmission employed. A single signal received on each incoming DACR line once every 24 hours	Continuous dc supervision	Systems are periodically polled for end-to-end communications integrity	Test signal from every transmitter once every 24 hours	Continuous dc supervision	Used as a portion of another type of transmission technology. End-to-end integrity monitored by the main transmission technology. Microwave portion is continuously monitored	Monitor for integrity or provide back-up channel tested as below
Annunciate, at the supervising station, the degradation and restoration of the transmission or communications channel	Within 200 seconds for Type III multiplex. Within 90 seconds for Type I and II multiplex.	Within 4 minutes using alternate phone line to report the trouble	Indicate automatically and operation under fault condition achieved either manually or automatically	Not exceed 90 seconds from the time of the actual failure	Only monitor the quality of signal received and indicate if the signal falls below minimum signal quality specified in code	Presented in a form to expedite prompt operator interpretation	Presented in a form to expedite prompt operator interpretation	Within 5 minutes (may use a second separate path to report failure)

Table A-5-5.1 Communications Methods for Supervising Stations (Continued)

Criteria	5-5.3.1 Active Multiplex	5-5.3.2 Digital Alarm Communicator Systems	5-5.3.3 McCulloh Systems	5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems	5-5.3.5 One-Way Private Radio Alarm Systems	5-5.3.6 Directly Connected Noncoded Systems	5-5.3.7 Private Microwave Radio Systems	5-5.4 Other Transmission Technologies
Redundant communication path where a portion of the transmission or communications channel cannot be monitored for integrity	Redundant path not required — supervising station always indicates a communications failure	Employ a combination of two separate transmission channels alternately tested at intervals not exceeding 24 hours	Redundant path not required — supervising station always indicates a communications failure. Exception is the use of non-metallic channels that require two channels or an immediate transfer to a standby channel	Redundant path not required — supervising station always indicates a communications failure	Minimum of two independent RF paths must be simultaneously employed	None required	Dual transmitters required if more than 5 buildings or premises or 50 initiating devices circuits	Provide a redundant path if communication failure not annunciated at supervising station
Interval testing of the back-up path(s)	For Type I, 1-hour testing for dedicated lines and 24-hour testing for dial-up. No requirement for Type II and III.	When two phone lines are used, test alternately every 24 hours. Testing for other back-up technologies, see 5-5.3.2.1.6.2	No testing requirement	Back-up path not required	No requirement because the quality of the signal is continuously monitored	Back-up path not required	Dual transmitters shall be operated on time ratio of 2:1 within each 24-hours	If back-up path required, test path once every 24-hours on alternating channels testing each channel every 48-hours
Annunciation of communication failure or ability to communicate at the protected premises	Not required — always annunciated at the supervising station that initiates corrective action	Indication of failure at premises due to line failure or failure to communicate after from 5 to 10 dialing attempts	Not required — always annunciated at the supervising station that initiates corrective action	Not required — always annunciated at the supervising station that initiates corrective action	Monitor the interconnection of the premises unit elements of transmitting equipment and indicate a failure at the premises or transmit a trouble signal to the supervising station	None required	None required	Systems where the transmitter at the local premises unit detects a communication failure before the supervising station, the premises unit will annunciate the failure within 5 minutes of detecting the failure
Time to restore signal receiving, processing, display, and recording equipment	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Spare digital alarm communicator receivers required for switchover to back-up receiver in 30 seconds. One back-up system unit for every 5 system units.	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes	Where duplicate equipment not provided, spare hardware required so a repair can be effected within 30 minutes. Complete set of critical spare parts on a 1 to 5 ratio of parts to system units or a duplicate functionally equivalent system unit for every 5 system units

Table A-5-5.1 Communications Methods for Supervising Stations (Continued)

Criteria	5-5.3.1 Active Multiplex	5-5.3.2 Digital Alarm Communicator Systems	5-5.3.3 McCulloh Systems	5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems	5-5.3.5 One-Way Private Radio Alarm Systems	5-5.3.6 Directly Connected Noncoded Systems	5-5.3.7 Private Microwave Radio Systems	5-5.4 Other Transmission Technologies
Loading capacities for system units and transmission and communications channels	512 buildings and premises on one system unit. Unlimited if you can switch to duplicate system unit within 30 seconds. Loading capacity for transmission and communications channels (trunks) is listed in Table 5-5.3.1.4.	See Table 5-5.3.2.2.2.3 for the maximum number of transmitters on a hunt group in a system unit	Alarm and sprinkler supervisory limited to 25 plants and 250 code wheels on one circuit. 60 scheduled guard reports per hour	512 buildings and premises on a system unit with no back-up. Unlimited if you can switch to a back-up in 30 seconds.	512 buildings and premises on a system unit with no back-up. Unlimited if you can switch to a back-up in 30 seconds.	A single circuit must not serve more than one plant.	Up to 5 buildings or premises or 50 initiating device circuits on one transmitter. Unlimited if dual transmitters are used with automatic switchover or manual switchover in 30 seconds	512 independent fire alarm systems on a system unit with no back-up. Unlimited if you can switch to a back-up in 30 seconds. The system shall be designed such that a failure of a transmission channel serving a system unit shall not result in the loss in the ability to monitor more than 3000 transmitters
End-to-end communication time for an alarm	90 seconds from initiation until it is recorded	Off-hook to on-hook not to exceed 90 seconds per attempt. 10 attempts maximum. 900 seconds maximum for all attempts.	Not addressed	90 seconds from initiation until it is recorded	90% probability to receive an alarm in 90 seconds, 99% probability in 180 seconds, 99.999% probability in 450 seconds	Not addressed	Not addressed	90 seconds from initiation of alarm until displayed to the operator and recorded on a media from which the information can be retrieved
Record and display rate of subsequent alarms at supervising station	Not slower than one every 10 additional seconds	Not addressed	Not addressed	When any number of subsequent alarms come in, record at a rate not slower than one every additional 10 seconds	When any number of subsequent alarms come in, record at a rate not slower than one every additional 10 seconds	Not addressed	Not addressed	No slower than one every 10 additional seconds
Signal error detection and correction	Not addressed	Signal repetition, digital parity check, or some equivalent means of signal verification must be used	Not addressed	Not addressed	Not addressed	Not applicable	Not addressed	Signal repetition, parity check, or some equivalent means of error detection and correction shall be used
Path sequence priority	Not addressed	The first transmission attempt uses the primary channel	Not addressed	Not addressed	Not addressed	Not addressed	Not addressed	No need for prioritization of paths. The requirement is that both paths are equivalent

Table A-5-5.1 Communications Methods for Supervising Stations (Continued)

Criteria	5-5.3.1 Active Multiplex	5-5.3.2 Digital Alarm Communicator Systems	5-5.3.3 McCulloh Systems	5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems	5-5.3.5 One-Way Private Radio Alarm Systems	5-5.3.6 Directly Connected Noncoded Systems	5-5.3.7 Private Microwave Radio Systems	5-5.4 Other Transmission Technologies
Carrier diversity	None required	Where long distance service (including WATS) is used, the second telephone number shall be provided by a different long distance service provider where there are multiple providers	Not addressed	Not addressed	Not addressed	Not addressed	Not addressed	When a redundant path is required, the alternate path shall be provided by a public communication service provider different from the primary path where available
Throughput probability	Not addressed	Demonstrate 90% probability of a system unit immediately answering a call or follow the loading Table 5-5.3.2.2.2.3. One-way radio back-up demonstrates 90% probability of transmission.	Not addressed	Not addressed	90% probability to receive an alarm in 90 seconds. 99% probability in 180 seconds. 99.999% in probability 450 seconds	Not addressed	Not addressed	When the supervising station does not regularly communicate with the transmitter at least once every 200 seconds, then the throughput probability of the alarm transmission must be at least 90% in 90 seconds, 99% in 180 seconds, 99.999% in 450 seconds
Unique premises identifier	Yes	Yes	Yes	Yes	Yes	Yes	Yes	If a transmitter shares a transmission or communication channel with other transmitters, it shall have a unique transmitter identifier
Unique flaws	None addressed	If call forwarding is used to communicate to the supervising station, verify the integrity of this feature every 4 hours	None addressed	None addressed	None addressed	None addressed	None addressed	From time to time, there may be unique flaws in a communication system. Unique requirements shall be written for these unique flaws

Table A-5-5.1 Communications Methods for Supervising Stations (Continued)

Criteria	5-5.3.1 Active Multiplex	5-5.3.2 Digital Alarm Communicator Systems	5-5.3.3 McCulloh Systems	5-5.3.4 Two-Way Radio Frequency (RF) Multiplex Systems	5-5.3.5 One-Way Private Radio Alarm Systems	5-5.3.6 Directly Connected Noncoded Systems	5-5.3.7 Private Microwave Radio Systems	5-5.4 Other Transmission Technologies
Signal priority	Fire alarm, supervisory, and trouble signals shall take precedence, in that respective order of priority, over all other signals (except life threatening signals over supervisory and trouble)	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	Chapter 1 on fundamentals requires that alarm signals take priority over supervisory signals unless there is sufficient repetition of the alarm signal to prevent the loss of an alarm signal	If the communication methodology is shared with any other usage, all fire alarm transmissions shall preempt and take precedence over any other usage. Fire alarm signals take precedence over supervisory signals
Sharing communications equipment on premises	Not addressed	Disconnect outgoing or incoming telephone call and prevent its use for outgoing telephone calls until signal transmission has been completed	Not addressed	Not addressed	Not addressed	Not addressed	Not addressed	If the transmitter is sharing on-premises communications equipment, the shared equipment shall be listed for the purpose (otherwise the transmitter must be installed ahead of the unlisted equipment)

A-5-5.2.1.2 It is not the intent of Section 5-5 to limit the use of listed equipment using alternate communications methods, provided these methods demonstrate performance characteristics that are equal to or superior to those technologies described in Section 5-5. Such demonstration of equivalency is to be evidenced by the equipment using the alternate communications methods meeting all the requirements of Chapter 1, including those that deal with such factors as reliability, monitoring for integrity, and listing. It is further expected that suitable proposals stating the requirements for such technology will be submitted for inclusion in subsequent editions of this code.

A-5-5.3.1.2 Where derived channels are used, normal operating conditions of the telephone equipment are not to inhibit or impair the successful transmission of signals. These normal conditions include, but are not limited to, the following:

- (1) Intraoffice calls with a transponder on the originating end
- (2) Intraoffice calls with a transponder on the terminating end
- (3) Intraoffice calls with transponders on both ends
- (4) Receipt and origination of long distance calls
- (5) Calls to announcement circuits
- (6) Permanent signal receiver off-hook tone
- (7) Ringing with no answer, with transponder on either the originating or the receiving end

- (8) Calls to tone circuits (that is, service tone, test tone, busy, or reorder)
- (9) Simultaneous signal with voice source
- (10) Simultaneous signal with data source
- (11) Tip and ring reversal
- (12) Cable identification equipment

A-5-5.3.1.2.3(b) Derived channel systems comprise Type 1 and Type 2 systems only.

A-5-5.3.2.1.3 In order to give the DACT the ability to disconnect an incoming call to the protected premises, telephone service should be of the type that provides for timed-release disconnect. In some telephone systems (step-by-step offices), timed-release disconnect is not provided.

A-5-5.3.2.1.5 A DACT can be programmed to originate calls to the DACR telephone lines (numbers) in any alternating sequence. The sequence can consist of single or multiple calls to one DACR telephone line (number), followed by single or multiple calls to a second DACR telephone line (number), or any combination thereof that is consistent with the minimum/maximum attempt requirements in 5-5.3.2.1.5.

A-5-5.3.2.1.6.1(8) A two-number ISDN line is not a substitute for the requirement to monitor the integrity of the path.

A-5-5.3.2.1.9 The requirement for use of two different long distance providers is to prevent a lost signal due to a fault in

one long distance provider's network. This requirement is not meant to apply in local situations where signal traffic is strictly within the area covered by one local telephone company.

Because it is never certain whether a subscriber has changed long distance providers, it is recommended that, if direct dialer service is used, a telephone call should be forced onto a specific long distance provider's network by using the dialing prefix carrier identification code (CIC) specific to each long distance provider.

A-5-5.3.2.1.11 Because call forwarding requires equipment at a telephone company central office that might occasionally interrupt the call forwarding feature, a signal should be initiated whereby the integrity of the forwarded telephone line (number) that is being called by DACTs is verified every 4 hours. This can be accomplished by a single DACT, either in service or used solely for verification, that automatically initiates and completes a transmission sequence to its associated DACR every 4 hours. A successful signal transmission sequence of any other type within the same 4-hour period should be considered sufficient to fulfill this requirement.

Call forwarding should not be confused with WATS or 800 service. The latter, differentiated from the former by dialing the 800 prefix, is a dedicated service used mainly for its toll-free feature; all calls are preprogrammed to terminate at a fixed telephone line (number) or to a dedicated line.

A-5-5.3.2.2.2.1 The timed-release disconnect considerations as outlined in A-5-5.3.2.1.3 apply to the telephone lines (numbers) connected to a DACR at the supervising station.

It might be necessary to consult with appropriate telephone service personnel to ensure that numbers assigned to the DACR can be individually accessed even where they are connected in rotary (a hunt group).

A-5-5.3.2.2.2.3 In determining system loading, Table 5-5.3.2.2.2.3 can be used, or it should be demonstrated that there is a 90 percent probability of incoming line availability. Table 5-5.3.2.2.2.3 is based on an average distribution of calls and an average connected time of 30 seconds per message. Therefore, where it is proposed to use Table 5-5.3.2.2.2.3 to determine system loading, if any factors are disclosed that could extend DACR connect time so as to increase the average connect time, the alternate method of determining system loading should be used. Higher (or possibly lower) loadings might be appropriate in some applications.

(a) Some factors that could increase (or decrease) the capacity of a hunt group follow.

- (1) Shorter (or longer) average message transmission time can influence hunt group capacity.
- (2) The use of audio monitoring (listen-in) slow-scan video or other similar equipment can significantly increase the connected time for a signal and reduce effective hunt group capacity.
- (3) The clustering of active burglar alarm signals can generate high peak loads at certain hours.
- (4) Inappropriate scheduling of 24-hour test signals can generate excessive peak loads.

(b) Demonstration of a 90 percent probability of incoming line availability can be accomplished by the following in-service monitoring of line activity.

- (1) Incoming lines are assigned to telephone hunt groups. When a DACT calls the main number of a hunt group, it can connect to any currently available line in that hunt group.

- (2) The receiver continuously monitors the "available" status of each line. A line is available when it is waiting for an incoming call. A line is unavailable for any of the following reasons:
 - a. Currently processing a call
 - b. Line in trouble
 - c. Audio monitoring (listen-in) in progress
 - d. Any other condition that makes the line input unable to accept calls
- (3) The receiver monitors the "available" status of the hunt group. A hunt group is available when any line in it is available.
- (4) A message is emitted by the receiver when a hunt group is unavailable for more than 1 minute out of 10 minutes. This message references the hunt group and the degree of overload.

A-5-5.3.2.2.2.4 The verification of the 24-hour DACR line test should be done early enough in the day to allow repairs to be made by the telephone company.

A-5-5.3.3.1.2 The recommended coded signal designations for a building having four floors and basements are provided in Table A-5-5.3.3.1.2.

Table A-5-5.3.3.1.2 Recommended Coded Signal Designations

Location	Coded Signal
Fourth floor	2-4
Third floor	2-3
Second floor	2-2
First floor	2-1
Basement	3-1
Sub-basement	3-2

A-5-5.3.3.1.4 The current readings, in accordance with 5-5.3.3.1.4(a), should be compared with the normal readings to determine if a change in the circuit condition has occurred. A zero current reading in accordance with 5-5.3.3.1.4(b) indicates that the circuit is clear of a foreign ground.

A-5-5.3.3.2.5(3) Though rare, it is understood that the occurrence of a wire-to-wire short on the primary trunk facility near the supervising station could disable the transmission system without immediate detection.

A-5-5.3.3.2.6(d)(3) Though rare, it is understood that the occurrence of a wire-to-wire short on the primary trunk facility near the supervising station could disable the transmission system without immediate detection.

A-5-5.3.3.3.5 At the time of system acceptance, verification should be made that manual fire alarm box signals are free of transmission channel interference.

A-5-5.3.4.4 The intent of the plurality of control sites is to safeguard against damage caused by lightning and to minimize the effect of interference on the receipt of signals. The control sites can be co-located.

A-5-5.3.5.2 It is intended that each RAT communicate with two or more independently located RARSRs. The location of such RARSRs should be such that they do not share common facilities.

NOTE: All probability calculations required for the purposes of Chapter 5 should be made in accordance with established communications procedures, should assume the maximum channel loading parameters specified, and should further assume that 25 RATs are actively in alarm and are being received by each RARSR.

A-5-5.3.6.5.2 If a single plant involves more than one gate entrance or involves a number of buildings, separate circuits might be required so that the alarm to the supervising station indicates the area to which the fire department is to be dispatched.

A-5-5.3.7.1 A private microwave radio can be used either as a transmission channel, to connect a transmitter to a supervising station or subsidiary station, or as a communications channel to connect a subsidiary station(s) to a supervising station(s). This can be done independently or in conjunction with wireline facilities.

A-5-5.3.7.2(b) Transmitters should be operated alternately, 16 hours on and 16 hours off.

A-5-5.5.1 The signal information can be permitted to be provided in coded form. Records can be permitted to be used to interpret these codes.

A-5-5.5.2 In order to expedite repairs, it is recommended that spare modules, such as printed circuit boards, CRT displays, or printers, be stocked at the supervising station.

A-5-5.5.3 For all forms of transmission, the maximum time to process an alarm signal should be 90 seconds. The maximum time to process a supervisory signal should be 4 minutes. The time to process an alarm or supervisory signal is defined as that time measured from receipt of a signal until retransmission or subscriber contact is initiated.

When the level of traffic in a supervising station system reaches a magnitude such that delayed response is possible, even if the loading tables or loading formulas of this code are not exceeded, it is envisioned that it will be necessary to employ an enhanced method of processing.

For example, in a system where a single DACR instrument provided with fire and burglar alarm service is connected to multiple telephone lines, it is conceivable that, during certain periods of the day, fire alarm signals could be delayed by the security signaling traffic, such as opening and closing signals. Such an enhanced system would perform as follows, upon receipt of a signal:

- (1) Automatically process the signals, differentiating between those that require immediate response by supervising station personnel and those that need only be logged
- (2) Automatically provide relevant subscriber information to assist supervising station personnel in their response
- (3) Maintain a timed, unalterable log of the signals received and the response of supervising station personnel to such signals

A-6-2.1 When choosing from available options to implement a public fire alarm reporting system, the operating agency should consider which of the choices would facilitate the maximum

reliability of the system, where such a choice is not cost prohibitive.

A-6-4.7 The current supply for designating lamps at street boxes should be secured at lamp locations from the local electric utility company.

Alternating-current power can be permitted to be superimposed on metallic fire alarm circuits for supplying designating lamps or for control or actuation of equipment devices for fire alarm or other emergency signals, provided the following conditions exist.

(a) Voltages between any wire and ground or between one wire and any other wire of the system should not exceed 150 volts, and the total resultant current in any line circuit should not exceed $1/4$ ampere.

(b) Components such as coupling capacitors, transformers, chokes, or coils are rated for 600-volt working voltage and have a breakdown voltage of at least twice the working voltage plus 1000 volts.

(c) There is no interference with fire alarm service under any conditions.

A-6-5.3 If the operating mechanism of a box creates sufficient sound to be heard by the user, the requirements are satisfied.

A-6-5.9 The current supply for designating lights at street boxes should be secured at lamp locations from the local electric utility company.

Alternating-current power can be permitted to be superimposed on metallic fire alarm circuits for supplying designating lamps or for control or actuation of equipment devices for fire alarm or other emergency signals, provided the following conditions exist.

(a) Voltage between any wire and ground or between one wire and any other wire of the system does not exceed 150 volts, and the total resultant current in any line circuit does not exceed $1/4$ ampere.

(b) Components such as coupling capacitors, transformers, chokes, or coils are rated for 600-volt working voltage and have a breakdown voltage of at least twice the working voltage plus 1000 volts.

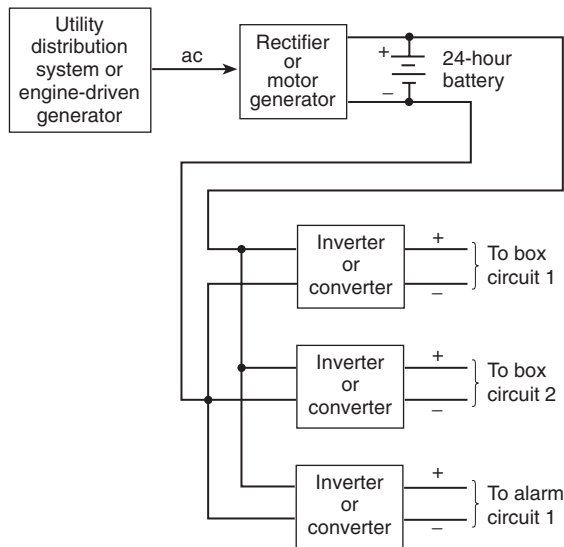
(c) There is no interference with fire alarm service under any conditions.

A-6-5.12.3 The following is an excerpt from the *FCC Rules and Regulations*, Vol. V, Part 90, March 1979:

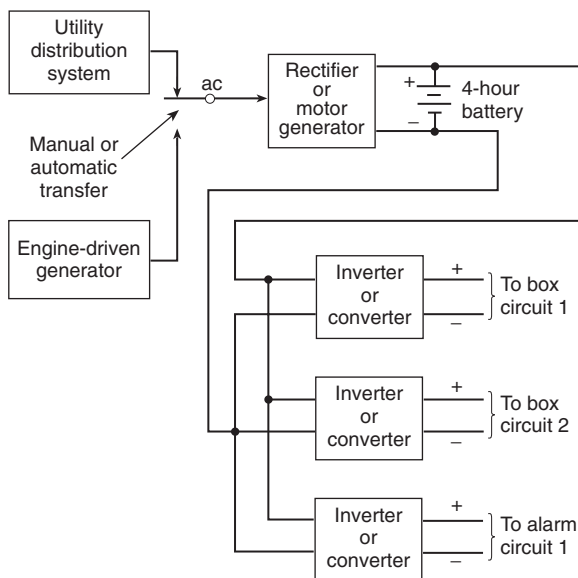
“Except for test purposes, each transmission must be limited to a maximum of 2 seconds and may be automatically repeated not more than two times at spaced intervals within the following 30 seconds; thereafter, the authorized cycle may not be reactivated for 1 minute.”

A-6-6 Where the intent is for complete coverage, it should not be necessary to travel in excess of one block or 500 ft (150 m) to reach a box. In residential areas, it should not be necessary to travel in excess of two blocks or 800 ft (240 m) to reach a box.

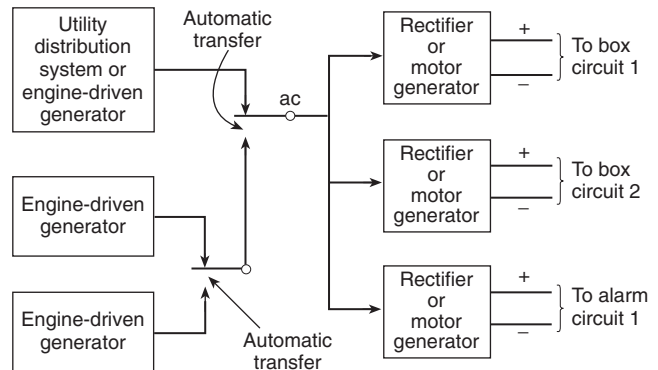
A-6-7.1.8.1(a) Figure A-6-7.1.8.1(a) illustrates a Form 4A arrangement.

Figure A-6-7.1.8.1(a) Form 4A.

A-6-7.1.8.1(b) Figure A-6-7.1.8.1(b) illustrates a Form 4B arrangement.

Figure A-6-7.1.8.1(b) Form 4B.

A-6-7.1.8.1(d) Figure A-6-7.1.8.1(d) illustrates a Form 4C arrangement. Refer to NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*.

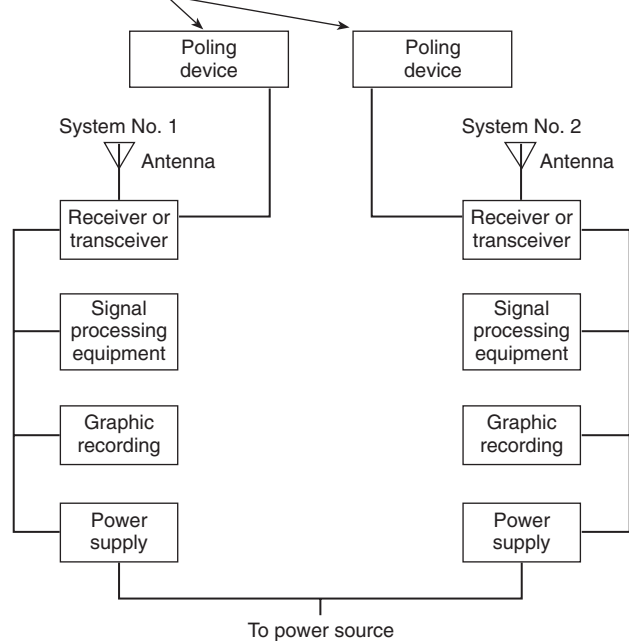
Figure A-6-7.1.8.1(d) Form 4C.

A-6-9.1.4 All requirements for circuit protection do not apply to coded radio reporting systems. These systems do not use metallic circuits.

A-6-14.3.1.1 Figure A-6-14.3.1.1 illustrates a Type A receiving network.

Figure A-6-14.3.1.1 Type A system receiving networks.

Poling required for transpondence-type (two-way) systems only.



A-6-14.6.3 The transmission of an actual emergency-related message, initiated at the same time it is preselected for a test message, and, in turn, preempts said test message, must satisfy the intent of this requirement.

A-6-16.4.1(a) The local energy-type system [refer to Figures A-6-16.4.1(a)(1) and A-6-16.4.1(a)(2)] is electrically isolated from the public fire alarm reporting system and has its own power supply. The tripping of the transmitting device does not depend on the current in the system. In a wired circuit, receipt of the alarm by the communications center when

the circuit is accidentally opened depends on the design of the transmitting device and the associated communications center equipment (in other words, whether or not the system is designed to receive alarms through manual or automatic ground operational facilities). In a radio box-type system, receipt of the alarm by the communications center depends on the proper operation of the radio transmitting and receiving equipment.

Figure A-6-16.4.1(a)(1) Local energy-type auxiliary fire alarm system.

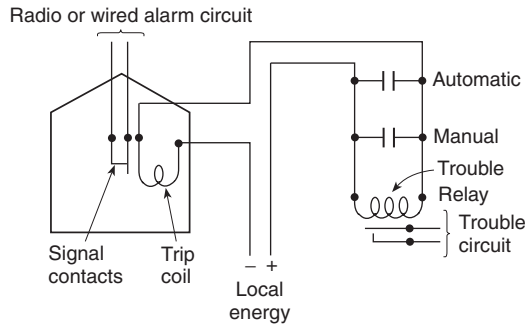
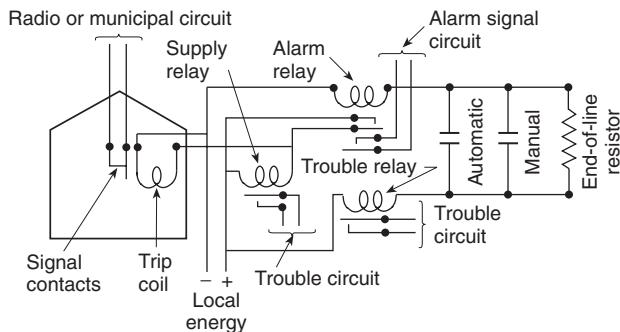


Figure A-6-16.4.1(a)(2) Local energy-type auxiliary fire alarm system.



A-6-16.4.1(b) The shunt-type system [refer to Figures A-6-16.4.1(b)(1) and A-6-16.4.1(b)(2)] is electrically connected to, and is an integral part of, the public fire alarm reporting system. A ground fault on the auxiliary circuit is a fault on the public fire alarm reporting system circuit, and an accidental opening of the auxiliary circuit sends a needless (or false) alarm to the communications center. An open circuit in the transmitting device trip coil is not indicated either at the protected property or at the communications center. Also, if an initiating device is operated, an alarm is not transmitted, but an open circuit indication is given at the communications center. If a public fire alarm reporting system circuit is open when a connected shunt-type system is operated, the transmitting device does not trip until the public fire alarm reporting system circuit returns to normal, at which time the alarm is transmitted, unless the auxiliary circuit is first returned to a normal condition.

Additional design restrictions for shunt-type systems are found in laws or ordinances.

Figure A-6-16.4.1(b)(1) Shunt-type auxiliary fire alarm system.

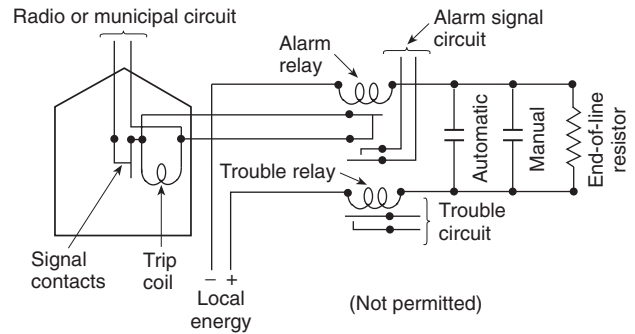
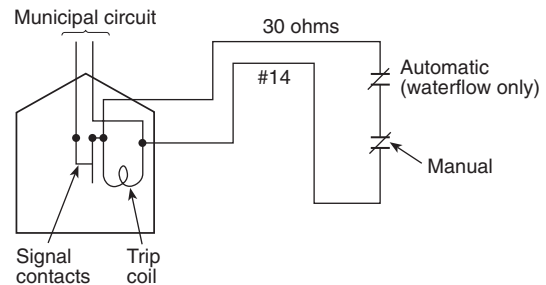


Figure A-6-16.4.1(b)(2) Shunt-type auxiliary fire alarm system.



A-7-1.3 Prior to any scheduled inspection or testing, the service company should consult with the building owner or the owner's designated representative. Issues of advance notification in certain occupancies, including advance notification time, building posting, systems interruption and restoration, evacuation procedures, accommodation for evacuees, and other related issues, should be agreed upon by all parties prior to any inspection or testing.

A-7-1.6.2 The additional devices to be tested should be a sample representation of the types of devices and locations on the system.

A-7-2.1 If the authority having jurisdiction strongly suspects significant deterioration or otherwise improper operation by a central station, a surprise inspection to test the operation of the central station should be made, but extreme caution should be exercised. This test is to be conducted without advising the central station. However, the public fire service communications center must be contacted when manual alarms, waterflow alarms, or automatic fire detection systems are tested so that the fire department will not respond. In addition, persons normally receiving calls for supervisory alarms should be notified when items such as gate valves and functions such as pump power are tested. Confirmation of the authenticity of the test procedure should be obtained and should be a matter for resolution between plant management and the central station.

A-7-2.2 The wiring diagrams depicted in Figures A-7-2.2(a)(1) through A-7-2.2(a)(17) are representative of typical circuits encountered in the field and are not intended to be all-inclusive.

The noted styles are as indicated in Table 3-5, Table 3-6, Table 3-7, and Table 5-5.3.2.2.3.

The noted systems are as indicated in NFPA 170, *Standard for Fire Safety Symbols*.

Because ground-fault detection is not required for all circuits, tests for ground-fault detection should be limited to those circuits equipped with ground-fault detection.

An individual point-identifying (addressable) initiating device operates on a signaling line circuit and not on a Style A, B, C, D, or E (Class B and Class A) initiating device circuit.

All of the following initiating device circuits are illustrative of either alarm or supervisory signaling. Alarm-initiating devices and supervisory initiating devices are not permitted on the same initiating device circuit.

In addition to losing its ability to receive an alarm from an initiating device located beyond an open fault, a Style A (Class B) initiating device circuit also loses its ability to receive an alarm when a single ground fault is present.

Style C and Style E (Class B and Class A) initiating device circuits can discriminate between an alarm condition and a wire-to-wire short. In these circuits, a wire-to-wire short provides a trouble indication. However, a wire-to-wire short prevents alarm operation. Shorting-type initiating devices cannot be used without an additional current or voltage limiting element.

Directly-connected system smoke detectors, commonly referred to as two-wire detectors, should be listed as being electrically and functionally compatible with the control unit and the specific subunit or module to which they are connected. If the detectors and the units or modules are not compatible, it is possible that, during an alarm condition, the detector's visible indicator will illuminate, but no change of state to the alarm condition will occur at the control unit. Incompatibility can also prevent proper system operation at extremes of operating voltage, temperature, and other environmental conditions.

Where two or more two-wire detectors with integral relays are connected to a single initiating device circuit and their relay contacts are used to control essential building functions (for example, fan shutdown, elevator recall), it should be clearly noted that the circuit might be capable of supplying only enough energy to support one detector/relay combination in an alarm mode. If control of more than one building function is required, each detector/relay combination used to control separate functions should be connected to separate initiating device circuits, or they should be connected to an initiating device circuit that provides adequate power to allow all the detectors connected to the circuit to be in the alarm mode simultaneously. During acceptance and reacceptance testing, this feature should always be tested and verified.

A speaker is an alarm-indicating appliance, and, if used as shown in the following diagrams, the principle of operation and supervision is the same as for other audible alarm indicating appliances (for example, bells and horns).

The testing of supervised remote relays is to be conducted in the same manner as for indicating appliances.

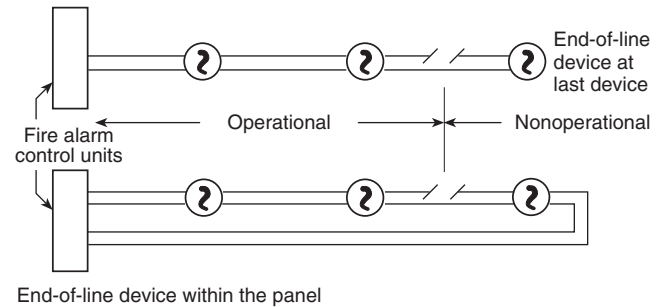
(a) Wiring Diagrams.

NOTE: When testing circuits, the correct wiring size, insulation type, and conductor fill should be verified in accordance with the requirements of NFPA 70, *National Electrical Code*.

- (1) *Nonpowered Alarm-Initiating or Supervisory-Initiating Devices (e.g., Manual Station or Valve Supervisory Switch) Connected to Style A, B, or C Initiating Device Circuits.* Disconnect conductor at device or control unit, then reconnect. Temporarily connect a ground to either leg of conductors, then remove ground. Both operations should indicate audible and visual trouble with subsequent restoration at control unit. Conductor-to-conductor short should initiate alarm. Style

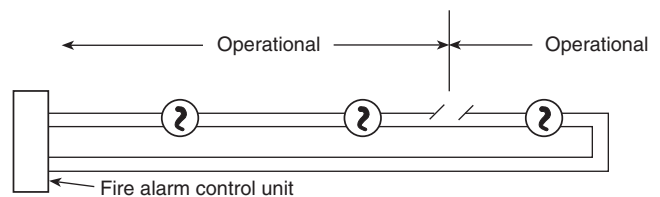
A and Style B (Class B) indicate trouble Style C (Class B). Style A (Class B) does not initiate alarm while in trouble condition.

Figure A-7-2.2(a)(1) Nonpowered alarm-initiating or supervisory-initiating devices connected to Style A, B, or C initiating device circuits.



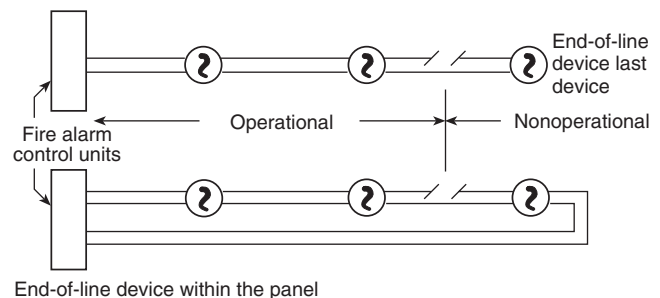
- (2) *Nonpowered Alarm-Initiating or Supervisory-Initiating Devices Connected to Style D or E Initiating Device Circuits.* Disconnect a conductor at a device at midpoint in the circuit. Operate a device on either side of the device with the disconnected conductor. Reset control unit and reconnect conductor. Repeat test with a ground applied to either conductor in place of the disconnected conductor. Both operations should indicate audible and visual trouble, then alarm or supervisory indication with subsequent restoration.

Figure A-7-2.2(a)(2) Nonpowered alarm-initiating or supervisory-initiating devices connected to Style D or E initiating device circuits.



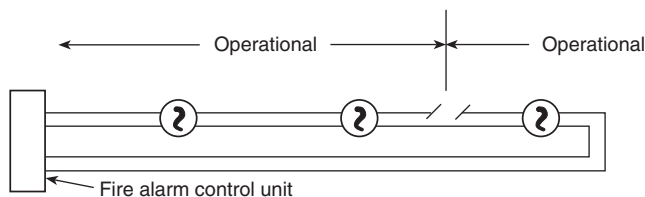
- (3) *Circuit-Powered (Two-Wire) Smoke Detectors for Style A, B, or C Initiating Device Circuits.* Remove smoke detector where installed with plug-in base or disconnect conductor from control unit beyond first device. Activate smoke detector per manufacturer's recommendations between control unit and circuit break. Restore detector or circuit, or both. Control unit should indicate trouble where fault occurs and alarm where detectors are activated between the break and the control unit.

Figure A-7-2.2(a)(3) Circuit-powered (two-wire) smoke detectors for Style A, B, or C initiating device circuits.



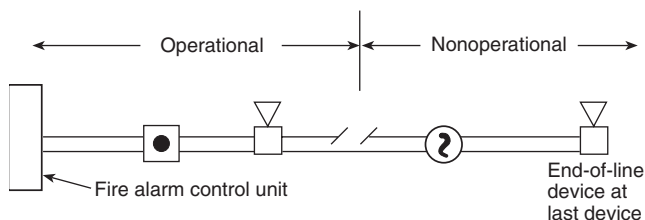
- (4) *Circuit-Powered (Two-Wire) Smoke Detectors for Style D or E Initiating Device Circuits.* Disconnect conductor at a smoke detector or remove where installed with a plug-in base at midpoint in the circuit. Operate a device on either side of the device with the fault. Reset control unit and reconnect conductor or detector. Repeat test with a ground applied to either conductor in place of the disconnected conductor or removed device. Both operations should indicate audible and visual trouble, then alarm indication with subsequent restoration.

Figure A-7-2.2(a)(4) Circuit-powered (two-wire) smoke detectors for Styles D or E initiating device circuits.



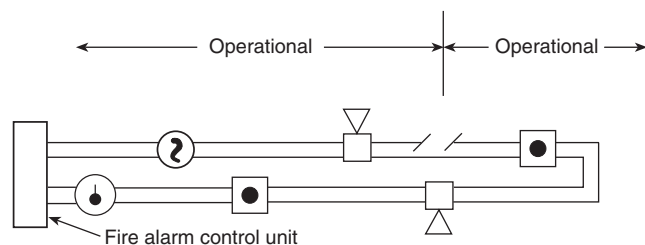
- (5) *Combination Alarm-Initiating Device and Indicating Appliance Circuits.* Disconnect a conductor either at indicating or initiating device. Activate initiating device between the fault and the control unit. Activate additional smoke detectors between the device first activated and the control unit. Restore circuit, initiating devices, and control unit. Confirm that all indicating appliances on the circuit operate from the control unit up to the fault and that all smoke detectors tested and their associated ancillary functions, if any, operate.

Figure A-7-2.2(a)(5) Combination alarm-initiating device and indicating appliance circuits.



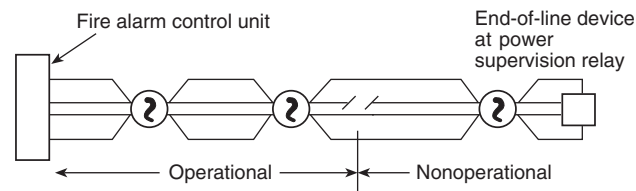
- (6) *Combination Alarm-Initiating Device and Indicating Appliance Circuits Arranged for Operation with a Single Open or Ground Fault.* Testing of the circuit is similar to that described in (e). Confirm that all indicating appliances operate on either side of fault.

Figure A-7-2.2(a)(6) Combination alarm-initiating device and indicating appliance circuits arranged for operation with a single open or ground fault.



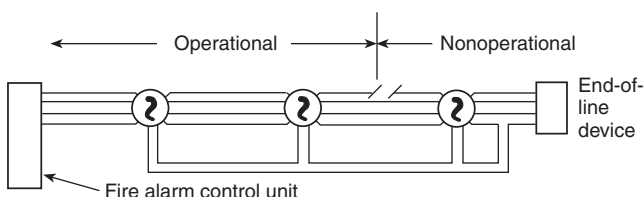
- (7) *Style A, B, or C Circuits with Four-Wire Smoke Detectors and an End-of-Line Power Supervision Relay.* Testing of the circuit is similar to that described in (c) and (d). Disconnect a leg of the power supply circuit beyond the first device on the circuit. Activate initiating device between the fault and the control unit. Restore circuits, initiating devices, and control unit. Audible and visual trouble should indicate at the control unit where either the initiating or power circuit is faulted. All initiating devices between the circuit fault and the control unit should activate. In addition, removal of a smoke detector from a plug-in-type base can also break the power supply circuit. Where circuits contain various powered and nonpowered devices on the same initiating circuit, verify that the nonpowered devices beyond the power circuit fault can still initiate an alarm. A return loop should be brought back to the last powered device and the power supervisory relay to incorporate into the end-of-line device.

Figure A-7-2.2(a)(7) Style A, B, or C circuits with four-wire smoke detectors and an end-of-line power supervision relay.



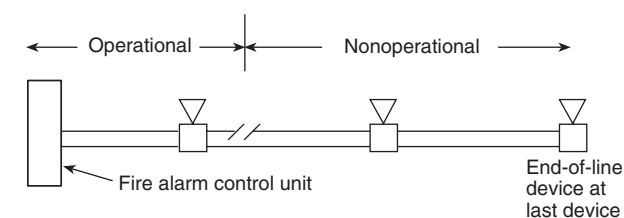
- (8) *Style A, B, or C Initiating Device Circuits with Four-Wire Smoke Detectors that Include Integral Individual Supervision Relays.* Testing of the circuit is similar to that described in (c) with the addition of a power circuit.

Figure A-7-2.2(a)(8) Style A, B, or C initiating device circuits with four-wire smoke detectors that include integral individual supervision relays.



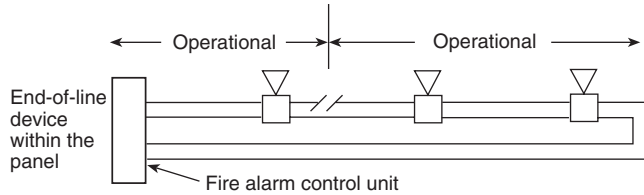
- (9) *Alarm Indicating Appliances Connected to Styles W and Y (Two-Wire) Circuits.* Testing of the indicating appliances connected to Style W and Style Y (Class B) is similar to that described in (c).

Figure A-7-2.2(a)(9) Alarm indicating appliances connected to Styles W and Y (two-wire) circuits.



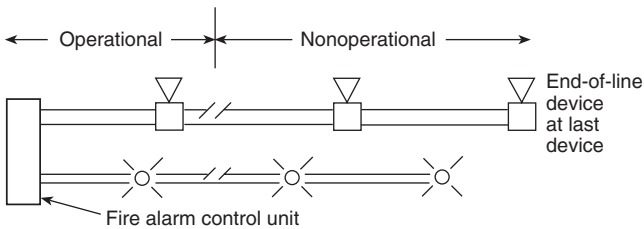
- (10) *Alarm Indicating Appliances Connected to Styles X and Z (Four-Wire) Circuits.* Testing of the indicating appliances connected to Style X and Style Z (Class B and Class A) is similar to that described in (d).

Figure A-7-2.2(a)(10) Alarm indicating appliances connected to Styles X and Z (four-wire) circuits.



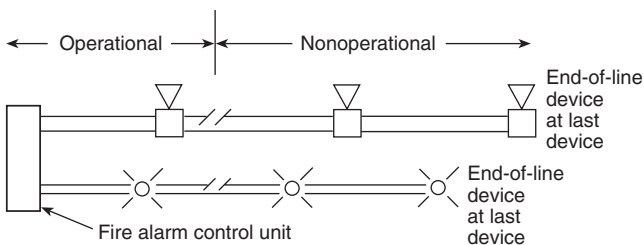
- (11) *System with a Supervised Audible Indicating Appliance Circuit and an Unsupervised Visible Indicating Appliance Circuit.* Testing of the indicating appliances connected to Style X and Style Z (Class B and Class A) is similar to that described in (d).

Figure A-7-2.2(a)(11) Supervised audible indicating appliance circuit and an unsupervised visible indicating appliance circuit.



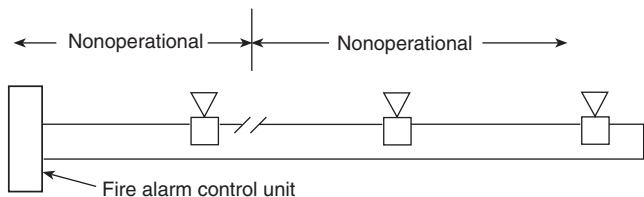
- (12) *System with Supervised Audible and Visible Indicating Appliance Circuits.* Testing of the indicating appliances connected to Style X and Style Z (Class B and Class A) is similar to that described in (d).

Figure A-7-2.2(a)(12) Supervised audible and visible indicating appliance circuits.



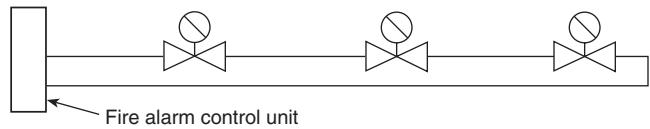
- (13) *Series Indicating Appliance Circuit, which No Longer Meets the Requirements of NFPA 72.* An open fault in the circuit wiring should cause a trouble condition.

Figure A-7-2.2(a)(13) Series indicating appliance circuit.



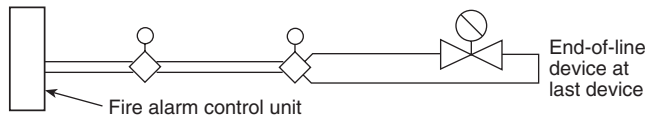
- (14) *Supervised Series Supervisory-Initiating Circuit with Sprinkler Supervisory Valve Switches Connected, which No Longer Meets the Requirements of NFPA 72.* An open fault in the circuit wiring of operation of the valve switch (or any supervisory signal device) should cause a trouble condition.

Figure A-7-2.2(a)(14) Supervised series supervisory-initiating circuit with sprinkler supervisory valve switches connected.



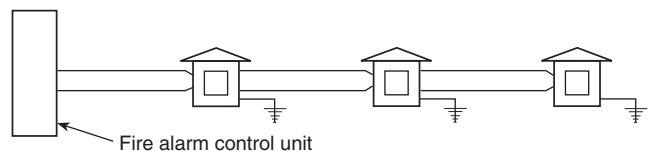
- (15) *Initiating Device Circuit with Parallel Waterflow Alarm Switches and a Series Supervisory Valve Switch, which No Longer Meets the Requirements of NFPA 72.* An open fault in the circuit wiring or operation of the valve switch should cause a trouble signal.

Figure A-7-2.2(a)(15) Initiating device circuit with parallel waterflow alarm switches and a series supervisory-valve switch.



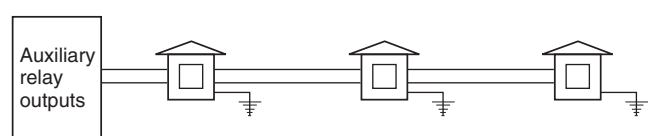
- (16) *System Connected to a Municipal Fire Alarm Master Box Circuit.* Disconnect a leg of municipal circuit at master box. Verify alarm sent to public communications center. Disconnect leg of auxiliary circuit. Verify trouble condition on control unit. Restore circuits. Activate control unit and send alarm signal to communications center. Verify control unit in trouble condition until master box reset.

Figure A-7-2.2(a)(16) System connected to a municipal fire alarm master box circuit.



- (17) *Auxiliary Circuit Connected to a Municipal Fire Alarm Master Box.* For operation with a master box, an open or ground fault (where ground detection is provided) on the circuit should result in a trouble condition at the control unit. A trouble signal at the control unit should persist until the master box is reset. For operation with a shunt trip master box, an open fault in the auxiliary circuit should cause an alarm on the municipal system.

Figure A-7-2.2(a)(17) Auxiliary circuit connected to a municipal fire alarm master box.



(b) *Circuit Styles.*

NOTE: Some testing laboratories and authorities having jurisdiction permit systems to be classified as a Style 7 (Class A) by the application of two circuits of the same style operating in parallel. An example of this is to take two series circuits, either Style 0.5 or Style 1.0 (Class B), and operate them in parallel. The logic is that if a condition occurs on one of the circuits, the other parallel circuit remains operative.

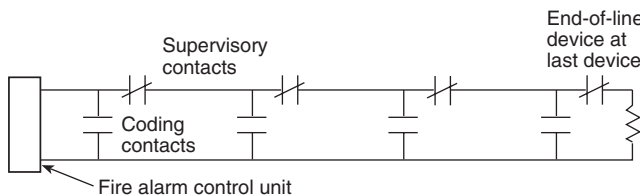
In order to understand the principles of the circuit, alarm receipt capability should be performed on a single circuit, and the style type, based on the performance, should be indicated on the record of completion.

- (1) *Style 0.5.* This signaling circuit operates as a series circuit in performance. This is identical to the historical series audible signaling circuits. Any type of break or ground in one of the conductors, or the internal of the multiple interface device, and the total circuit is rendered inoperative.

To test and verify this type of circuit, either a conductor should be lifted or an earth ground should be placed on a conductor or a terminal point where the signaling circuit attaches to the multiplex interface device.

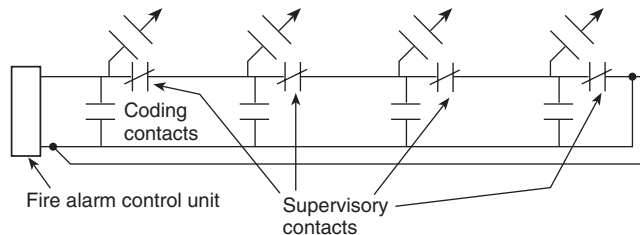
- (2) *Style 0.5(a) (Class B) Series.* Style 0.5(a) functions so that, when a box is operated, the supervisory contacts open, making the succeeding devices nonoperative while the operating box sends a coded signal. Any alarms occurring in any successive devices will not be received at the receiving station during this period.

Figure A-7-2.2(b)(2) Style 0.5(a) (Class B) series.



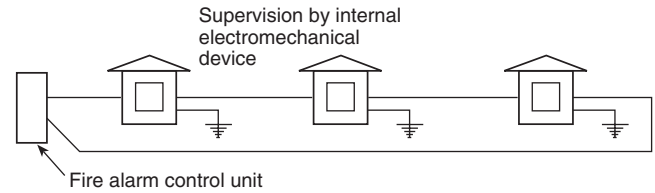
- (3) *Style 0.5(b) (Class B) Shunt.* The contact closes when the device is operated and remains closed to shunt out the remainder of the system until the code is complete.

Figure A-7-2.2(b)(3) Style 0.5(b) (Class B) shunt.



- (4) *Style 0.5(c) (Class B) Positive Supervised Successive.* An open or ground fault on the circuit should cause a trouble condition at the control unit.

Figure A-7-2.2(b)(4) Style 0.5(c) (Class B) positive supervised successive.



- (5) *Style 1.0 (Class B).* This is a series circuit identical to the diagram for Style 0.5, except that the fire alarm system hardware has enhanced performance. A single earth ground can be placed on a conductor or multiplex interface device, and the circuit and hardware still have alarm operability.

If a conductor break or an internal fault occurs in the pathway of the circuit conductors, the entire circuit becomes inoperative.

To verify alarm receipt capability and the resulting trouble signal, place an earth ground on one of the conductors or at the point where the signaling circuit attaches to the multiplex interface device. One of the transmitters or an initiating device should then be placed into alarm.

Figure A-7-2.2(b)(5)(a) Style 1.0 (Class B).

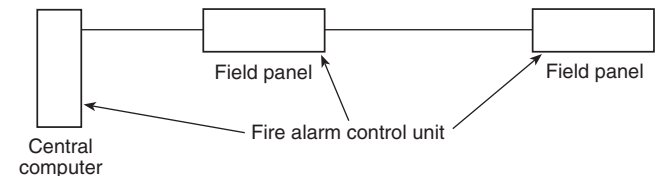
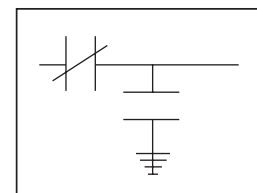
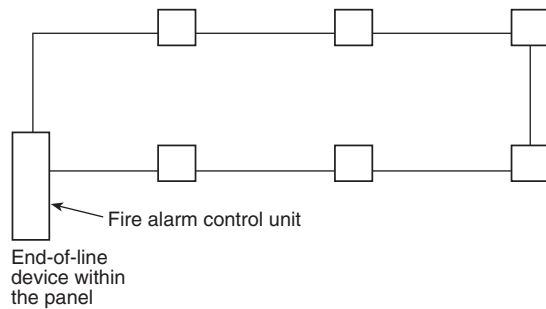


Figure A-7-2.2(b)(5)(b) Typical transmitter layout.



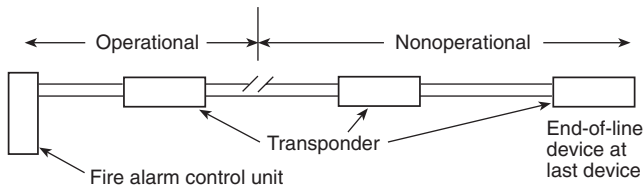
- (6) *Typical McCulloh Loop.* This is the central station McCulloh redundant-type circuit and has alarm receipt capability on either side of a single break.

- a. To test, lift one of the conductors and operate a transmitter or initiating device on each side of the break. This activity should be repeated for each conductor.
- b. Place an earth ground on a conductor and operate a single transmitter or initiating device to verify alarm receipt capability and trouble condition for each conductor.
- c. Repeat the instructions of (a) and (b) at the same time and verify alarm receipt capability, and verify that a trouble condition results.

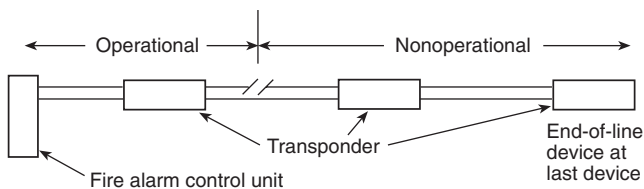
Figure A-7-2.2(b)(6) Typical McCulloh loop.

- (7) *Style 3.0 (Class B)*. This is a parallel circuit in which multiplex interface devices transmit signal and operating power over the same conductors. The multiplex interface devices might be operable up to the point of a single break. Verify by lifting a conductor and causing an alarm condition on one of the units between the central alarm unit and the break. Either lift a conductor to verify the trouble condition or place an earth ground on the conductors. Test for all the valuations shown on the signaling table.

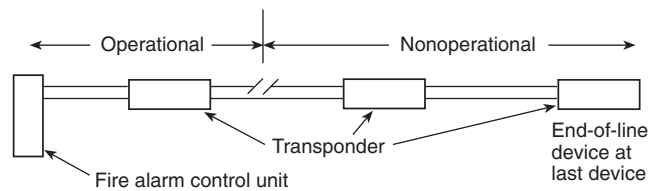
On ground-fault testing, verify alarm receipt capability by actuating a multiplex interface initiating device or a transmitter.

Figure A-7-2.2(b)(7) Style 3.0 (Class B).

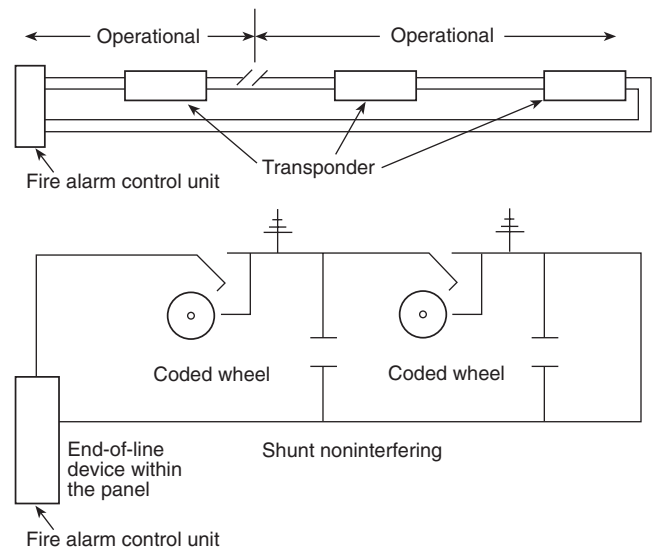
- (8) *Style 3.5 (Class B)*. Repeat the instructions for Style 3.0 (Class B) and verify the trouble conditions by either lifting a conductor or placing a ground on the conductor.

Figure A-7-2.2(b)(8) Style 3.5 (Class B).

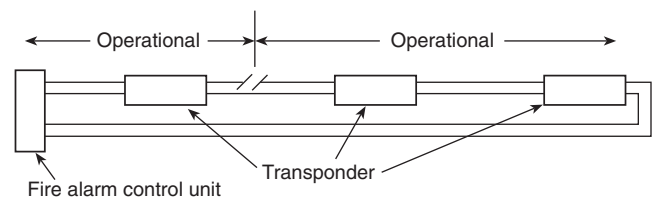
- (9) *Style 4.0 (Class B)*. Repeat the instructions for Style 3.0 (Class B) and include a loss of carrier where the signal is being used.

Figure A-7-2.2(b)(9) Style 4.0 (Class B).

- (10) *Style 4.5 (Class B)*. Repeat the instructions for Style 3.5 (Class B). Verify alarm receipt capability while lifting a conductor by actuating a multiple interface device or transmitter on each side of the break.

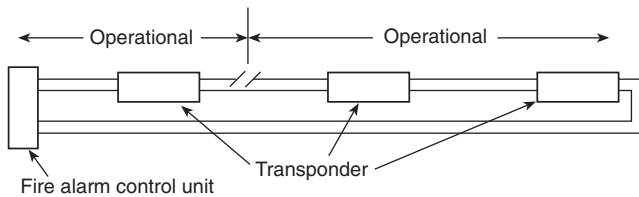
Figure A-7-2.2(b)(10) Style 4.5 (Class B).

- (11) *Style 5.0 (Class A)*. Verify the alarm receipt capability and trouble annunciation by lifting a conductor and actuating a multiplex interfacing device or a transmitter on each side of the break. For the earth ground verification, place an earth ground and certify alarm receipt capability and trouble annunciation by actuating a single multiplex interfacing device or a transmitter.

Figure A-7-2.2(b)(11) Style 5.0 (Class A).

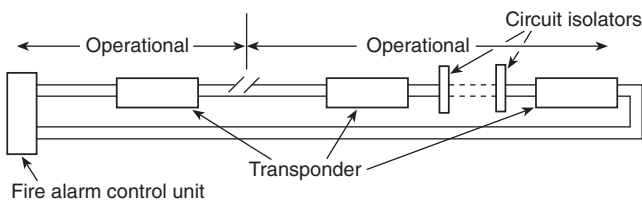
- (12) *Style 6.0 (Class A)*. Repeat the instructions for Style 2.0 [Class A (a) through (c)]. Verify the remaining steps for trouble annunciation for the various combinations.

Figure A-7-2.2(b)(12) Style 6.0 (Class A).



(13) *Style 6.0 (with Circuit Isolators) (Class A)*. For the portions of the circuits electrically located between the monitoring points of circuit isolators, follow the instructions for a Style 7.0 (Class A) circuit. It should be clearly noted that the alarm receipt capability for remaining portions of the circuit protection isolators is not the capability of the circuit, but is permitted with enhanced system capabilities.

Figure A-7-2.2(b)(13) Style 6.0 (with circuit isolators) (Class A).



(14) *Style 7.0 (Class A)*. Repeat the instructions for testing of Style 6.0 (Class A) for alarm receipt capability and trouble annunciation.

NOTE 1: A portion of the circuit between the alarm processor or central supervising station and the first circuit isolator does not have alarm receipt capability in the presence of a wire-to-wire short. The same is true for the portion of the circuit from the last isolator to the alarm processor or the central supervising station.

NOTE 2: Some manufacturers of this type of equipment have isolators as part of the base assembly. Therefore, in the field, this component might not be readily observable without the assistance of the manufacturer's representative.

Figure A-7-2.2(b)(14)(a) Style 7.0 (Class A).

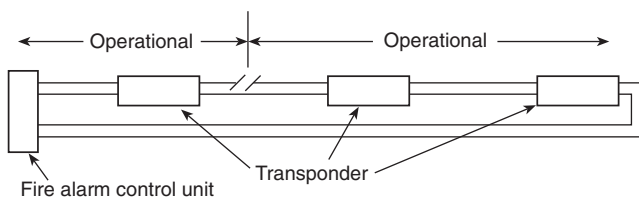
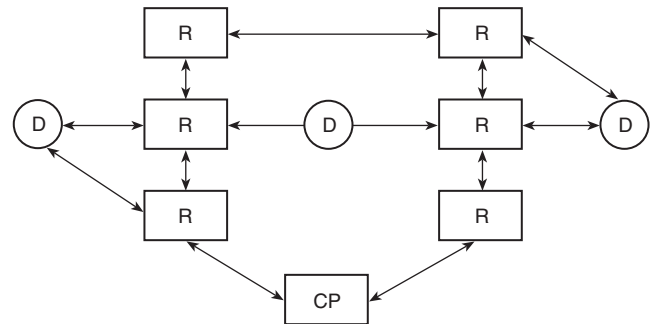


Figure A-7-2.2(b)(14)(b) Low-power radio (wireless) fire alarm system.



CP = Wireless control panel
(with power supply and standby power)
R = Wireless repeater
(with power supply and standby power)
D = Wireless initiating, indicating, and control device
(either primary battery or primary standby battery)

Figure A-7-2.2(b)(14)(c) Two-way RF multiplex systems.

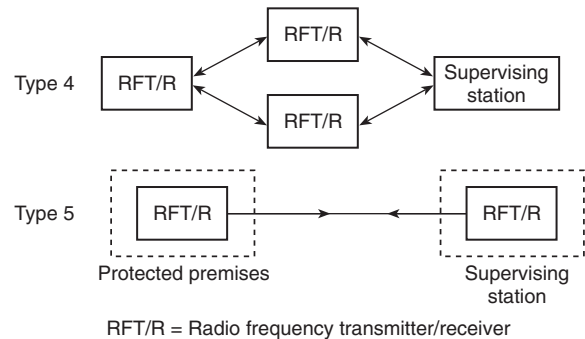


Figure A-7-2.2(b)(14)(d) One-way radio alarm system.

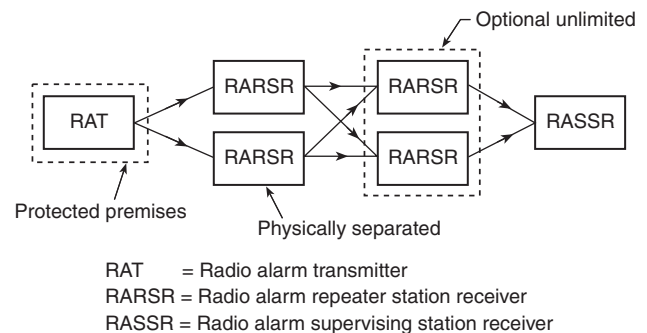
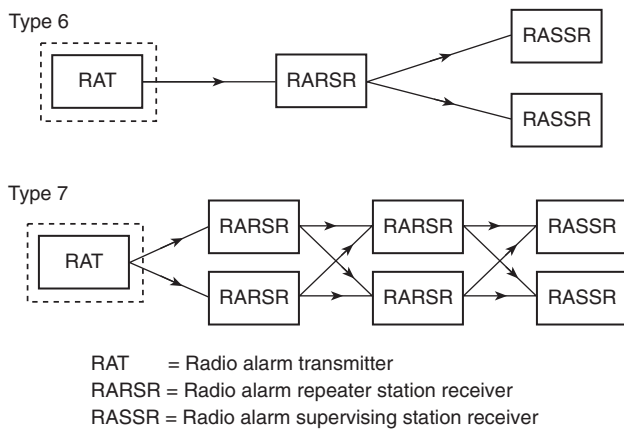
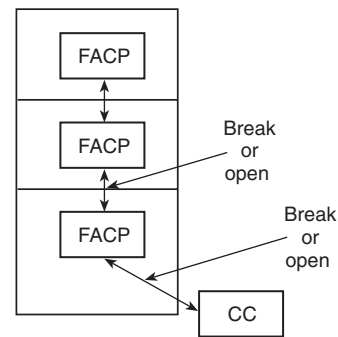
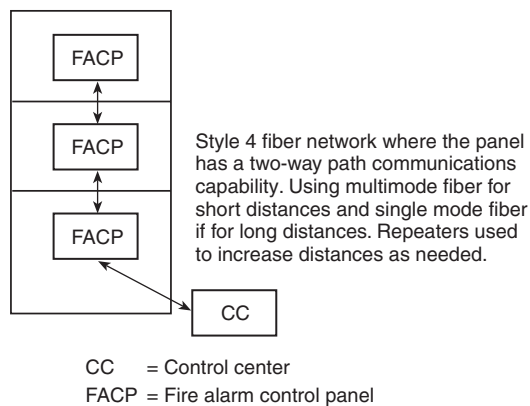
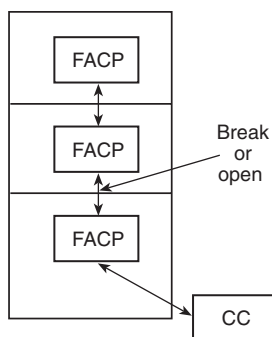


Figure A-7-2.2(b)(14)(e) One-way radio alarm system.**Figure A-7-2.2(b)(14)(h) Style 4 fiber network.**

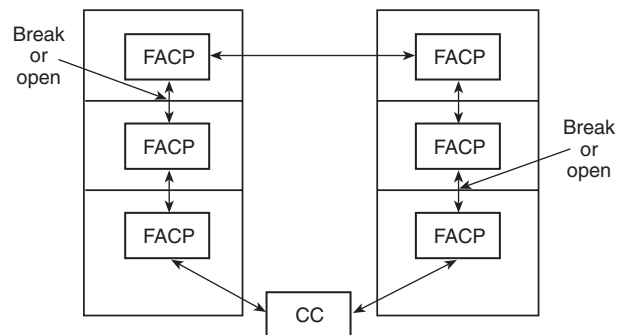
Style 4 fiber network where the panel has a two-way path communications capability. A double break isolates the panels and the control center in this case. In this case, there is one LAN and one isolated panel operating on its own. Control center is isolated completely with no communications with the network.

CC = Control center
FACP = Fire alarm control panel

Figure A-7-2.2(b)(14)(f) Style 4 fiber network.**Figure A-7-2.2(b)(14)(g) Style 4 fiber network.**

Style 4 fiber network where the panel has a two-way path communications capability. A single break separates the system into two LANs both with Style 4 capabilities.

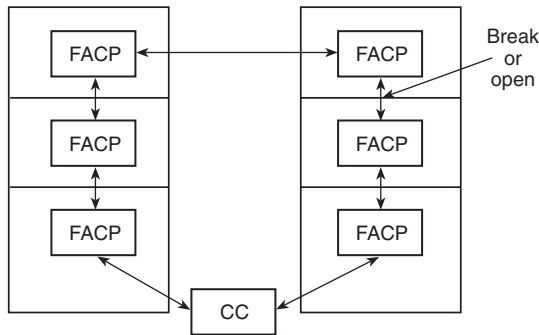
CC = Control center
FACP = Fire alarm control panel

Figure A-7-2.2(b)(14)(i) Style 7 fiber network.

Style 7 fiber network where the panel has a two-way path communications capability with the two breaks now breaking into two LANs, both functioning as independent networks with the same Style 7 capabilities.

CC = Control center
FACP = Fire alarm control panel

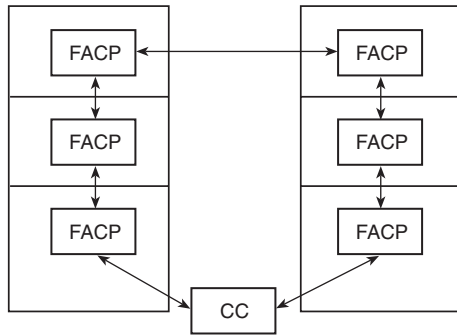
Figure A-7.2.2(b)(14)(j) Style 7 fiber network.



Style 7 fiber network where the panel has a two-way path communications capability, with one break. System remains as one LAN and meets Style 7.

CC = Control center
FACP = Fire alarm control panel

Figure A-7.2.2(b)(14)(k) Style 7 fiber network.



Style 7 fiber network where the panel has a two-way path communications capability.

CC = Control center
FACP = Fire alarm control panel

(c) *Batteries.* To maximize battery life, nickel-cadmium batteries should be charged as in Table A-7-2.2(c) (1).

Table A-7-2.2(c)(1) Voltage for Nickel-Cadmium Batteries

Float voltage	1.42 volts/cell + 0.01 volt
High rate voltage	1.58 volts/cell + 0.07 volt – 0.00 volt

Note: High and low gravity voltages are (+) 0.07 volt and (–) 0.03 volt, respectively.

To maximize battery life, the battery voltage for lead-acid cells should be maintained within the limits shown in Table A-7-2.2(c) (2).

Table A-7-2.2(c)(2) Voltage for Lead-Acid Batteries

Float Voltage	High-Gravity Battery (Lead Calcium)	Low-Gravity Battery (Lead Antimony)
Maximum	2.25 volts/cell	2.17 volts/cell
Minimum	2.20 volts/cell	2.13 volts/cell
High rate voltage	—	2.33 volts/cell

The following procedure is recommended for checking the state of charge for nickel-cadmium batteries:

- (1) The battery charger should be switched from float to high-rate mode.
- (2) The current, as indicated on the charger ammeter, will immediately rise to the maximum output of the charger, and the battery voltage, as shown on the charger voltmeter, will start to rise at the same time.
- (3) The actual value of the voltage rise is unimportant, because it depends on many variables. The length of time it takes for the voltage to rise is the important factor.
- (4) If, for example, the voltage rises rapidly in a few minutes, then holds steady at the new value, the battery is fully charged. At the same time, the current will drop to slightly above its original value.
- (5) In contrast, if the voltage rises slowly and the output current remains high, the high-rate charge should be continued until the voltage remains constant. Such a condition is an indication that the battery is not fully charged, and the float voltage should be increased slightly.

A-7-2.2 Table Line/Item 6.c.1. Example: $4000 \text{ mAh} \times \frac{1}{25} = 160 \text{ mA}$ charging current at 25°C (77°F).

A-7-2.2 Table Line/Item 7(c). The voltmeter sensitivity has been changed from 1000 ohms per volt to 100 ohms per volt so that false ground readings (caused by induced voltages) are minimized.

A-7-2.2 Table Line/Item 13.a.2. Fusible thermal link detectors are commonly used to close fire doors and fire dampers. They are actuated by the presence of external heat, which causes a solder element in the link to fuse, or by an electric thermal device, which, when energized, generates heat within the body of the link, causing the link to fuse and separate.

A-7-3.1 Equipment performance can be affected by building modifications, occupancy changes, changes in environmental conditions, device location, physical obstructions, device orientation, physical damage, improper installation, degree of cleanliness, or other obvious problems that might not be indicated through electrical supervision.

A-7-3.2 It is suggested that the annual test be conducted in segments so that all devices are tested annually.

A-7-3.2.1 Detectors that cause unwanted alarms should be tested at their lower listed range (or at 0.5 percent obscuration if unmarked or unknown). Detectors that activate at less than this level should be replaced.

A-7-3.2.4 The addressable term was determined by the Technical Committee in Formal Interpretation 79-8 on NFPA 72D and Formal Interpretation 87-1 on NFPA 72A.

A-7-5.1 For final determination of record retention, refer to 7-3.2.1 for sensitivity options.

A-7-5.2.2(9) One method used to define the required sequence of operations and to document the actual sequence of operations is an input/output matrix. [Refer to Figure A-7-5.2.2(9).]

A-8-1 Household Fire Warning Protection.

(a) *Fire Danger in the Home.* Fire is the third leading cause of accidental death. Residential occupancies account for most fire fatalities, and most of these deaths occur at night during the sleeping hours.

Most fire injuries also occur in the home. It is estimated that 1.5 million Americans are injured by fire each year. Many never resume normal lives.

It is estimated that each household will experience three (usually unreported) fires per decade and two fires serious enough to report to a fire department per lifetime.

(b) *Fire Safety in the Home.* NFPA 72 is intended to provide reasonable fire safety for persons in family living units. Reasonable fire safety can be produced through the following three-point program:

- (1) Minimizing fire hazards
- (2) Providing a fire warning system
- (3) Having and practicing an escape plan

(c) *Minimizing Fire Hazards.* This code cannot protect all persons at all times. For instance, the application of this code might not provide protection against the following three traditional fatal fire scenarios:

- (1) Smoking in bed
- (2) Leaving children home alone
- (3) Cleaning with flammable liquids such as gasoline

However, Chapter 8 can lead to reasonable safety from fire when the three points under A-8-1(b) are observed.

(d) *Fire Warning System.* There are two types of fire to which household fire warning equipment needs to respond. One is a rapidly developing, high-heat fire. The other is a slow, smoldering fire. Either can produce smoke and toxic gases.

Household fires are especially dangerous at night when the occupants are asleep. Fires produce smoke and deadly gases that can overcome occupants while they are asleep. Furthermore, dense smoke reduces visibility. Most fire casualties are victims of smoke and gas inhalation rather than burns. To warn against a fire, Chapter 8 requires smoke detectors in accordance with 8-1.4.1 and recommends heat or smoke detectors in all other major areas. [Refer to A-8-1.2.1(c).]

(e) *Family Escape Plan.* There often is very little time between the detection of a fire and the time it becomes deadly. This interval can be as little as 1 or 2 minutes. Thus, this code requires detection means to give a family some advance warning of the development of conditions that become dangerous to life within a short period of time. Such warning, however, could be wasted unless the family has planned in advance for rapid exit from their residence. Therefore, in addition to the fire warning system, this code requires exit plan information to be furnished.

Figure A-7-5.2.2(9) Typical input/output matrix.

System Outputs																															
System Inputs	Control Unit Annunciation															Notification								Required Fire Safety Control						Supplementary	
	Activate common alarm signal indicator	Activate audible alarm signal	Activate common supervisory signal indicator	Activate audible supervisory signal	Activate common trouble signal indicator	Activate audible trouble signal	Activate 1st floor (zone 1) alarm indicator	Activate 1st floor (zone 2) alarm indicator	Activate 2nd floor evacuation signals	Display/print change of status	Transmit fire alarm signal to supervising station	Transmit trouble signal to supervising station	Recall elevator to supervising station	Recall elevator to primary rear door	Close smoke life dampers in rated doors	Activate 1st floor smoke exhaust	Activate 2nd floor smoke exhaust	Unlock exits	Activate 3rd floor smoke exhaust	Initiate suppression system pre-discharge alarms	Engage releasing cabinets	Activate suppression system releasing sequence	Pressure stairwells	Shutdown process #1	Shutdown process #2	Shutdown process #3	Activate exterior strobe at (d) response point				
1 Manual fire alarm boxes – 1st floor	●	●																											●	1	
2 Manual fire alarm boxes – 2nd floor	●	●					●																						●	2	
3 Manual fire alarm boxes – 3rd floor	●	●							●																				●	3	
4 Smoke detectors – 1st floor	●	●				●																						●	4		
5 Smoke detectors – 3rd floor	●	●					●									●													●	5	
6 Smoke detectors – 1st floor	●	●						●																					●	6	
7 Smoke detectors – 1st floor elev. lobby	●	●				●									●														●	7	
8 2nd floor computer rm. smoke det.-zone 1	●	●					●																						●	8	
9 2nd floor computer rm. smoke det.-zone 2	●	●					●																						●	9	
10 In-duct smoke detector – supply fan 1	●	●					●																						●	10	
11 In-duct smoke detector – supply fan 2	●	●					●																						●	11	
12 In-duct smoke detector – 1st floor return	●	●																											●	12	
13 In-duct smoke detector – 2nd floor return	●	●					●																						●	13	
14 In-duct smoke detector – 3rd floor return	●	●						●																					●	14	
15 Heat detectors – 1st floor mech. rm.	●	●					●																						●	15	
16 Heat detectors – 2nd floor storage room	●	●						●																					●	16	
17 Heat detectors – 3rd floor janitor's closet	●	●							●																				●	17	
18 Waterflow – 1st floor	●	●						●																					●	18	
19 Waterflow – 2nd floor	●	●						●																					●	19	
20 Waterflow – 3rd floor	●	●							●																				●	20	
21 Sprinkler control valve – 1st floor			●	●																									●	21	
22 Sprinkler control valve – 2nd floor			●	●																									●	22	
23 Sprinkler control valve – 3rd floor			●	●																									●	23	
24 Fire pump running		●	●																										●	24	
25 Fire pump power failure/phase reversal			●	●																									●	25	
26 Fire alarm ac power failure			●	●																									●	26	
27 Fire alarm system low battery					●	●																							●	27	
28 Open circuit					●	●																							●	28	
29 Ground fault					●	●																							●	29	
30 Notification appliance circuit short					●	●																							●	30	

Planning and practicing for fire conditions with a focus on rapid exit from the residence are important. Drills should be held so that all family members know the action to be taken. Each person should plan for the possibility that exit out of a bedroom window could be necessary. An exit out of the residence without the need to open a bedroom is essential.

(f) *Special Provisions for the Disabled.* For special circumstances where the life safety of an occupant(s) depends on prompt rescue by others, the fire warning system should include means of prompt automatic notification to those who are to be depended on for rescue.

A-8-1.1 Chapter 8 does not attempt to cover all equipment, methods, and requirements that might be necessary or advantageous for the protection of lives and property from fire.

NFPA 72 is a “minimum code.” It provides a number of requirements related to household fire-warning equipment that are deemed to be the practical and necessary minimum for average conditions at the present state of the art.

A-8-1.1.2 Good fire protection requires that the equipment periodically be maintained. If the householder is unable to perform the required maintenance, a maintenance agreement should be considered.

A-8-1.2.1 One of the most critical factors of any fire alarm system is the location of the fire-detecting devices. This appendix is not a technical study. It is an attempt to provide some fundamentals on detector location. For simplicity, only those types of detectors recognized by Chapter 8 (that is, smoke and heat detectors) are discussed. In addition, special problems requiring engineering judgment, such as locations in attics and in rooms with high ceilings, are not covered.

(a) *Where to Locate the Required Smoke Detectors in Existing Construction.* The major threat from fire in a family living unit occurs at night when everyone is asleep. The principal threat to persons in sleeping areas comes from fires in the remainder of the unit. Therefore, a smoke detector(s) is best located between the bedroom areas and the rest of the unit. In units with only one bedroom area on one floor, the smoke detector(s) should be located as shown in Figure A-8-1.2.1(a).

In family living units with more than one bedroom area or with bedrooms on more than one floor, more than one smoke detector is required, as shown in Figure A-8-1.2.1(b).

In addition to smoke detectors outside of the sleeping areas, Chapter 8 requires the installation of a smoke detector on each additional story of the family living unit, including the basement. These installations are shown in Figure A-8-1.2.1(c). The living area smoke detector should be installed in the living room or near the stairway to the upper level, or in both locations. The basement smoke detector should be installed in close proximity to the stairway leading to the floor above. Where installed on an open-joisted ceiling, the detector should be placed on the bottom of the joists. The detector should be positioned relative to the stairway so as to intercept smoke coming from a fire in the basement before the smoke enters the stairway.

(b) *Where to Locate the Required Smoke Detectors in New Construction.* All of the smoke detectors specified in A-8-1.2.1(a) for existing construction are required, and, in addition, a smoke detector is required in each bedroom.

Figure A-8-1.2.1(a) A smoke detector should be located between the sleeping area and the rest of the family living unit.

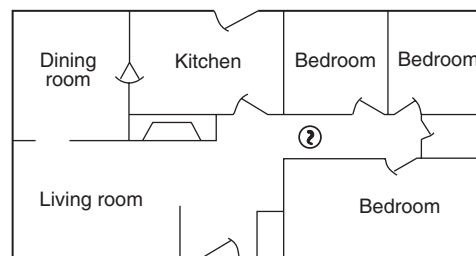


Figure A-8-1.2.1(b) In family living units with more than one sleeping area, a smoke detector should be provided to protect each sleeping area in addition to detectors required in bedrooms.

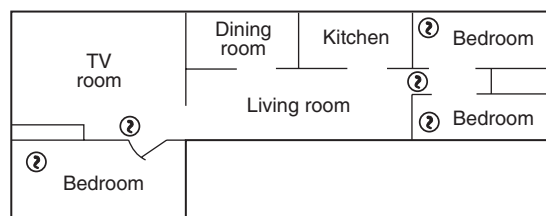
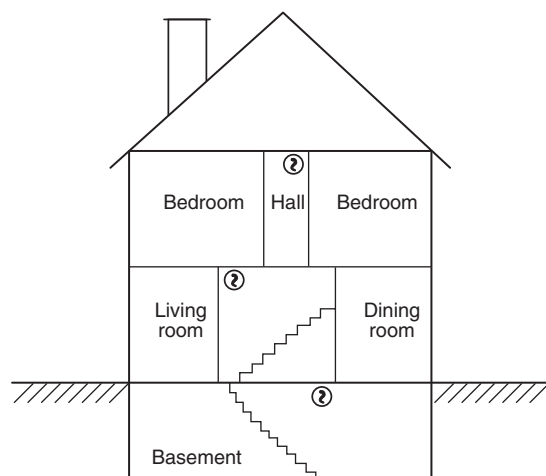


Figure A-8-1.2.1(c) A smoke detector should be located on each story.



(c) *Are More Smoke Detectors Desirable?* The required number of smoke detectors might not provide reliable early warning protection for those areas separated by a door from the areas protected by the required smoke detectors. For this reason, it is recommended that the householder consider the use of additional smoke detectors for those areas for increased protection. The additional areas include the basement, bedrooms, dining room, furnace room, utility room, and hallways not protected by the required smoke detectors. The installation of smoke detectors in kitchens, attics (finished or unfinished), or garages is not normally recommended, as these locations occasionally experience conditions that can result in improper operation.

A-8-1.2.2 At times, depending on conditions, the audibility of detection devices could be seriously impaired when occupants are within the bedroom area. For instance, there might be a

noisy window air conditioner or room humidifier generating an ambient noise level of 55 dBA or higher. The detection device alarms need to penetrate through the closed doors and be heard over the bedroom's noise levels with sufficient intensity to awaken sleeping occupants therein. Test data indicate that detection devices that have sound pressure ratings of 85 dBA of 10 ft (3 m) and that are installed outside the bedrooms can produce about 15 dBA over ambient noise levels of 55 dBA in the bedrooms. This is likely to be sufficient to awaken the average sleeping person.

Detectors located remote from the bedroom area might not be loud enough to awaken the average person. In such cases, it is recommended that detectors be interconnected in such a way that the operation of the remote detector causes an alarm of sufficient intensity to penetrate the bedrooms. The interconnection can be accomplished by the installation of a fire detection system, by the wiring together of multiple station alarm devices, or by the use of line carrier or radio frequency transmitters/receivers.

A-8-1.2.3 The use of the distinctive three-pulse temporal pattern fire alarm evacuation signal required by 3-8.4.1.2 had been previously recommended by this code since 1979. It has since been adopted as both an American National Standard (ANSI S3.41, *Audible Emergency Evacuation Signal*) and an International Standard (ISO 8201, *Audible Emergency Evacuation Signal*).

Copies of both of these standards are available from the Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, NY 10017-3483.

The standard fire alarm evacuation signal is a three-pulse temporal pattern using any appropriate sound. The pattern consists of the following in this order:

- (1) An on phase lasting 0.5 second \pm 10 percent.
- (2) An off phase lasting 0.5 second \pm 10 percent for three successive on periods.
- (3) An off phase lasting 1.5 seconds \pm 10 percent [refer to Figures A-8-1.2.3(a) and (b)]. The signal should be repeated for a period appropriate for the purposes of evacuation of the building, but for not less than 180 seconds. A single-stroke bell or chime sounded at on intervals lasting 1 second \pm 10 percent, with a 2-second \pm 10 percent off interval after each third on stroke, may be permitted [refer to Figure A-8-1.2.3(c)].

The minimum repetition time may be permitted to be manually interrupted.

Figure A-8-1.2.3(a) Temporal pattern parameters.

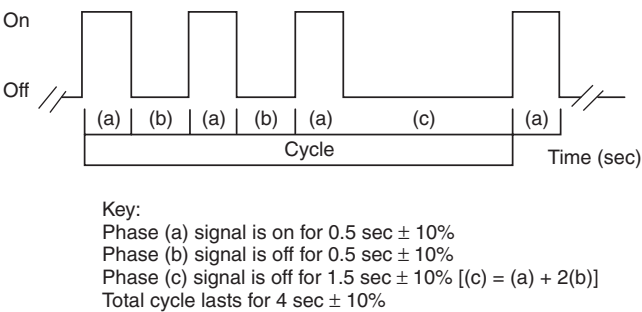


Figure A-8-1.2.3(b) Temporal pattern imposed on signaling appliances that emit a continuous signal while energized.

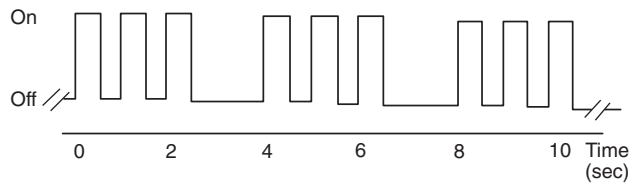
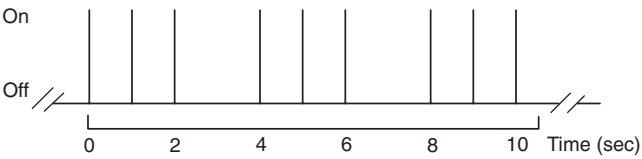


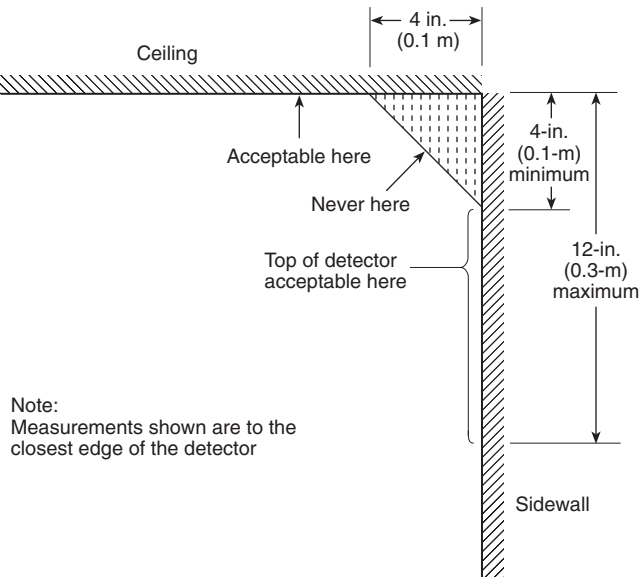
Figure A-8-1.2.3(c) Temporal pattern imposed on a single-stroke bell or chime.



A-8-1.2.4 Location and Type of Devices.

(a) *Smoke Detector Mounting — Dead Air Space.* The smoke from a fire generally rises to the ceiling, spreads out across the ceiling surface, and begins to bank down from the ceiling. The corner where the ceiling and wall meet is an air space into which the smoke could have difficulty penetrating. In most fires, this dead air space measures about 4 in. (0.1 m) along the ceiling from the corner and about 4 in. (0.1 m) down the wall, as shown in Figure A-8-1.2.4(a). Detectors should not be placed in this dead air space.

Figure A-8-1.2.4(a) Example of proper mounting of detectors.



Smoke and heat detectors should be installed in those locations recommended by the manufacturer, except in those cases where the space above the ceiling is open to the outside and little or no insulation is present over the ceiling. Such cases result in the ceiling being excessively cold in the winter or excessively hot in the summer. Where the ceiling is significantly different in temperature from the air space below, smoke and heat have difficulty reaching the ceiling and a

detector that is located on that ceiling. In this situation, placement of the detector on a sidewall, with the top 4 in. to 12 in. (0.1 m to 0.3 m) from the ceiling is recommended.

The situation described above for uninsulated or poorly insulated ceilings can also exist, to a lesser extent, in outside walls. The recommendation is to place the smoke detector on a sidewall. However, where the sidewall is an exterior wall with little or no insulation, an interior wall should be selected. It should be recognized that the condition of inadequately insulated ceilings and walls can exist in multiple dwelling unit housing (apartments), single dwelling unit housing, and mobile homes.

In those family living units employing radiant heating in the ceiling, the wall location is the recommended location. Radiant heating in the ceiling can create a hot-air, boundary layer along the ceiling surface, which can seriously restrict the movement of smoke and heat to a ceiling-mounted detector.

A 1992 survey of more than 1000 homes conducted by the U. S. Consumer Product Safety Commission found that 25 percent of the smoke alarms failed to operate when tested with smoke and the integral test button. Of these, 60 percent were restored to operation simply by installing a new battery or reconnecting the ac power. Most owners reported that they had disconnected power because of nuisance alarms, overwhelmingly related to cooking. Many of these problem smoke alarms were located within a few feet of the cooking facilities.

Locating smoke alarms away from sources of nuisance alarms can minimize these problems. Photoelectric-type smoke alarms are less likely to alarm from normal cooking than are the ionization type and should be considered for installation on the floor containing the cooking facilities. Some smoke alarms have a temporary silencing means that can be activated during cooking to reduce nuisance alarms. The two types of smoke alarms are equally susceptible to steam from bathrooms but locating them at least 3 ft from the bathroom door should minimize such problems. Having both types of smoke alarms in a home is a good idea from the viewpoint of response to different types of fires, but where interconnected it is important to make sure that the interconnect circuits are compatible.

(b) *Heat Detection.*

- (1) *General.* While Chapter 8 does not require heat detectors as part of the basic protection scheme, it is recommended that the householder consider the use of additional heat detectors for the same reasons presented under A-8-1.2.1(c). The additional areas lending themselves to protection with heat detectors are the kitchen, dining room, attic, (finished or unfinished), furnace room, utility room, basement, and integral or attached garage. For bedrooms, the installation of a smoke detector is recommended over the installation of a heat detector for protection of the occupants from fires in their bedrooms.
- (2) *Heat Detector Mounting — Dead Air Space.* Heat from a fire rises to the ceiling, spreads out across the ceiling surface, and begins to bank down from the ceiling. The corner where the ceiling and the wall meet is an air space into which heat has difficulty penetrating. In most fires, this dead air space measures about 4 in. (0.1 m) along the ceiling from the corner and 4 in. (0.1 m) down the wall as shown in Figure A-8-1.2.4(a). Heat detectors should not be placed in this dead air space.

The placement of the heat detector is critical where maximum speed of fire detection is desired. Thus, a logical location for a detector is the center of the ceiling. At this location, the detector is closest to all areas of the room.

If the heat detector cannot be located in the center of the ceiling, an off-center location on the ceiling can be used.

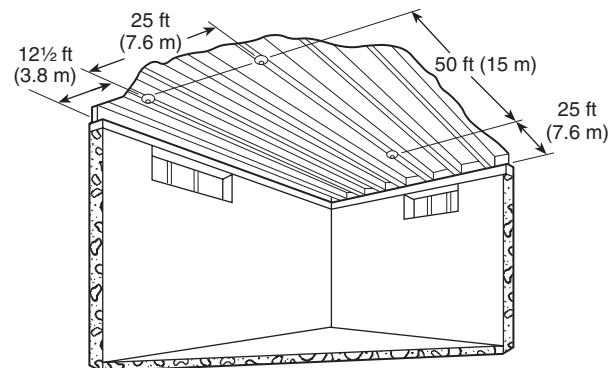
The next logical location for mounting heat detectors is on the sidewall. Any detector mounted on the sidewall should be located as near as possible to the ceiling. A detector mounted on the sidewall should have the top of the detector between 4 in. and 12 in. (0.1 m and 0.3 m) from the ceiling. [See Figure A-8-1.2.4(a).]

- (3) *Spacing of Heat Detectors.* If a room is too large for protection by a single heat detector, several detectors should be used. It is important that they be properly located so all parts of the room are covered. (For further information on the spacing of detectors refer to Chapter 2.)
- (4) *Where the Distance Between Heat Detectors Should be Further Reduced.* The distance between heat detectors is based on data obtained from the spread of heat across a smooth ceiling. If the ceiling is not smooth, the placement of the detector should be tailored to the situation.

For instance, with open wood joists, heat travels freely down the joist channels so that the maximum distance between detectors [50 ft (15 m)] can be used. However, heat has trouble spreading across the joists, so the distance in this direction should be one-half the distance allowed between detectors, as shown in Figure A-8-1.2.4(b), and the distance to the wall is reduced to $12\frac{1}{2}$ ft (3.8 m). Since one-half of 50 ft (15 m) is 25 ft (7.6 m), the distance between detectors across open wood joists should not exceed 25 ft (7.6 m), as shown in Figure A-8-1.2.4(b), and the distance to the wall is reduced [$\frac{1}{2} \times 25$ ft (7.6 m)] to 12.5 ft (3.8 m). Detectors should be mounted on the bottom of the joists and not up in joist channels.

Walls, partitions, doorways, ceiling beams, and open joists interrupt the normal flow of heat, thus creating new areas to be protected.

Figure A-8-1.2.4(b) Open joists, attics, and extra-high ceilings are some of the areas that require special knowledge for installation.

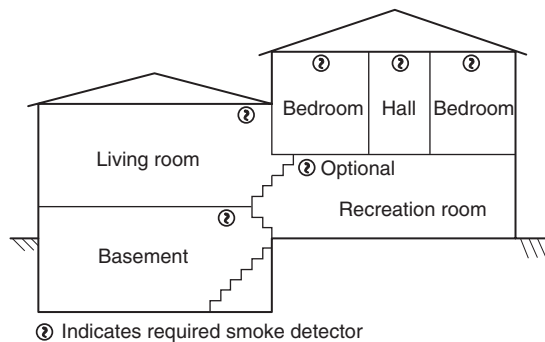


In addition to the special requirements for heat detectors installed on ceilings with exposed joists, reduced spacing also might be required due to other structural characteristics of the protected area, possible drafts, or other conditions that could affect detector operation.

A-8-1.4.1 Refer to Figure A-8-1.4.1 where required smoke detectors are shown. Smoke detectors are optional where a

door is not provided between a living room and a recreation room.

Figure A-8-1.4.1 Split level arrangement.



A-8-1.4.2 One of the common problems associated with residential smoke detectors is the nuisance alarms that are usually triggered by products of combustion from cooking, smoking, or other household particulates. While an alarm for such a condition is anticipated and tolerated by the occupant of a dwelling unit through routine living experience, the alarm is not permitted where it also sounds alarms in other dwelling units or in common use spaces. Nuisance alarms caused by cooking are a very common occurrence, and inspection authorities should be aware of the possible ramifications where the coverage is extended beyond the limits of the dwelling unit.

A-8-2.1.1 Experience has shown that all hostile fires in dwelling units generate smoke to some degree. This is also true with respect to heat buildup from fires. However, the results of full-scale experiments conducted over the past several years in the United States, using typical fires in dwelling units, indicate that detectable quantities of smoke precede detectable levels of heat in nearly all cases. In addition, slowly developing, smoldering fires can produce smoke and toxic gases without a significant increase in the room's temperature. Again, the results of experiments indicate that detectable quantities of smoke precede the development of hazardous atmospheres in nearly all cases.

For the above reasons, the required protection in this code uses smoke detectors as the primary life safety equipment for providing a reasonable level of protection against fire.

Of course, it is possible to install fewer detectors than required in this code. It could be argued that the installation of only one fire detector, whether a smoke or heat detector, offers some lifesaving potential. While this is true, it is the recommendation of NFPA 72 that the smoke detector requirements as stated in 8-2.1.1 are the minimum that should be considered.

The installation of additional detectors of either the smoke or heat type should result in a higher degree of protection. Adding detectors to rooms that are normally closed off from the required detectors increases the escape time because the fire does not need to build to the higher level necessary to force smoke out of the closed room to the required detector. As a consequence, it is recommended that the householder consider the installation of additional fire protection devices. However, it should be understood that Chapter 8 does not require additional detectors over and above those required in 8-1.4.1.

A-8-3.4 If homeowner inspection, testing, and maintenance are required or assumed, the equipment should be installed in an accessible manner. It is a good practice to establish a specific schedule for tests.

A-8-4.3.2 If screening alarm signals to minimize response to false alarms is to be implemented, the following should be considered.

- (1) Was the verification call answered at the protected premises?
- (2) Did the respondent provide proper identification?
- (3) Is it necessary for the respondent to identify the cause of the alarm signal?
- (4) Should the public service fire communications center be notified and advised that an alarm signal was received, including the response to the verification call, when an authorized respondent states that the fire service response is not desired?
- (5) Should the public service fire communications center be notified and advised that an alarm signal was received, including the response to the verification call, for all other situations, including both a hostile fire and no answer verification call?
- (6) What other actions should be required by a standard operating procedure?

Appendix B Engineering Guide for Automatic Fire Detector Spacing

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

Users of Appendix B should refer back to the text of NFPA 72 to familiarize themselves with the limitations of the design methods summarized herein.

B-1 Introduction.

B-1.1 Scope. Appendix B provides information intended to supplement Chapter 2. It includes a procedure for determining detector spacing based on the objectives set for the system, size, and rate of growth of fire to be detected, various ceiling heights, ambient temperatures, and response characteristics of the detectors. In addition to providing an engineering method for the design of detection systems using plume-dependant detectors, heat detectors, and smoke detectors, this appendix also provides guidance on the use of radiant energy-sensing detectors.

B-1.2 General. Appendix B has been revised in its entirety from previous editions. The correlations originally used to develop the tables and graphs for heat and smoke detector spacings in the earlier editions have been updated to be consistent with current research. These revisions correct the errors in the original correlations. In earlier editions the tables and graphs were based on an assumed heat of combustion of 20,900 kJ/kg. The effective heat of combustion for common cellulosic materials is usually taken to be approximately 12,500 kJ/kg. The equations in this appendix were produced using test data and data correlations for cellulosic (wood) fuels that have a total heat of combustion of about 12,500 kJ/kg.

B-1.2.1 For the purposes of this appendix, the heat produced by a fire is manifested either as convective heat or radiant heat. It is assumed that conductive heat transfer is of little consequence during the early stages of the development of a fire,

where this appendix is relevant. A convective heat release rate fraction equal to 75 percent of the total heat release rate has been used in this appendix. Users should refer to references 12 and 13 in C-2 for fuels or burning conditions that are substantially different from these conditions.

B-1.2.2 The design methods for plume-dependant fire detectors provided in this appendix are based on full-scale fire tests funded by the Fire Detection Institute in which all fires were geometrically growing flaming fires. (See *Environments of Fire Detectors — Phase 1: Effect of Fire Size, Ceiling Height and Material; Measurements Vol. I and Analysis Vol. II.*)

B-1.2.3 The guidance applicable to smoke detectors is limited to a theoretical analysis based on the flaming fire test data and is not intended to address the detection of smoldering fires.

B-1.2.4 The design methods for plume-dependant fire detectors do not address the detection of steady-state fires.

B-1.2.5 The design methods for plume-dependant fire detectors used in this appendix are only applicable when employed in the context of applications where the ceiling is smooth and level. It cannot be used for ceilings where there are beams, joists, or bays formed by beams and purlins. The research upon which the following methods have been based did not consider the effect of beams, joists, and bays in sufficient detail to justify the use of this appendix to those applications.

B-1.3 Purpose. The purpose of Appendix B is to provide a performance basis for the location and spacing of fire detection initiating devices. The sections for heat and smoke detectors provide an alternative design method to the prescriptive approach presented in Chapter 2 (that is, based on their listed spacings). The section on radiant energy-sensing detectors elaborates on the performance-based criteria already existing in Chapter 2. A performance-based approach allows one to consider potential fire growth rates and fire signatures, the individual compartment characteristics, and damageability characteristics of the targets (for example, occupants, equipment, contents, structures, and so on) in order to determine the location of a specific type of detector to meet the objectives established for the system.

B-1.3.1 Under the prescriptive approach, heat detectors are installed according to their listed spacing. The listed spacing is determined in a full-scale fire test room. The fire test room used for the determination of listed spacing for heat detectors has a ceiling height of 15 ft 9 in. (4.8 m). A steady-state, flammable liquid fire with a heat release rate of approximately 1200 Btu/sec (1137 kW), located 3 ft (0.9 m) above the floor is used as the test fire. Special, 160°F (71°C) test sprinklers are installed on a 10 ft (3 m) × 10 ft (3 m) spacing array such that the fire is in the center of the sprinkler array. The heat detec-

tors being tested are installed in a square array with increasing spacing centered about the fire location. The elevation of the test fire is adjusted during the test to produce the temperature versus time curve at the test sprinkler heads to yield actuation of the heads in 2.0 minutes ± 10 seconds. The largest heat detector spacing that achieves alarm before the actuation of the sprinkler heads in the test becomes the listed spacing for the heat detector. See Figure A-2-2.4.1(c). If the room dimensions, ambient conditions, and fire and response characteristics of the detector are different from above, the response of the heat detector must be expected to be different as well. Therefore, the use of an installed detector spacing that is different from the listed spacing might be warranted through the use of a performance-based approach if

- (1) The design objectives are different from designing a system that operates at the same time as a sprinkler in the approval test.
- (2) Faster response of the device is desired.
- (3) A response of the device to a smaller fire than used in the approved test is required.
- (4) Accommodation to room geometry that is different than used in the listing process.
- (5) Other special considerations, such as ambient temperature, air movement, ceiling height, or other obstruction, are different from or are not considered in the approval tests.
- (6) A fire other than a steady-state 1200 Btu/sec (1137 kW) fire is contemplated.

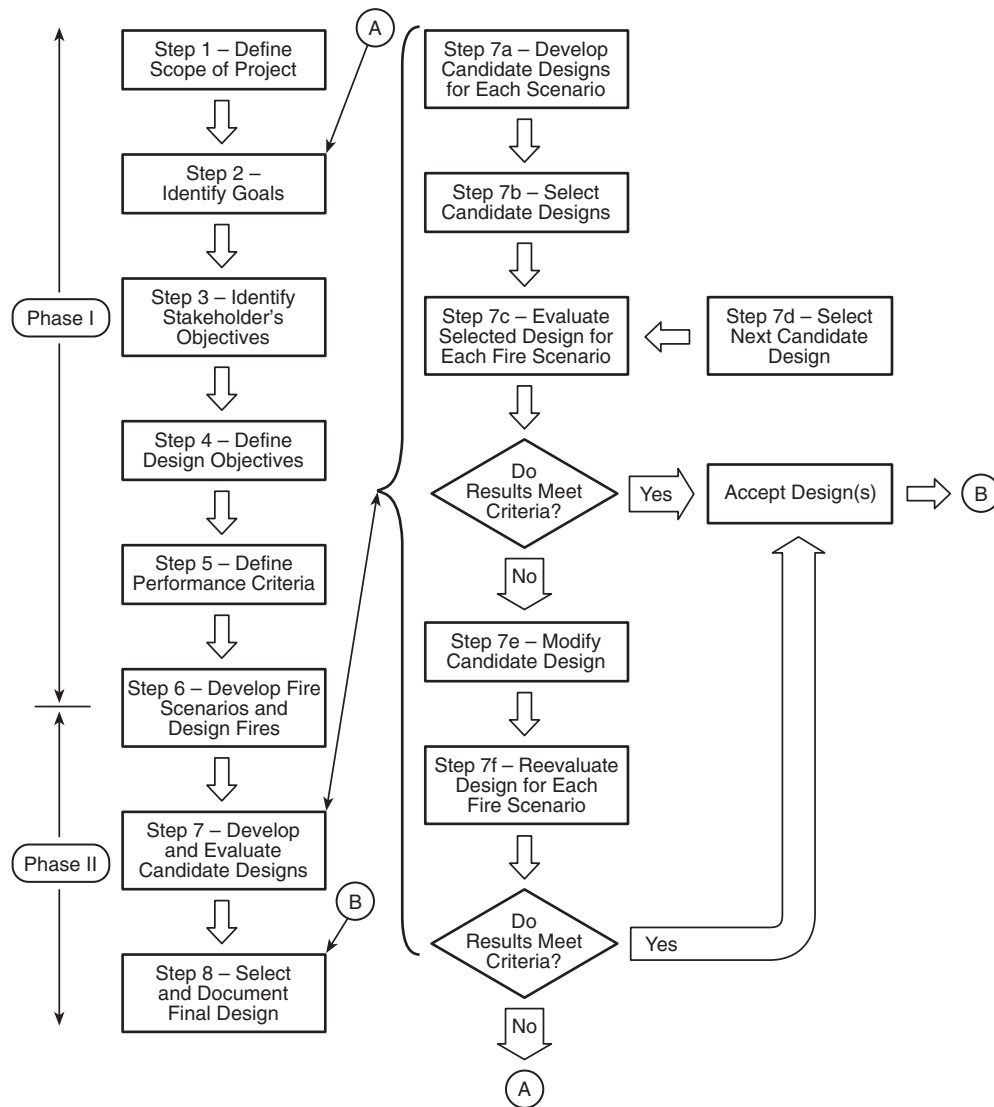
B-2 Performance-Based Approach to Designing and Analyzing Fire Detection Systems.

B-2.1 Overview. Subsection B-2.1 provides an overview of a systematic approach to conducting a performance-based design or analysis of a fire detection system. The approach has been outlined by Custer and Meacham and the SFPE *Engineering Guide to Performance Based Fire Protection Analysis and Design* [40], and is summarized below in the context of design and analysis of fire detection systems. (Refer to Figure B-2.1.) This approach has been divided into two phases: defining goals and objectives and system design and evaluation.

B-2.2 Phase 1 — Defining Goals and Objectives.

B-2.2.1 Define Scope of Project. The initial step of this approach is to identify information relative to the overall scope of work on the project, including characteristics of the building, design intent, design and construction team organization, constraints on design and project schedule, proposed building construction and features, relevant hazards, how the building functions, occupant characteristics, and so on.

Figure B-2.1 Overview of the performance-based design process. [25]



B-2.2.1.1 While defining the project's scope, the designer will identify which of the three situations in Table B-2.2.1.1 best describes the project at hand (that is, a performance-based analysis of an existing detection system in an existing building).

Table B-2.2.1.1 Design/Analysis Situation

Building Type	System Type	Design/Analysis
New	New	Design
Existing	New	Design
Existing	Existing	Analysis

B-2.2.2 Identify Goals. Fire protection assets are acquired in order to attain one or more of the following four goals:

- (1) To provide life safety (occupants, employees, fire fighters, and so on)
- (2) To protect property and heritage (structure, contents, and so on)
- (3) To provide for continuity of operations (protect stakeholder's mission, operating capability, and so on)
- (4) To limit the environmental impact of fire (toxic products, fire-fighting water run-off, and so on)

B-2.2.2.1 Fire protection goals are like other goals in that they are generally easy to agree on, are qualitative, and are non-controversial in nature. They express the desired overall out-

come to be achieved, that is, to provide life safety to the building occupants.

B-2.2.2.2 When starting the performance-based process, the various parties including the stakeholders (that is, the architect, building owner, insurance carrier, building or fire officials, and so on), the authority having jurisdiction, and the design engineer work together to prioritize the basic fire protection goals. Prioritizing is based on the stakeholder's objective and the building and occupancy involved. For example, life safety is a high priority in a hospital or stadium, while property protection might have an equally high priority in a large warehouse or historic building.

B-2.2.3 Identify Stakeholder's Objectives. Each stakeholder must explicitly state her or his objectives in terms of acceptable loss for the various goals previously stated.

B-2.2.3.1 Stakeholder objectives specify how much safety the stakeholder wants, needs, or can afford. "No loss of life within the room of origin" is a sample stakeholder objective or statement of the stakeholder's maximum acceptable loss.

B-2.2.3.2 The stakeholder's objectives are generally not stated in fire protection engineering terms.

B-2.2.3.3 Note that in a performance-based code environment, the code will most likely define a performance objective or stakeholder objective.

B-2.2.4 Define Design Objectives. The stakeholder's objective must then be explicitly stated and quantified in fire protection engineering terms that describe how the objective will be achieved. This demands that the design objectives be expressed quantitatively. See Tables B-2.2.5.4(a) through (c).

B-2.2.4.1 The design objective provides a description of how the stakeholder's objective will be achieved in general fire protection engineering terms prior to this description being quantified. The general objective is then reduced to explicit and quantitative fire protection engineering terms. The explicit fire protection engineering objectives provide a performance benchmark against which the predicted performance of a candidate design is evaluated.

B-2.2.5 Define Performance Criteria. Once the design objective has been established, specific, quantitatively expressed criteria that indicate attainment of the performance objective are developed.

B-2.2.5.1 Performance criteria provide a yardstick or threshold values that can measure a potential design's success in meeting stakeholder objectives and their associated design objectives. [25]

B-2.2.5.2 Quantification of the design objectives into performance criteria involves determination of the various fire-induced stresses that are a reflection of the stated loss objectives. Performance criteria can be expressed in various terms, including temperature, radiant flux, a rate of heat release, or concentration of a toxic or corrosive species that must not be exceeded.

B-2.2.5.3 Once the design performance criteria are established, appropriate safety factors are applied to obtain the working design criteria. The working design criteria reflect the performance that must be achieved by the detection system. This performance level must allow appropriate actions to be undertaken (for example, activate suppression systems, occupants egress, notify fire department, and so on) to meet the

objectives. An acceptable fire detection system design provides the detection of the fire sufficiently early in its development to permit the other fire protective systems to meet or exceed the relevant performance criteria established for those systems.

B-2.2.5.4 Throughout the process identified as Phase I and II, communication should be maintained with the authorities having jurisdiction (AHJs) to review and develop consensus on the approach being taken. It is recommended that this communication commence as early in the design process as possible. The AHJ should also be involved in the development of performance criteria. Often the acceptance of a performance-based design in lieu of a design based on a prescriptive approach relies on demonstrating equivalence. This is called the comparative method, where the engineer demonstrates that the performance-based design responds at least as well, if not better than, a system designed using a prescriptive approach.

Table B-2.2.5.4(a) Defining Goals and Objectives — Life Safety

Fire Protection Goal	Provide life safety
Stakeholder's Objective	No loss of life within compartment of origin
Design Objective	Maintain tenable conditions within the compartment of origin
Performance Criteria	Maintain: Temperatures below $xx^{\circ}\text{C}$ Visibility above yy ft CO concentration below zz ppm for tt minutes

Table B-2.2.5.4(b) Defining Goals and Objectives — Property Protection

Fire Protection Goal	Provide protection of property
Stakeholder's Objective	No fire damage outside compartment of origin
Design Objective	Limit the spread of flame to the compartment of origin
Performance Criteria	Maintain upper layer temperature below $xx^{\circ}\text{C}$ and radiation level to the floor below yy kW/m^2 to prevent flashover.

Table B-2.2.5.4(c) Defining Goals and Objectives — Continuity of Operations

Fire Protection Goal	Provide continuity of operations
Stakeholder's Objective	Prevent any interruption to business operations in excess of 2 hours
Design Objective	Limit the temperature and the concentration of HCl to within acceptable levels for continued operation of the equipment
Performance Criteria	Provide detection such that operation of a gaseous suppression system will maintain temperatures below $xx^{\circ}\text{C}$, and HCl levels below yy ppm

B-2.3 Phase II — System Design and Evaluation.

B-2.3.1 Develop Fire Scenarios. A fire scenario defines the development of a fire and the spread of combustion products throughout a compartment or building. A fire scenario represents a set of fire conditions that are deemed a threat to a building and its occupants and/or contents, and, therefore, should be addressed in the design of the fire protection features of the structure. [25]

B-2.3.1.1 The process of developing a fire scenario is a combination of hazard analysis and risk analysis. The hazard analysis identifies potential ignition sources, fuels, and fire development. Risk is the probability of occurrence multiplied by the consequences of that occurrence. The risk analysis looks at the impact of the fire to the surroundings or target items.

B-2.3.1.2 The fire scenario should include a description of various conditions, including building characteristics, occupant characteristics, and fire characteristics. [25, 40]

B-2.3.1.2.1 Building Characteristics. Building characteristics include the following:

- (1) Configuration (area; ceiling height; ceiling configuration, such as flat, sloped beams; windows and doors, and thermodynamic properties)
- (2) Environment (ambient temperature, humidity, background noise, and so on)
- (3) Equipment (heat-producing equipment, HVAC, manufacturing equipment, and so on)
- (4) Functioning characteristics (occupied, during times, days, and so on)
- (5) Target locations

(Note target items, that is, areas associated with stakeholder objectives, along the expected route of spread for flame, heat, or other combustion products.)

B-2.3.1.2.2 Occupant Characteristics. Occupant characteristics include the following:

- (1) Alertness (sleeping, awake, and so on)
- (2) Age
- (3) Mobility
- (4) Quantity and location within the building
- (5) Sex
- (6) Responsiveness
- (7) Familiarity with the building
- (8) Mental challenges

B-2.3.1.2.3 Fire Characteristics. Fire characteristics include the following:

- (1) Ignition sources — temperature, energy, time, and area of contact with potential fuels
- (2) Initial fuels — state (solid, liquid, gas spray, vapor); type and quantity of fuel; fuel configuration; fuel location (against wall, in corner, in open); rate of heat release and fire growth; type and production rate of fire signatures (smoke, CO, CO₂, and so on)
- (3) Secondary fuels — proximity to initial fuels; amount; distribution, ease of ignitability (*see initial fuels*); and extension potential (beyond compartment, structure, area, if outside)

B-2.3.1.2.4 An example of a fire scenario in a computer room might be as follows.

The computer room is 30 ft (9.1 m) × 20 ft (6 m) and 8 ft (2.8 m) high. It is occupied 12 hours a day, 5 days a week. The occupants are mobile and familiar with the building. There

are no fixed fire suppression systems protecting this location. The fire department is capable of responding to the scene in 6 minutes, and an additional 15 minutes for fire ground evolution is needed.

Overheating of a resistor leads to the ignition of a printed circuit board and interconnecting cabling. This leads to a fire that quickly extends up into the above ceiling space containing power and communications cabling. The burning of this cabling produces large quantities of dense, acrid smoke and corrosive products of combustion that spread throughout the computer suite. This causes the loss of essential computer and telecommunications services for 2 months.

B-2.3.2 Develop Design Fires. The design fire is the fire the system is intended to detect. When specifying a design fire, the specifics regarding the ignition, growth, steady-state output (if appropriate), and decay of the fire are expressed quantitatively.

B-2.3.2.1 Fire development varies depending on the combustion characteristics of the fuel or fuels involved, the physical configuration of the fuels, the availability of combustion air, and the influences due to the compartment. Once a stable flame is attained, most fires grow in an accelerating pattern (*see Figure B-2.3.2.1.2.8*), reach a steady state characterized by a maximum heat release rate, and then enter into a decay period as either the availability of fuel or combustion air becomes limited. Fire growth and development are limited by factors such as quantity of fuel, arrangement of fuel, quantity of oxygen, and the effect of manual and automatic suppression systems.

B-2.3.2.1.1 Fires can be characterized by their rate of heat release, measured in terms of the number of Btus per second (kW) of heat liberated. Typical maximum heat release rates (Q_m) for a number of different fuels and fuel configurations are provided in Tables B-2.3.2.3.1(a) and (c). The heat release rate of a fire can be described as a product of a heat release density and fire area using the following equation:

$$Q_m = qA \quad (1)$$

where:

$$\begin{aligned} Q_m &= \text{maximum or peak heat release rate (Btu/sec)} \\ q &= \text{heat release rate density per unit floor area} \\ &\quad (\text{Btu/sec}\cdot\text{ft}^2) \\ A &= \text{floor area of the fuel (ft}^2\text{)} \end{aligned}$$

B-2.3.2.1.2 Example. A particular hazard analysis is to be based on a fire scenario involving a 10-ft × 10-ft (3-m × 3-m) stack of wood pallets stored 5 ft (1.5 m) high. Approximately what peak heat release rate can be expected?

B-2.3.2.1.2.1 From Table B-2.3.2.3.1(a), the heat release rate density (q) for 5-ft (1.5-m) high wood pallets is approximately 330 Btu/sec·ft².

B-2.3.2.1.2.2 The area is 10 ft × 10 ft = (3 m × 3 m), or 100 ft² (9 m²). Using equation (1) to determine the heat release rate yields the following:

$$\begin{aligned} Q_m &= qA \\ 330 \times 100 &= 33,000 \text{ Btu/sec} \end{aligned}$$

B-2.3.2.1.2.3 As indicated in the Table B-2.3.2.3.1(a), this fire generally produces a medium to fast fire growth rate reaching 1000 Btu/sec (1055 kW) in approximately 90 to 190 seconds.

B-2.3.2.1.2.4 Fires can also be defined by their growth rate or the time (t_g) it takes for the fire to reach a given heat release rate. Previous research [16] has shown that most fires grow exponentially and can be expressed by what is termed the “power law fire growth model,” which follows

$$Q \cong t^p \quad (2)$$

where:

$$\begin{aligned} Q &= \text{heat release rate (Btu/sec or kW)} \\ p &= 2 \\ t &= \text{time (sec)} \end{aligned}$$

B-2.3.2.1.2.5 In fire protection, fuel packages are often described as having a growth time (t_g). This is the time necessary after the ignition with a stable flame for the fuel package to attain a heat release rate of 1000 Btu/sec (1055 kW). The following equations describe the growth of design fires:

$$Q = \frac{1000}{t_g^2} t^2 \text{ (Btu/sec)} \quad (3)$$

or

$$Q = \frac{1055}{t_g^2} t^2 \text{ (kW)}$$

and thus

$$Q = \alpha t^2$$

where:

$$\begin{aligned} \alpha &= \text{fire growth rate [1000}/t_g^2 \text{ (Btu/sec}^3\text{) or 1055}/t_g^2 \text{ (kW/sec}^2\text{)]} \\ Q &= \text{heat release rate (Btu/sec)} \\ t_g &= \text{fire growth time to reach 1000 Btu/sec (1055 kW) after established burning} \\ t &= \text{time after established burning occurs (sec)} \end{aligned}$$

B-2.3.2.1.2.6 Tables B-2.3.2.3.1(a) and (e) provide values for t_g , the time necessary to reach a heat release rate of 1000 Btu/sec (1055 kW), for a variety of materials in various configurations.

B-2.3.2.1.2.7 Test data from 40 furniture calorimeter tests, as indicated in Table B-2.3.2.3.1(e), have been used to independently verify the power law fire growth model, $Q = \alpha t^2$. [14] For reference, the table contains the test numbers used in the original NIST reports.

The virtual time of origin (t_v) is the time at which a stable flame had appeared and the fires began to obey the power law fire growth model. Prior to t_v , the fuels might have smoldered but did not burn vigorously with an open flame. The model curves are then predicted by the following equations:

$$Q = \alpha(t - t_v)^2 \quad (4)$$

or

$$Q = \left(\frac{1000}{t_g^2} \right) (t - t_v)^2 \text{ (Btu/sec)}$$

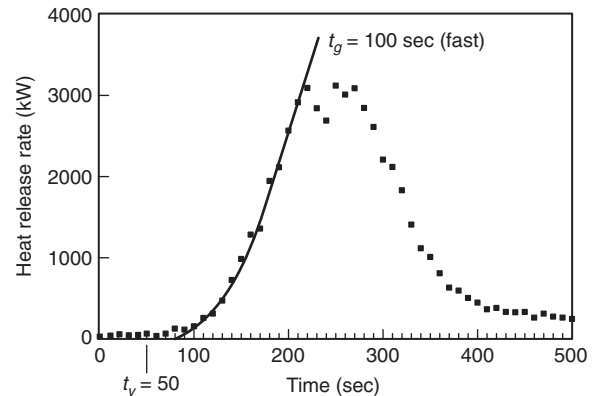
$$Q = \left(\frac{1055}{t_g^2} \right) (t - t_v)^2 \text{ (kW)}$$

where:

$$\begin{aligned} \alpha &= \text{fire growth rate [1000}/t_g^2 \text{ (Btu/sec}^3\text{) or 1055}/t_g^2 \text{ (kW/sec}^2\text{)]} \\ Q &= \text{heat release rate (Btu/sec)} \\ t_g &= \text{fire growth time to reach 1000 Btu/sec (1055 kW)} \\ t &= \text{time after established burning occurs (sec)} \\ t_v &= \text{virtual time of origin (sec)} \end{aligned}$$

B-2.3.2.1.2.8 Figure B-2.3.2.1.2.8 is an example of an actual test data with a power law curve superimposed.

Figure B-2.3.2.1.2.8 Test 38, foam sofa.



B-2.3.2.1.2.9 For purposes of this appendix, fires are classified as being either slow-, medium-, or fast-developing from the time that established burning occurs until the fire reaches a heat release rate of 1000 Btu/sec (1055 kW). Table B-2.3.2.1.2.9 results from using the relationships discussed above. [See also Table B-2.3.2.3.1(a).]

Table B-2.3.2.1.2.9 Power Law Heat Release Rates

Fire Growth Rate	Growth Time (t_g)	α (kW/sec ²)
Slow	$t_g \geq 400$ sec	$\alpha \leq 0.0066$
Medium	$150 \leq t_g < 400$ sec	$0.0066 < \alpha \leq 0.0469$
Fast	$t_g < 150$ sec	$\alpha > 0.0469$

B-2.3.2.1.2.10 The correlation between flame height and heat release rate can be used to assist in deciding on an appropriate design fire. As shown in Figure B-2.3.2.1.2.10, flame height and fire size are directly related. [2] The lines in Figure B-2.3.2.1.2.10 were derived from the following equation:

$$h_f = 0.584(kQ)^{2/5} \quad (5)$$

where:

h_f = flame height (ft)

k = wall effect factor

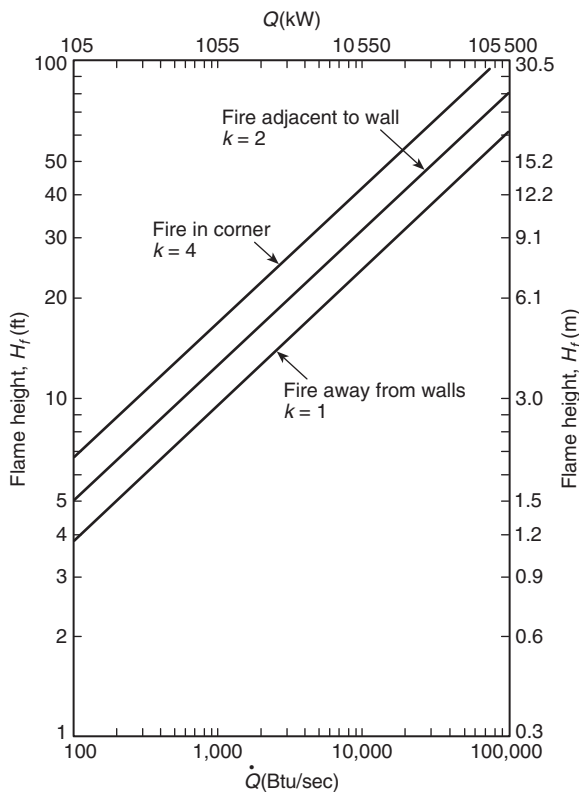
Q = heat release rate (Btu/sec)

Where there are no nearby walls, use $k = 1$.

Where the fuel package is near a wall, use $k = 2$.

Where the fuel package is in a corner, use $k = 4$.

Figure B-2.3.2.1.2.10 Heat release rate vs. flame height.



B-2.3.2.1.3 Example. What is the average flame height of a fire with a heat release rate of 1000 Btu/sec located in the middle of a compartment?

From Figure B-2.3.2.1.2.10, find the heat release rate on the abscissa and read estimated flame height from the ordinate, or use equation (5).

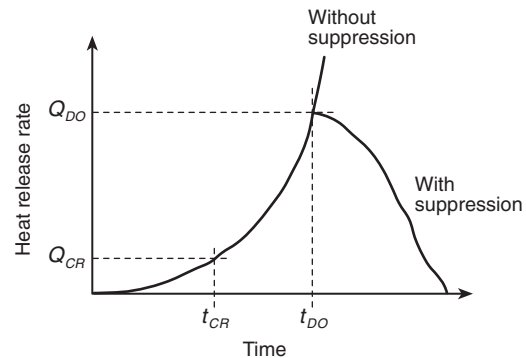
$$h_f = 0.584(kQ)^{2/5}$$

$$h_f = 0.584(1 \times 1000 \text{ Btu/sec})^{2/5}$$

$$h_f = 9.25 \text{ ft (2.8 m)}$$

B-2.3.2.2 Selection of Critical Fire Size. Because all fire control means require a finite operation time, there is a critical difference between the time at which the fire must be detected and the time at which it achieves the magnitude of the design fire. Even though a fire has been detected, this does not mean that it stops growing. Fires typically grow exponentially until they become ventilation controlled, and limited by the availability of fuel, or until some type of fire suppression or extinguishment is commenced. Figure B-2.3.2.2 shows that there can be a significant increase in the heat release rate with only a small change in time due to the exponential growth rate of fire.

Figure B-2.3.2.2 Critical and design objective heat release rates vs. time.



B-2.3.2.2.1 Once the design objectives and the design fire have been established, the engineer will need to establish two points on the design fire curve: Q_{DO} and Q_{CR} .

B-2.3.2.2.2 Q_{DO} represents the heat release rate, or product release rate, which produces conditions representative of the design objective. This is the "design fire." However, Q_{DO} does not represent the point in time at which detection is needed. Detection must occur sufficiently early in the development of the fire to allow for any intrinsic reaction time of the detection as well as the operation time for fire suppression or extinguishing systems. There will be delays in both detection of the fire as well as the response of equipment, or persons, to the alarm.

B-2.3.2.2.3 A critical fire size (Q_{CR}) is identified on the curve that accounts for the delays in detection and response. This point represents the maximum permissible fire size at which detection must occur that allows appropriate actions to be taken to keep the fire from exceeding the design objective (Q_{DO}).

B-2.3.2.2.4 Delays are inherent in both the detection system as well as in the response of the equipment or people that need to react once a fire is detected. Delays associated with the detection system include a lag in the transport of combustion products from the fire to the detector and response time lag of the detector, alarm verification time, processing time of the detector, and processing time of the control panel. Delays are also possible with an automatic fire extinguishing system(s) or suppression system(s). Delay can be introduced by alarm verification or crossed zone detection systems, filling and dis-

charge times of pre-action systems, delays in agent release required for occupant evacuation (for example, CO₂ systems), and the time required to achieve extinguishment.

B-2.3.2.2.5 Occupants do not always respond immediately to a fire alarm. The following must be accounted for when evaluating occupant safety issues:

- (1) Time expected for occupants to hear the alarm (due to sleeping or manufacturing equipment noise)
- (2) Time to decipher the message (for example, voice alarm system)
- (3) Time to decide whether to leave (get dressed, gather belongings, call security)
- (4) Time to travel to an exit

B-2.3.2.2.6 Response of the fire department or fire brigade to a fire incident involves several different actions that need to occur sequentially before containment and extinguishment efforts of the fire can even begin. These actions should also be taken into account to properly design detection systems that meet the design objectives. These actions typically include the following:

- (1) Detection (detector delays, control panel delays, and so on)
- (2) Notification to the monitoring station (remote, central station, proprietary, and so on)
- (3) Notification of the fire department
- (4) Alarm handling time at the fire department
- (5) Turnout time at the station
- (6) Travel time to the incident
- (7) Access to the site
- (8) Set-up time on site
- (9) Access to building
- (10) Access to fire floor
- (11) Access to area of involvement
- (12) Application of extinguishant on the fire

B-2.3.2.2.7 Unless conditions that limit the availability of combustion air or fuel exist, neither the growth of the fire nor the resultant damage stop until fire suppression begins. The time needed to execute each step of the fire response sequence of

actions must be quantified and documented. When designing a detection system, the sum of the time needed for each step in the response sequence (t_{delay}) must be subtracted from the time at which the fire attains the design objective (t_{DO}) in order to determine the latest time and fire size (Q_{CR}) in the fire development at which detection can occur and still achieve the system design objective.

B-2.3.2.2.8 The fire scenarios and design fires selected should include analysis of best and worst case conditions and their likelihood of occurring. It is important to look at different conditions and situations and their effects on response.

B-2.3.2.3 Data Sources. To produce a design fire curve, information is needed regarding the burning characteristics of the object(s) involved. Data can be obtained from either technical literature or by conducting small or large scale calorimeter tests.

B-2.3.2.3.1 Some information is contained here in Figure B-2.3.2.3.1 and Tables B-2.3.2.3.1(a) through (e).

Figure B-2.3.2.3.1 Power law heat release rates.

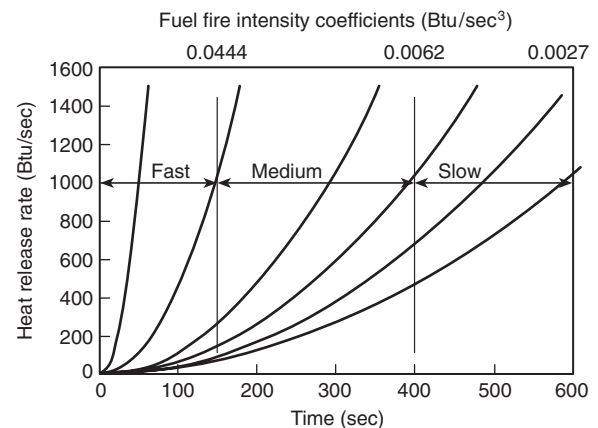


Table B-2.3.2.3.1(a) Maximum Heat Release Rates — Warehouse Materials

Warehouse Materials	Growth Time (t_g) (sec)	Heat Release Density (Q) (Btu/sec·ft²)	Classification
1. Wood pallets, stack, 1½ ft high (6%–12% moisture)	150–310	110	fast–medium
2. Wood pallets, stack, 5 ft high (6%–12% moisture)	90–190	330	fast
3. Wood pallets, stack, 10 ft high (6%–12% moisture)	80–110	600	fast
4. Wood pallets, stack, 16 ft high (6%–12% moisture)	75–105	900	fast
5. Mail bags, filled, stored 5 ft high	190	35	medium
6. Cartons, compartmented, stacked 15 ft high	60	200	fast
7. Paper, vertical rolls, stacked 20 ft high	15–28	—	†
8. Cotton (also PE, PE/cot, acrylic/nylon/PE), garments in 12-ft high racks	20–42	—	†
9. Cartons on pallets, rack storage, 15 ft–30 ft high	40–280	—	fast–medium
10. Paper products, densely packed in cartons, rack storage, 20 ft high	470	—	slow
11. PE letter trays, filled, stacked 5 ft high on cart	190	750	medium
12. PE trash barrels in cartons, stacked 15 ft high	55	250	fast
13. FRP shower stalls in cartons, stacked 15 ft high	85	110	fast
14. PE bottles, packed in item 6	85	550	fast
15. PE bottles in cartons, stacked 15 ft high	75	170	fast
16. PE pallets, stacked 3 ft high	130	—	fast
17. PE pallets, stacked 6 ft–8 ft high	30–55	—	fast
18. PU mattress, single, horizontal	110	—	fast
19. PE insulation board, rigid foam, stacked 15 ft high	8	170	†
20. PS jars, packed in item 6	55	1200	fast
21. PS tubs nested in cartons, stacked 14 ft high	105	450	fast
22. PS toy parts in cartons, stacked 15 ft high	110	180	fast
23. PS insulation board, rigid, stacked 14 ft high	7	290	†
24. PVC bottles, packed in item 6	9	300	†
25. PP tubs, packed in item 6	10	390	†
26. PP and PE film in rolls, stacked 14 ft high	40	350	†
27. Distilled spirits in barrels, stacked 20 ft high	23–40	—	†
28. Methyl alcohol	—	65	—
29. Gasoline	—	200	—
30. Kerosene	—	200	—
31. Diesel oil	—	180	—

For SI units: 1 ft = 0.305 m.

Notes:

1. The heat release rates per unit floor area are for fully involved combustibles, assuming 100 percent combustion efficiency. The growth times shown are those required to exceed 1000 Btu/sec heat release rate for developing fires, assuming 100 percent combustion efficiency.

2. PE = polyethylene, PS = polystyrene, PVC = polyvinyl chloride, PP = polypropylene, PU = polyurethane, and FRP = fiberglass-reinforced polyester.

†Fire growth rate exceeds design data.

Table B-2.3.2.3.1(b) Maximum Heat Release Rates from Fire Detection Institute Analysis

Materials	Approximate Values (Btu/sec)
Medium wastebasket with milk cartons	100
Large barrel with milk cartons	140
Upholstered chair with polyurethane foam	350
Latex foam mattress (heat at room door)	1200
Furnished living room (heat at open door)	4000-8000

Table B-2.3.2.3.1(c) Unit Heat Release Rates for Fuels Burning in the Open (NFPA 92B)

Commodity	Heat Release Rate (Btu/sec)
Flammable liquid pool	290/ft ² of surface
Flammable liquid spray	2000/gpm of flow
Pallet stack	1000/ft of height
Wood or PMMA* (vertical)	
2-ft height	30/ft of width
6-ft height	70/ft of width
8-ft height	180/ft of width
12-ft height	300/ft of width
Wood or PMMA*	
Top of horizontal surface	63/ft ² of surface
Solid polystyrene (vertical)	
2-ft height	63/ft of width
6-ft height	130/ft of width
8-ft height	400/ft of width
12-ft height	680/ft of width
Solid polystyrene (horizontal)	120/ft ² of surface
Solid polypropylene (vertical)	
2-ft height	63/ft of width
6-ft height	100/ft of width
8-ft height	280/ft of width
12-ft height	470/ft of width
Solid polypropylene (horizontal)	70/ft ² of surface

*Polymethyl Methacrylate (Plexiglas™, Lucite™, Acrylic)

Table B-2.3.2.3.1(d) Characteristics of Ignition Sources (NFPA 92B)

	Typical Heat Output (W)	Burn Time ^a (sec)	Maximum Flame Height (mm)	Flame Width (mm)	Maximum Heat Flux (kW/m ²)
Cigarette 1.1 g (not puffed, laid on solid surface), bone dry, conditioned to 50% relative humidity	5	1200	—	—	42
	5	1200	—	—	35
Methenamine pill, 0.15 g	45	90	—	—	4
Match, wooden, laid on solid surface	80	20–30	30	14	18–20
Wood cribs, BS 5852 Part 2					
No. 4 crib, 8.5 g	1,000	190	—	—	15 ^d
No. 5 crib, 17 g	1,900	200	—	—	17 ^d
No. 6 crib, 60 g	2,600	190	—	—	20 ^d
No. 7 crib, 126 g	6,400	350	—	—	25 ^d
Crumpled brown lunch bag, 6 g	1,200	80	—	—	—
Crumpled wax paper, 4.5 g (tight)	1,800	25	—	—	—
Crumpled wax paper, 4.5 g (loose)	5,300	20	—	—	—
Folded double-sheet newspaper, 22 g (bottom ignition)	4,000	100	—	—	—
Crumpled double-sheet newspaper, 22 g (top ignition)	7,400	40	—	—	—
Crumpled double-sheet newspaper, 22 g (bottom ignition)	17,000	20	—	—	—
Polyethylene wastebasket, 285 g, filled with 12 milk cartons (390 g)	50,000	200 ^b	550	200	35 ^c
Plastic trash bags, filled with cellulosic trash (1.2–14 kg) ^c	120,000–350,000	200 ^b	—	—	—

For SI Units: 1 in. = 25.4 mm; 1 Btu/sec = 1.055 W; 1 oz = 0.02835 kg = 28.35 g; 1 Btu/ft²·sec = 11.35 kW/m²

^a Time duration of significant flaming

^b Total burn time in excess of 1800 seconds

^c As measured on simulation burner

^d Measured from 25 mm away

^e Results vary greatly with packing density

Table B-2.3.2.3.1(e) Furniture Heat Release Rates [3, 14, 16]

Test No.	Item/Description/Mass	Growth Time (t_g) (sec)	Classification	Fuel Fire Intensity Coefficient (α) (kW/sec ²)	Virtual Time (t_v) (sec)	Maximum Heat Release Rates (kW)
15	Metal wardrobe, 41.4 kg (total)	50	fast	0.4220	10	750
18	Chair F33 (trial love seat), 29.2 kg	400	slow	0.0066	140	950
19	Chair F21, 28.15 kg (initial)	175	medium	0.0344	110	350
19	Chair F21, 28.15 kg (later)	50	fast	0.4220	190	2000
21	Metal wardrobe, 40.8 kg (total) (initial)	250	medium	0.0169	10	250
21	Metal wardrobe, 40.8 kg (total) (average)	120	fast	0.0733	60	250
21	Metal wardrobe, 40.8 kg (total) (later)	100	fast	0.1055	30	140
22	Chair F24, 28.3 kg	350	medium	0.0086	400	700
23	Chair F23, 31.2 kg	400	slow	0.0066	100	700
24	Chair F22, 31.9 kg	2000	slow	0.0003	150	300
25	Chair F26, 19.2 kg	200	medium	0.0264	90	800
26	Chair F27, 29.0 kg	200	medium	0.0264	360	900
27	Chair F29, 14.0 kg	100	fast	0.1055	70	1850
28	Chair F28, 29.2 kg	425	slow	0.0058	90	700
29	Chair F25, 27.8 kg (later)	60	fast	0.2931	175	700
29	Chair F25, 27.8 kg (initial)	100	fast	0.1055	100	2000
30	Chair F30, 25.2 kg	60	fast	0.2931	70	950
31	Chair F31 (love seat), 39.6 kg	60	fast	0.2931	145	2600
37	Chair F31 (love seat), 40.4 kg	80	fast	0.1648	100	2750
38	Chair F32 (sofa), 51.5 kg	100	fast	0.1055	50	3000
39	1/2-in. plywood wardrobe with fabrics, 68.5 kg	35	†	0.8612	20	3250
40	1/2-in. plywood wardrobe with fabrics, 68.32 kg	35	†	0.8612	40	3500
41	1/8-in. plywood wardrobe with fabrics, 36.0 kg	40	†	0.6594	40	6000
42	1/8-in. plywood wardrobe with fire- retardant interior finish (initial growth)	70	fast	0.2153	50	2000
42	1/8-in. plywood wardrobe with fire- retardant interior finish (later growth)	30	†	1.1722	100	5000
43	Repeat of 1/2-in. plywood wardrobe, 67.62 kg	30	†	1.1722	50	3000
44	1/8-in. plywood wardrobe with fire- retardant latex paint, 37.26 kg	90	fast	0.1302	30	2900

Table B-2.3.2.3.1(e) Furniture Heat Release Rates [3, 14, 16] (Continued)

Test No.	Item/Description/Mass	Growth Time (t_g) (sec)	Classification	Fuel Fire Intensity Coefficient (α) (kW/sec ²)	Virtual Time (t_v) (sec)	Maximum Heat Release Rates (kW)
45	Chair F21, 28.34 kg	100	†	0.1055	120	2100
46	Chair F21, 28.34 kg	45	†	0.5210	130	2600
47	Chair, adj. back metal frame, foam cushions, 20.82 kg	170	medium	0.0365	30	250
48	Easy chair CO7, 11.52 kg	175	medium	0.0344	90	950
49	Easy chair F34, 15.68 kg	200	medium	0.0264	50	200
50	Chair, metal frame, minimum cushion, 16.52 kg	200	medium	0.0264	120	3000
51	Chair, molded fiberglass, no cushion, 5.28 kg	120	fast	0.0733	20	35
52	Molded plastic patient chair, 11.26 kg	275	medium	0.0140	2090	700
53	Chair, metal frame, padded seat and back, 15.54 kg	350	medium	0.0086	50	280
54	Love seat, metal frame, foam cushions, 27.26 kg	500	slow	0.0042	210	300
56	Chair, wood frame, latex foam cushions, 11.2 kg	500	slow	0.0042	50	85
57	Love seat, wood frame, foam cushions, 54.6 kg	350	medium	0.0086	500	1000
61	Wardrobe, ³ / ₄ -in. particleboard, 120.33 kg	150	medium	0.0469	0	1200
62	Bookcase, plywood with aluminum frame, 30.39 kg	65	fast	0.2497	40	25
64	Easy chair, molded flexible urethane frame, 15.98 kg	1000	slow	0.0011	750	450
66	Easy chair, 23.02 kg	76	fast	0.1827	3700	600
67	Mattress and box spring, 62.36 kg (later)	350	medium	0.0086	400	500
67	Mattress and box spring, 62.36 kg (initial)	1100	slow	0.0009	90	400

For SI units: 1 ft = 0.305 m; 1000 Btu/sec = 1055 kW; 1 lb = 0.435 kg.

Note: For tests 19, 21, 29, 42, and 67, different power law curves were used to model the initial and the latter realms of burning. In examples such as these, engineers should choose the fire growth parameter that best describes the realm of burning to which the detection systems is being designed to respond.

† Fire growth exceeds design data.

B-2.3.2.3.2 Graphs of heat release data from the 40 furniture calorimeter tests can be found in *Investigation of a New Sprinkler Sensitivity Approval Test: The Plunge Test*. Best fit power law fire growth curves have been superimposed on the graphs. Data from these curves can be used with this guide to design or analyze fire detection systems that are intended to respond to similar items burning under a flat ceiling. Table B-2.3.2.3.1(e) is a summary of the data.

B-2.3.2.3.3 In addition to heat release rate data, the original NIST reports [3] contain data on particulate conversion and radiation from the test specimens. These data can be used to determine the threshold fire size (heat release rate) at which tenability becomes endangered or the point at which additional fuel packages might become involved in the fire.

B-2.3.2.3.4 The *NFPA Fire Protection Handbook* [22], *SFPE Handbook of Fire Protection Engineering*, and *Upholstered Furniture*

Heat Release Rates Measured with a Furniture Calorimeter contain further information on heat release rates and fire growth rates.

B-2.3.2.3.5 Technical literature searches can be performed using a number of resources including FIREDOC, a document base of fire literature that is maintained by NIST.

B-2.3.2.3.6 A series of design fire curves are included as part of the “Fastlite” computer program available from NIST.

B-2.3.3 Develop and Evaluate Candidate Fire Detection Systems. Once the design objectives, the potential fire scenarios, and the room characteristics are well understood, the designer can select an appropriate detection strategy to detect the fire before its critical fire size (Q_{CR}) is reached. Important factors to consider include the type of detector, its sensitivity to expected fire signatures, its alarm threshold level and required duration at that threshold, expected installed location (for example, distance from fire, or below ceiling), and freedom from nuisance response to expected ambient conditions. (See Chapter 2 and Appendix A.)

B-2.3.3.1 Reliability of the detection system and individual components should be computed and included in the selection and evaluation of the candidate fire detection system. A performance-based alternative design cannot be deemed performance-equivalent unless the alternative design provides comparable reliability to the prescriptive design it is intended to replace.

B-2.3.3.2 Various methods are available to evaluate whether a candidate design will achieve the previously established performance criteria. Some methods are presented in Section B-3.

B-2.3.4 Select and Document Final Design. The last step in the process is the preparation of design documentation and equipment and installation specifications.

B-2.3.4.1 These documents should encompass the following information [25]:

- (1) Participants in the process — persons involved, their qualifications, function, responsibility, interest, and contributions
- (2) Scope of work — purpose of conducting the analysis or design, part of the building evaluated, assumptions, and so on.
- (3) Design approach — approach taken, where and why assumptions were made, and engineering tools and methodologies applied
- (4) Project information — hazards, risks, construction type, materials, building use, layout, existing systems, occupant characteristics, and so on.
- (5) Goals and objectives — agreed upon goals and objectives, how they were developed, who agreed to them and when
- (6) Performance criteria — clearly identify performance criteria and related objective(s), including any safety, reliability, or uncertainty factors applied, and support for these factors where necessary
- (7) Fire scenarios and design fires — description of fire scenarios used, bases for selecting and rejecting fire scenarios, assumptions, and restrictions.
- (8) Design alternative(s) — describe design alternative(s) chosen, basis for selecting and rejecting design alternative(s), heat release rate, assumptions, and limitations. [This step should include the specific design objective (Q_{DO}) and the critical heat release rate (Q_{CR}) used, comparison of results with the performance criteria and

design objectives, and a discussion of the sensitivity of the selected design alternative to changes in the building use, contents, fire characteristics, occupants, and so on.]

- (9) Engineering tools and methods used — description of engineering tools and methods used in the analysis or design, including appropriate references (literature, date, software version, and so on), assumptions, limitations, engineering judgments, input data, validation data or procedures, and sensitivity analyses
- (10) Drawings and specifications — detailed design and installation drawings and specification
- (11) Test, inspection, and maintenance requirements (see Chapter 7)
- (12) Fire safety management concerns — allowed contents and materials in the space in order for the design to function properly, training, education, and so on.
- (13) References — software documentation, technical literature, reports, technical data sheets, fire test results, and so on.

B-2.3.5 Management. It is important to ensure that the systems are designed, installed, commissioned, maintained, and tested on regular intervals as indicated in Chapter 7. In addition, the person conducting the testing and inspections should be aware of the background of the design and the need to evaluate not only the detector and whether it operates, but also to be aware of changing conditions including the following:

- (1) Hazard being protected changes
- (2) Location of the hazard changes
- (3) Other hazards are introduced into the area
- (4) Ambient environment
- (5) Invalidity of any of the design assumptions

B-3 Evaluation of Heat Detection System Performance.

B-3.1 General. Section B-3 provides a method for determining the application spacing for both fixed-temperature heat detectors (including sprinklers) and rate-of-rise heat detectors. This method is only valid for use when detectors are to be placed on a large, flat ceiling. It predicts detector response to a geometrically growing flaming fire at a specific fire size. This method takes into account the effects of ceiling height, radial distance between the detector and the fire, threshold fire size [critical heat release rate (Q_{CR})], rate of fire development, and detector response time index. For fixed temperature detectors, the ambient temperature and the temperature rating of the detector are also considered. This method also allows for the adjustment of the application spacing for fixed-temperature heat detectors to account for variations in ambient temperature (T_a) from standard test conditions.

B-3.1.1 This method can also be used to estimate the fire size at which detection will occur, an existing array of listed heat detectors installed at a known spacing, ceiling height, and ambient conditions.

B-3.1.2 The effect of rate of fire growth and fire size of a flaming fire, as well as the effect of ceiling height on the spacing and response of smoke detectors can also be determined using this method.

B-3.1.3 The methodology contained herein uses theories of fire development, fire plume dynamics, and detector performance. These are considered the major factors influencing detector response. This methodology does not address several lesser phenomena that, in general, are considered unlikely to have a significant influence. A discussion of ceiling drag, heat

loss to the ceiling, radiation to the detector from a fire, re-radiation of heat from a detector to its surroundings, and the heat of fusion of eutectic materials in fusible elements of heat detectors and their possible limitations on the design method are provided in References 4, 11, 16, and 18 in Appendix C.

B-3.1.4 The methodology in Section B-3 does not address the effects of ceiling projections, such as beams and joists, on detector response. While it has been shown that these components of a ceiling have a significant effect on the response of heat detectors, research has not yet resulted in a method for quantifying this effect. The prescriptive adjustments to detector spacing in Chapter 5 should be applied to application spacings derived from this methodology.

B-3.2 Considerations Regarding Input Data.

B-3.2.1 Required Data. The following data are necessary in order to use the methods in this appendix for either design or analysis.

(a) *Design.* Data required to determine design include the following:

H = ceiling height or clearance above fuel

Q_d or t_d = threshold fire size at which response must occur or the time t_d to detector response

RTI = response time index for the detector (heat detectors only) or its listed spacing

T_a = ambient temperature

T_s = detector operating temperature (heat detectors only)

T_s/min = rate of temperature change set point for rate-of-rise heat detectors

α or t_g = fuel fire intensity coefficient (α) or the fire growth time (t_g)

(b) *Analysis.* Data required to determine analysis include the following:

H = ceiling height or clearance above fuel

RTI = response time index for the detector (heat detectors only) or its listed spacing

S = actual installed spacing of the existing detectors

T_a = ambient temperature

T_s = detector operating temperature (heat detectors only)

T_s/min = rate of temperature change set point for rate-of-rise heat detectors

α or t_g = fuel fire intensity coefficient (α) or the fire growth time (t_g)

B-3.2.2 Ambient Temperature Considerations.

B-3.2.2.1 The maximum ambient temperature expected to occur at the ceiling will directly effect the choice of temperature rating for a fixed-temperature heat detector application. However, the minimum ambient temperature likely to be present at the ceiling is also very important. When ambient temperature at the ceiling decreases, more heat from a fire is needed to bring the air surrounding the detector's sensing element up to its rated (operating) temperature. This results in slower response when the ambient temperature is lower. In the case of a fire that is growing over time, lower ambient temperatures result in a larger fire size at the time of detection.

B-3.2.2.2 Selection of the minimum ambient temperature can therefore have a significant effect on the calculations. The engineer must decide what temperature to use for these calculations and document why that temperature was chosen. Because the response time of a given detector to a given fire is

dependent only on the detector's time constant and the temperature difference between ambient and the detector rating, the use of the lowest anticipated ambient temperature for the space results in the most conservative design. For unheated spaces, a review of historical weather data would be appropriate. However, such data might show extremely low temperatures that occur relatively infrequently, such as every 100 years. Depending on actual design considerations, it might be more appropriate to use an average minimum ambient temperature. In any case, a sensitivity analysis should be performed to determine the effect of changing the ambient temperature on the design results.

B-3.2.2.3 In a room or work area that has central heating, the minimum ambient temperature would usually be about 68°F (20°C). On the other hand, certain warehouse occupancies might be heated only enough to prevent water pipes from freezing and, in this case, the minimum ambient temperature may be considered to be 35°F (2°C), even though, during many months of the year, the actual ambient temperature may be much higher.

B-3.2.3 Ceiling Height Considerations.

B-3.2.3.1 A detector ordinarily operates sooner if it is nearer to the fire. Where ceiling heights exceed 16 ft (4.9 m), ceiling height is the dominant factor in the detection system response.

B-3.2.3.2 As flaming combustion commences, a buoyant plume forms. The plume is comprised of the heated gases and smoke rising from the fire. The plume assumes the general shape of an inverted cone. The smoke concentration and temperature within the cone varies inversely as a variable exponential function of the distance from the source. This effect is very significant in the early stages of a fire, because the angle of the cone is wide. As a fire intensifies, the angle of the cone narrows and the significance of the effect of height is lessened.

B-3.2.3.3 As the ceiling height increases, a larger-size fire is necessary to actuate the same detector in the same length of time. In view of this, it is very important that the designer consider the size of the fire and rate of heat release that might develop before detection is ultimately obtained.

B-3.2.3.4 The procedures presented in this section are based on analysis of data for ceiling heights up to 30 ft (9.1 m). No data was analyzed for ceiling heights greater than 30 ft (9.1 m). In spaces where the ceiling heights exceed this limit, this section offers no guidance. [40]

B-3.2.3.5 The relationships presented here are based on the difference between the ceiling height and the height of the fuel item involved in the fire. It is recommended that the designer assume the fire is at floor level and use the actual distance from floor to ceiling for the calculations. This will yield a design that is conservative, and actual detector response can be expected to exceed the needed speed of response in those cases where the fire begins above floor level.

B-3.2.3.6 Where the designer desires to consider the height of the potential fuel in the room, the distance between the base of the fuel and the ceiling should be used in place of the ceiling height. This design option is only appropriate if the minimum height of the potential fuel is always constant and the concept is approved by the authority having jurisdiction.

B-3.2.4 Operating Temperature.

B-3.2.4.1 The operating temperature, or rate of temperature change, of the detector required for response is obtained from the manufacturer's data and is determined during the listing process.

B-3.2.4.2 The difference between the rated temperature of a fixed temperature detector (T_s) and the maximum ambient temperature (T_a) at the ceiling should be as small as possible. To reduce unwanted alarms, the difference between operating temperature and the maximum ambient temperature should be not less than 20°F (11°C). (See Chapter 2.)

B-3.2.4.3 If using combination detectors incorporating both fixed temperature and rate-of-rise heat detection principles to detect a geometrically growing fire, the data contained herein for rate-of-rise detectors should be used in selecting an installed spacing, because the rate-of-rise principle controls the response. The fixed temperature set point is determined from the maximum anticipated ambient temperature.

B-3.2.5 Time Constant and Response Time Index (RTI).

B-3.2.5.1 The flow of heat from the ceiling jet into a heat detector sensing element is not instantaneous. It occurs over a period of time. A measure of the speed with which heat transfer occurs, the thermal response coefficient is needed to accurately predict heat detector response. This is currently called the detector time constant (τ_0). The time constant is a measure of the detector's sensitivity. In theory, the sensitivity of a heat detector, τ_0 or RTI, should be determined by validated test. [8] Currently, such a test is not available. Given the detector's listed spacing and the detector's rated temperature (T_s), Table B-3.2.5.1, developed in part by Heskestad and Delichatsios [10], can be used to find the detector time constant.

B-3.2.6 Fire Growth Rate.

B-3.2.6.1 Fire growth varies depending on the combustion characteristics and the physical configuration of the fuels involved. After ignition, most fires grow in an accelerating pattern. Some information regarding the fire growth rate for various fuels have been provided previously in this appendix.

B-3.2.6.2 If the heat release history for a particular fire is known, the α or t_g can be calculated using curve fitting techniques for implementation into the method detailed herein. [16]

B-3.2.6.3 In most cases, the exact fuel(s) and growth rates will not be known. Engineering judgment should therefore be used to select α or t_g that is expected to approximate the fire. Sensitivity analysis should also be performed to determine the effect on response from changes in the expected fire growth rate. In some analyses the effect on response will be negligible. Other cases might show that a more thorough analysis of potential fuels and fire scenarios is necessary.

B-3.2.7 Threshold Fire Size. The user should refer to previous sections regarding discussions on determining threshold fire sizes (Q_{DO} and Q_{CR}) to meet the design objectives.

B-3.3 Heat Detector Spacing.

B-3.3.1 Fixed-Temperature Heat Detector Spacing. The following method can be used to determine the response of fixed-temperature heat detectors for designing or analyzing heat detection systems.

B-3.3.1.1 The objective of designing a detection system is to determine the spacing of detectors required to respond to a given set of conditions and goals. In order to achieve the objectives, detector response must occur when the fire reaches a critical heat release rate, or in a specified time.

Table B-3.2.5.1 Time Constants (τ_0) for Any Listed Heat Detector

Listed Spacing (ft)	Underwriters Laboratories Inc.						Factory Mutual Research Corporation (All Temperatures)
	128°	135°	145°	160°	170°	196°	
10	400	330	262	195	160	97	196
15	250	190	156	110	89	45	110
20	165	135	105	70	52	17	70
25	124	100	78	48	32	—	48
30	95	80	61	36	22	—	36
40	71	57	41	18	—	—	—
50	59	44	30	—	—	—	—
70	36	24	9	—	—	—	—

For SI units: 1 ft = 0.305 m.

Notes:

1. These time constants are based on an analysis [10] of the Underwriters Laboratories Inc. and Factory Mutual listing test procedures.

2. These time constants can be converted to response time index (RTI) values by using the following equation:

$$RTI = \tau_0 (5.0 \text{ ft/sec})^{1/2} \text{ (Refer also to B-3.3.)}$$

*At a reference velocity of 5 ft/sec (1.5 m/sec).

B-3.3.1.2 When analyzing an existing detection system, the engineer is looking to determine the size of the fire at the time that the detector responds.

B-3.3.2 Theoretical Background. [26, 28]

B-3.3.2.1 The design and analysis methods contained in Appendix B are the joint result of extensive experimental work and of mathematical modeling of the heat and mass transfer processes involved. The original method was developed by Heskestad and Delichatsios [9, 10], Beyler [4], and Schifiliti [16]. It was recently updated by Marrion [28] to reflect changes in the original correlations as discussed in work by Heskestad and Delichatsios [11] and Marrion [27]. Subsection B-3.3.2 outlines methods and data correlations used to model the heat transfer to a heat detector, as well as velocity and temperature correlations for growing fires at the location of the detector. Only the general principles are described here. More detailed information is available in References 4, 9, 10, 16, and 28 in Appendix C.

B-3.3.3 Heat Detector Correlations. [26, 28] The heat transfer to a detector can be described by the following equation:

$$Q_{\text{total}} = Q_{\text{cond}} + Q_{\text{conv}} + Q_{\text{rad}} (\text{kW or Btu/sec}) \quad (6)$$

where:

- Q_{total} = total heat transfer to a detector
- Q_{cond} = conductive heat transfer
- Q_{conv} = convective heat transfer
- Q_{rad} = radiative heat transfer

B-3.3.3.1 Because detection typically occurs during the initial stages of a fire, the radiant heat transfer component (Q_{rad}) can be considered negligible. In addition, because the heat sensing elements of most of the heat detectors are thermally isolated from the rest of the detection unit, as well as from the ceiling, it can be assumed that the conductive portion of the heat release rate (Q_{cond}) is also negligible, especially when compared to the convective heat transfer rate. Because the majority of the heat transfer to the detection element is via convection, the following equation can be used to calculate the total heat transfer:

$$Q = Q_{\text{conv}} = H_c A (T_g - T_d) (\text{kW or Btu/sec}) \quad (7)$$

where:

- Q_{conv} = convective heat transfer
- H_c = convective heat transfer coefficient for the detector in kW/m²·°C or in Btu/ft²·sec·°F
- A = surface area of the detector's element
- T_g = temperature of fire gases at the detector
- T_d = temperature rating, or set point, of the detector

B-3.3.3.2 Assuming the detection element can be treated as a lumped mass (m) (kg or lbm) its temperature change can be defined as follows:

$$\frac{dT_d}{dt} = \frac{Q}{mc} (\text{deg/sec}) \quad (8)$$

where:

- Q = heat release rate (Btu/sec or kW)
- m = detector element's mass
- c = detector element's specific heat (kJ/kg·°C or Btu/lbm·°F)

B-3.3.3.3 Substituting this into the previous equation, the change in temperature of the detection element over time can be expressed as follows:

$$\frac{dT_d}{dt} = \frac{H_c A (T_g - T_d)}{mc} \quad (9)$$

Note that the variables are identified in Section B-7.

B-3.3.3.4 The use of a time constant (τ) was proposed by Heskestad and Smith [8] in order to define the convective heat transfer to a specific detector's heat sensing element. This time constant is a function of the mass, specific heat, convective heat transfer coefficient, and area of the element and can be expressed as follows:

$$\tau = \frac{mc}{H_c A} (\text{sec}) \quad (10)$$

where:

- m = detector element's mass
- c = detector element's specific heat (kJ/kg·°C or Btu/lbm·°F)
- H_c = convective heat transfer coefficient for the detector (kW/m²·°C or Btu/ft²·sec·°F)
- A = surface area of the detector's element
- τ = detector time constant

B-3.3.3.5 As seen in the equation (10), τ is a measure of the detector's sensitivity. By increasing the mass of the detection element, the time constant, and thus the response time, increases.

B-3.3.3.6 Substituting into equation (9) produces the following:

$$\frac{dT_d}{dt} = \frac{T_g - T_d}{\tau}$$

Note that the variables are identified in Section B-7.

B-3.3.3.7 Research has shown [24] that the convective heat transfer coefficient for sprinklers and heat detection elements are similar to that of spheres, cylinders, and so on, and is thus approximately proportional to the square root of the velocity of the gases passing the detector. As the mass, thermal capacity, and area of the detection element remain constant, the following relationship can be expressed as the response time index (RTI) for an individual detector:

$$\tau u^{1/2} \sim \tau_0 u_0^{1/2} = \text{RTI} \quad (11)$$

where:

- τ = detector time constant
- u = velocity of fire gases (m/sec)

u_0 = instantaneous velocity of fire gases
(m/sec or ft/sec)

RTI = response time index

B-3.3.3.8 If τ_0 is measured at a given reference velocity (u_0), τ can be determined for any other gas velocity (u) for that detector. A plunge test is the easiest way to measure τ_0 . It has also been related to the listed spacing of a detector through a calculation. Table B-3.2.5.1 presents results from these calculations [10]. The RTI value can then be obtained by multiplying τ_0 values by $u_0^{1/2}$.

B-3.3.3.9 It has become customary to refer to the time constant using a reference velocity of $u_0 = 5$ ft/sec (1.5 m/sec). For example, where $u_0 = 5$ ft/sec (1.5 m/sec), a τ_0 of 30 seconds corresponds to an RTI of $67 \text{ sec}^{1/2}/\text{ft}^{1/2}$ (or $36 \text{ sec}^{1/2}/\text{m}^{1/2}$). On the other hand, a detector that has an RTI of $67 \text{ sec}^{1/2}/\text{ft}^{1/2}$ would have a τ_0 of 23.7 sec, if measured in an air velocity of 8 ft/sec (2.4 m/sec).

B-3.3.3.10 The following equation can therefore be used to calculate the heat transfer to the detection element, and thus determine its temperature from its local fire-induced environment.

$$\frac{dT_d}{dt} = \frac{u^{1/2}(T_g - T_d)}{\text{RTI}} \quad (12)$$

Note that the variables are identified in Section B-7.

B-3.3.4 Temperature and Velocity Correlations. [26, 28] In order to predict the operation of any detector, it is necessary to characterize the local environment created by the fire at the location of the detector. For a heat detector, the important variables are the temperature and velocity of the gases at the detector. Through a program of full-scale tests and the use of mathematical modeling techniques, general expressions for temperature and velocity at a detector location have been developed by Heskestad and Delichatsios (refer to references 4, 9, 10, and 16 in Section C-2). These expressions are valid for fires that grow according to the following power law relationship:

$$Q(\text{kW}) = \alpha(\text{Btu/sec}^2)t^p \quad (13)$$

where:

Q = theoretical convective fire heat release rate
 α = fire growth rate
 t = time
 p = positive exponent

B-3.3.4.1 Relationships have been developed by Heskestad and Delichatsios [9] for temperature and velocity of fire gases in a ceiling jet. These have been expressed as follows [26]:

$$U_p^* = \frac{u}{A^{1/(3+p)} u^{1/(3+p)} H^{(p-1)/(3+p)}} = f\left(t_p^*, \frac{r}{H}\right) \quad (14)$$

$$\Delta T_p^* = g\left(t_p^*, \frac{r}{H}\right) = \frac{\Delta T}{A^{2/(3+p)} \left(\frac{T_a}{g}\right) \alpha^{2/(3+p)} H^{-(5-p)/(3+p)}}$$

where:

$$t_p^* = \frac{t}{A^{-1/(3+p)} \alpha^{-1/(3+p)} H^{4/(3+p)}}$$

and

$$A = \frac{g}{C_p T_a \rho_0}$$

Note that the variables are identified in Section B-7.

B-3.3.4.2 Using the above correlations, Heskestad and Delichatsios [9], and with later updates from another paper by Heskestad [11], the following correlations were presented for fires that had heat release rates that grew according to the power law equation, with $p = 2$. As previously discussed [10, 18], the $p = 2$ power law fire growth model can be used to model the heat release rate of a wide range of fuels. These fires are therefore referred to as *t-squared* fires.

$$t_{2f}^* = 0.861 \left(1 + \frac{r}{H}\right) \quad (15)$$

$$\Delta T_2^* = 0 \text{ for } t_2^* < t_{2f}^*$$

$$\Delta T_2^* = \left[\frac{t_2^* - t_{2f}^*}{0.146 + 0.242r/H} \right]^{4/3} \text{ for } t_2^* \geq t_{2f}^*$$

$$\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.59 \left(\frac{r}{H} \right)^{-0.63}$$

Note that the variables are identified in Section B-7.

B-3.3.4.3 Work by Beyler [4] determined that the above temperature and velocity correlations could be substituted into the heat transfer equation for the detector and integrated. His analytical solution is as follows:

$$T_d(t) - T_d(0) = \left(\frac{\Delta T}{\Delta T_2^*} \right) \Delta T_2^* \left[\frac{1 - (1 - e^{-Y})}{Y} \right]$$

$$\frac{dT_d(t)}{dt} = \frac{\left(\frac{4}{3} \right) \left(\frac{\Delta T}{\Delta T_2^*} \right) (\Delta T_2^*)^{1/4} (1 - e^{-Y})}{\left(\frac{t}{t_2^*} \right) D}$$

where:

$$Y = \left(\frac{3}{4} \right) \left(\frac{u}{u_2^*} \right)^{1/2} \left[\frac{u_2^*}{\Delta T_2^*^{1/2}} \right]^{1/2} \left(\frac{\Delta T_2^*}{\text{RTI}} \right) \left(\frac{t}{t_2^*} \right) D \quad (17)$$

and

$$D = 0.146 + 0.242r/H$$

Note that variables are identified in Section B-7.

B-3.3.4.4 The steps involved in solving these equations for either a design or analysis situation are presented in Figure B-3.3.4.4 [28].

Figure B-3.3.4.4 Fire detection design and analysis worksheet. [28]

Fire Detection Design and Analysis Worksheet [28]
Design Example

1.	Determine ambient temperature (T_a) ceiling height or height above fuel (H).	$T_a = \underline{\hspace{2cm}} ^\circ\text{C} + 273 = \underline{\hspace{2cm}} \text{K}$ $H = \underline{\hspace{2cm}} \text{m}$
2.	Determine the fire growth characteristic (α or t_g) for the expected design fire.	$\alpha = \underline{\hspace{2cm}} \text{kW/s}^2$ $t_g = \underline{\hspace{2cm}} \text{sec}$
3a.	Define the characteristics of the detectors.	$T_s = \underline{\hspace{2cm}} \text{C}$ $\text{RTI} = \underline{\hspace{2cm}} \text{m}^{1/2}\text{s}^{1/2}$ $\frac{dT_d}{dt} = \underline{\hspace{2cm}} ^\circ\text{C/min}$ $\tau_0 = \underline{\hspace{2cm}} \text{sec}$
3b.	<i>Design</i> — Establish system goals (t_{CR} or Q_{CR}) and make a first estimate of the distance (r) from the fire to the detector.	$t_{CR} = \underline{\hspace{2cm}} \text{sec}$ $r = \underline{\hspace{2cm}} \text{m}$ $Q_{CR} = \underline{\hspace{2cm}} \text{kW}$
3b.	<i>Analysis</i> — Determine spacing of existing detectors and make a first estimate of the response time or the fire size at detector response ($Q = \alpha t^2$).	$r = \underline{\hspace{2cm}} * 1.41 = \underline{\hspace{2cm}} = S \text{ (m)}$ $Q = \underline{\hspace{2cm}} \text{kW}$ $t_d = \underline{\hspace{2cm}} \text{sec}$
4.	Using equation (15), calculate the nondimensional time (t_{2f}^*) at which the initial heat front reaches the detector.	$t_{2f}^* = 0.861 \left(1 + \frac{r}{H}\right)$ $t_{2f}^* = \underline{\hspace{2cm}}$
5.	Calculate the factor A defined in equation (14).	$A = \frac{g}{C_p T_a \rho_0}$ $A = \underline{\hspace{2cm}}$
6.	Use the required response time along with equation (14) and $p = 2$ to calculate the corresponding value of t_2^* .	$t_2^* = \frac{t}{A^{-1/(3+p)} \alpha^{-1/(3+p)} H^{4/(3+p)}}$ $t_2^* = \underline{\hspace{2cm}}$
7.	If $t_2^* > t_{2f}^*$ continue to step 8. If not, try a new detector position (r) and return to step 4.	
8.	Calculate the ratio $\frac{u}{u_p}$ using equation (18).	$\frac{u}{u_p} = A^{1/(3+p)} \alpha^{1/(3+p)} H^{(p-1)/(3+p)}$ $\frac{u}{u_p} = \underline{\hspace{2cm}}$
9.	Calculate the ratio $\frac{\Delta T}{\Delta T_2^*}$ using equation (19).	$\frac{\Delta T}{\Delta T_2^*} = A^{2/(3+p)} (T_a/g) \alpha^{2/(3+p)} H^{-(5-p)/(3+p)}$ $\frac{\Delta T}{\Delta T_2^*} = \underline{\hspace{2cm}}$
10.	Use equation (15) to calculate ΔT_2^* .	$\Delta T_2^* = \left[\frac{t_2^* - t_{2f}^*}{(0.146 + 0.242r/H)} \right]^{4/3}$ $\Delta T_2^* = \underline{\hspace{2cm}}$
11.	Use equation (17) to calculate the ratio $\frac{u_2^*}{(\Delta T_2^*)^{1/2}}$.	$\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.59 \left(\frac{r}{H}\right)^{-0.63}$ $\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = \underline{\hspace{2cm}}$
12.	Use equations (16) and (17) to calculate Y .	$Y = \left(\frac{3}{4}\right) \left(\frac{u}{u_2^*}\right)^{1/2} \left[\frac{u_2^*}{\Delta T_2^*}\right]^{1/2} \left(\frac{\Delta T_2^*}{\text{RTI}}\right) \left(\frac{t}{t_2^*}\right) D$ $Y = \underline{\hspace{2cm}}$
13.	<i>Fixed Temperature HD</i> — Use equation (16) to calculate the resulting temperature of the detector.	$T_d(t) = \left(\frac{\Delta T}{\Delta T_2^*}\right) \Delta T_2^* \left[1 - \frac{(1 - e^{-Y})}{Y}\right] + T_d(0)$ $T_d(t) = \underline{\hspace{2cm}}$
14.	<i>Rate of Rise HD</i> — Use equation (16).	$dT_d = \left[\left(\frac{4}{3}\right) \left(\frac{\Delta T}{\Delta T_2^*}\right) (\Delta T_2^*)^{1/4} \frac{(1 - e^{-Y})}{[(t/t_2^*)D]}\right] dT_d$ $dT_d = \underline{\hspace{2cm}}$
15.	If: 1. $T_d < T_s$ 2. $T_d > T_s$ 3. $T_d = T$	<div style="text-align: center;">Repeat Procedure Using</div> <div style="display: flex; justify-content: space-between;"> <div> Design 1. a larger r 2. a smaller r 3. $s = 1.41 \times r = \underline{\hspace{2cm}} \text{m}$ </div> <div> Analysis 1. a larger t_r 2. a smaller t_r 3. $t_r = \underline{\hspace{2cm}} \text{sec}$ </div> </div>

B-3.3.5 Limitations. [26] If velocity and temperature of the fire gases flowing past a detector cannot be accurately determined, errors will be introduced when calculating the response of a detector. The graphs presented by Heskestad and Delichatsios indicate the errors in the calculated fire gas temperatures and velocities [10]. A detailed analysis of these errors is beyond the scope of this appendix, however, some discussion is warranted. In using the method described above, the user should be aware of the limitations of these correlations, as outlined in Reference 26. The designer should also refer back to the original reports.

Graphs of actual and calculated data show that errors in ΔT_2^* can be as high as 50 percent, although generally there appears to be much better agreement. The maximum errors occur at r/H values of about 0.37. All other plots of actual and calculated data, for various r/H , show much smaller errors. In terms of the actual change in temperature over ambient, the maximum errors are on the order of 5°C to 10°C. The larger errors occur with faster fires and lower ceilings.

At $r/H = 0.37$, the errors are conservative when the equations are used in a design problem. That is, the equations predicted lower temperatures. Plots of data for other values of r/H indicate that the equations predict slightly higher temperatures.

Errors in fire-gas velocities are related to errors in temperatures. The equations show that the velocity of the fire gases is proportional to the square root of the change in temperatures of the fire gases. In terms of heat transfer to a detector, the detector's change in temperature is proportional to the change in gas temperature and the square root of the fire-gas velocity. Hence, the expected errors bear the same relationships.

Based on the above, errors in predicted temperatures and velocities of fire gases will be greatest for fast fires and low ceilings. Sample calculations simulating these conditions show errors in calculated detector spacings on the order of plus or minus one meter, or less.

B-3.3.5.1 The procedures presented in this appendix are based on an analysis of test data for ceiling heights up to 30 ft (9.1 m). No data was analyzed for ceilings greater than 30 ft (9.1 m). The reader should refer to Reference 40 for additional insight.

B-3.3.6 Design Examples.

B-3.3.6.1 Define Project Scope. A fire detection system is to be designed for installation in an unsprinklered warehouse building. The building has a large, flat ceiling that is approximately 4 m (13.1 ft) high. The ambient temperature inside is normally 10°C (50°F). The municipal fire service has indicated that it can begin putting water on the fire within 5.25 minutes of receiving the alarm.

B-3.3.6.2 Identify Goals. Provide protection of property.

B-3.3.6.3 Define Stakeholder's Objective. No fire spread from initial fuel package.

B-3.3.6.4 Define Design Objective. Prevent radiant ignition of adjacent fuel package.

B-3.3.6.5 Develop Performance Criteria. After discussions with the plant fire brigade with regard to their capability and analyzing the radiant energy levels necessary to ignite adjacent fuel packages it was determined that the fire should be detected and suppression activities started prior to it reaching 10,000 kW.

B-3.3.6.6 Develop Fire Scenarios and the Design Fire.

Evaluation of the potential contents to be warehoused identified the areas where wood pallets are stored to be one of the highest fire hazards.

B-3.3.6.6.1 The fire scenario involving the ignition of a stack of wood pallets will therefore be evaluated. The pallets are stored 1.5 m (5 ft) high. Fire test data [see Table B-2.3.2.3.1(a)] indicate that this type of fire follows the t^2 power law equation with a t_g equal to approximately 150 to 310 seconds. In order to be conservative, the faster fire growth rate will be used. Thus,

$$\begin{aligned} Q(\text{kW}) &= \alpha(\text{kW/sec}^2)t^p \\ 1055(\text{kW}) &= \alpha(\text{kW/sec}^2)(150 \text{ sec})^2 \\ \alpha &= 0.047(\text{kW/sec}^2) \end{aligned}$$

Note that variables are identified in Section B-7.

B-3.3.6.7 Using the power law growth equation with $p = 2$, the time after open flaming until the fire grows to 10,000 kW can be calculated as follows:

$$\begin{aligned} Q &= \left(\frac{1055}{t_c^2} \right) t_{DO}^2 = \alpha t^2 \\ t_{DO} &= 461 \text{ seconds} \end{aligned} \quad (18)$$

Note that variables are identified in Section B-7.

B-3.3.6.8 The critical heat release rate and time to detection can therefore be calculated as follows, assuming t_{respond} equals the 1 minute necessary for the fire brigade to respond to the alarm and begin discharging water.

$$\begin{aligned} t_{CR} &= t_{DO} - t_{\text{respond}} \\ t_{CR} &= 461 - 315 = 146 \text{ seconds} \end{aligned} \quad (19)$$

and thus

$$\begin{aligned} Q_{CR} &= \alpha t_{CR}^2 \\ Q_{CR} &= 1000 \text{ kW} \end{aligned}$$

Note that variables are identified in Section B-7.

B-3.3.7 Develop Candidate Designs. Fixed-temperature heat detectors have been selected for installation in the warehouse with a 57°C (135°F) operating temperature and a UL-listed spacing of 30 ft (9.1 m). From Table B-3.2.5.1, the time constant is determined to be 80 seconds when referenced to a gas velocity of 1.5 m/sec (5 ft/sec). When used with equation (11), the detector's RTI can be calculated as follows:

$$\begin{aligned} \text{RTI} &= t_0 u_0^{1/2} \\ \text{RTI} &= 98 \text{ m}^{1/2} \text{ sec}^{1/2} \end{aligned} \quad (20)$$

B-3.3.7.1 In order to begin calculations, it will be necessary to make a first guess at the required detector spacing. For this example, a first estimate of 4.7 m (15.3 ft) is used. This correlates to a radial distance of 3.3 m (10.8 ft).

B-3.3.8 Evaluate Candidate Designs. These values can then be entered into the design and analysis worksheet shown in Figure B-3.3.8 in order to evaluate the candidate design.

Figure B-3.3.8 Fire detection design and analysis worksheet [28] — design example.

Fire Detection Design and Analysis Worksheet [28]
Design Example

1.	Determine ambient temperature (T_a) ceiling height or height above fuel (H).	$T_a = 10^\circ\text{C} + 273 = 283\text{ K}$ $H = 4\text{ m}$
2.	Determine the fire growth characteristic (α or t_g) for the expected design fire.	$\alpha = 0.047\text{ kW/s}^2$ $t_g = 150\text{ sec}$
3a.	Define the characteristics of the detectors.	$T_s = 57^\circ\text{C}$ $\text{RTI} = 98\text{ m}^{1/2}\text{s}^{1/2}$ $\frac{dT_d}{dt} = \text{ }^\circ\text{C/min}$ $\tau_0 = \text{ } \text{sec}$
3b.	<i>Design</i> — Establish system goals (t_{CR} or Q_{CR}) and make a first estimate of the distance (r) from the fire to the detector.	$t_{CR} = 146\text{ sec}$ $r = 3.3\text{ m}$ $Q_{CR} = 1000\text{ kW}$
3b.	<i>Analysis</i> — Determine spacing of existing detectors and make a first estimate of the response time or the fire size at detector response ($Q = \alpha t^2$).	$r = \text{ } * 1.41 = \text{ } = S\text{ (m)}$ $Q = \text{ } \text{ kW}$ $t_d = \text{ } \text{ sec}$
4.	Using equation (15), calculate the nondimensional time (t_{2f}^*) at which the initial heat front reaches the detector.	$t_{2f}^* = 0.861 \left(1 + \frac{r}{H}\right)$ $t_{2f}^* = 1.57$
5.	Calculate the factor A defined in equation (14).	$A = \frac{g}{C_p T_a \rho_0}$ $A = 0.030$
6.	Use the required response time along with equation (14) and $p = 2$ to calculate the corresponding value of t_2^* .	$t_2^* = \frac{t}{A^{-1/(3+p)} \alpha^{-1/(3+p)} H^{4/(3+p)}}$ $t_2^* = 12.98$
7.	If $t_2^* > t_{2f}^*$ continue to step 8. If not, try a new detector position (r) and return to step 4.	
8.	Calculate the ratio $\frac{u}{u_p^*}$ using equation (18).	$\frac{u}{u_p^*} = A^{1/(3+p)} \alpha^{1/(3+p)} H^{(p-1)/(3+p)}$ $\frac{u}{u_p^*} = 0.356$
9.	Calculate the ratio $\frac{\Delta T}{\Delta T_2^*}$ using equation (19).	$\frac{\Delta T}{\Delta T_2^*} = A^{2/(3+p)} (T_a/g) \alpha^{2/(3+p)} H^{-(5-p)/(3+p)}$ $\frac{\Delta T}{\Delta T_2^*} = 0.913$
10.	Use equation (15) to calculate ΔT_2^* .	$\Delta T_2^* = \left[\frac{t_2^* - t_{2f}^*}{(0.146 + 0.242r/H)} \right]^{4/3}$ $\Delta T_2^* = 105.89$
11.	Use equation (17) to calculate the ratio $\frac{u_2^*}{(\Delta T_2^*)^{1/2}}$.	$\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.59 \left(\frac{r}{H} \right)^{-0.63}$ $\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.66$
12.	Use equations (16) and (17) to calculate Y .	$Y = \left(\frac{3}{4} \right) \left(\frac{u}{u_2^*} \right)^{1/2} \left[\frac{u_2^*}{\Delta T_2^*} \right]^{1/2} \left(\frac{\Delta T_2^*}{\text{RTI}} \right) \left(\frac{t}{t_2^*} \right) D$ $Y = 1.533$
13.	<i>Fixed Temperature HD</i> — Use equation (16) to calculate the resulting temperature of the detector.	$T_d(t) = \left(\frac{\Delta T}{\Delta T_2^*} \right) \Delta T_2^* \left[1 - \frac{(1 - e^{-Y})}{Y} \right] + T_d(0)$ $T_d(t) = 57.25$
14.	<i>Rate of Rise HD</i> — Use equation (16).	$dT_d = \left[\left(\frac{4}{3} \right) \left(\frac{\Delta T}{\Delta T_2^*} \right) (\Delta T_2^*)^{1/4} \frac{(1 - e^{-Y})}{[(t/t_2^*)D]} \right] dT_d$ $dT_d =$
15.	If: 1. $T_d < T_s$ 2. $T_d > T_s$ 3. $T_d = T$	Repeat Procedure Using Design 1. a larger r 2. a smaller r 3. $s = 1.41 \times r = 4.7\text{ m}$ Analysis 1. a larger t_r 2. a smaller t_r 3. $t_r = \text{ } \text{ sec}$

B-3.3.8.1 After 146 seconds, when the fire has grown to 1000 kW and at a radial distance of 3.3 m (10.8 ft) from the center of the fire, the detector temperature is calculated to be 57°C. This is the detector actuation temperature. If the calculated temperature of the detector were higher than the actuation temperature, then the radial distance could be increased. The calculation would then be repeated until the calculated detector temperature is approximately equal to the actuation temperature.

B-3.3.8.2 The last step is to use the final calculated value of r with the equation relating spacing to radial distance. This will determine the maximum installed detector spacing that will result in detector response within the established goals.

$$\begin{aligned} S &= 2^{1/2} r \\ S &= 4.7 \text{ m} \end{aligned} \quad (21)$$

where:

S = spacing of detectors
 r = radial distance from fire plume axis (m or ft)

B-3.3.8.3 Example of Analysis.

B-3.3.8.3.1 The following example shows how an existing heat detection system or a proposed design can be analyzed to determine the response time or fire size at response. The scenario that was analyzed in the previous example will be used again, with the exception that the warehouse building has existing heat detectors. The fire, building, and detectors have the same characteristics as the previous example with the exception of spacing. The detectors are spaced evenly on the ceiling at 9.2 m (30 ft) intervals.

B-3.3.8.3.2 The following equation is used to determine the maximum radial distance from the fire axis to a detector:

$$S = 1.414 r \quad (22)$$

or

$$\begin{aligned} r &= \frac{S}{1.414} \\ r &= 6.5 \text{ m} \end{aligned}$$

where:

S = spacing of detectors
 r = radial distance from fire plume axis (m or ft)

B-3.3.8.3.3 Next, the response time of the detector or the fire size at response is estimated. In the design above, the fire grew to 1000 kW in 146 seconds when the detector located at a distance of 3.3 m (10.8 ft) responded. As the radial distance in this example is larger, a slower response time and thus a larger fire size at response is expected. A first approximation at the response time is made at 3 minutes. The corresponding fire size is found using the following $p = 2$ power law fire growth equation:

$$\begin{aligned} Q(\text{kW}) &= \alpha(\text{kW/sec}^2)t^p \\ Q &= (1055/150^2)(180 \text{ sec})^2 \\ Q &= 1519 \text{ kW} \end{aligned}$$

B-3.3.8.3.4 This data can be incorporated into the fire detection design and analysis worksheet shown in Figure B-3.3.8.3.4 in order to carry out the remainder of the calculations.

Figure B-3.3.8.3.4 Fire detection design and analysis worksheet [28] — analysis example 2.

Fire Detection Design and Analysis Worksheet [28]
Analysis Example 2

1.	Determine ambient temperature (T_a) ceiling height or height above fuel (H).	$T_a = 10$ °C + 273 = 283 K $H = 4$ m
2.	Determine the fire growth characteristic (α or t_g) for the expected design fire.	$\alpha = 0.047$ kW/s ² $t_g = 150$ sec
3a.	Define the characteristics of the detectors.	$T_s = 57$ C RTI = 98 m ^{1/2} s ^{1/2} $\frac{dT_d}{dt} =$ °C/min $\tau_0 =$ sec
3b.	<i>Design</i> — Establish system goals (t_{CR} or Q_{CR}) and make a first estimate of the distance (r) from the fire to the detector.	$t_{CR} =$ sec $r =$ m $Q_{CR} =$ kW
3b.	<i>Analysis</i> — Determine spacing of existing detectors and make a first estimate of the response time or the fire size at detector response ($Q = \alpha t^2$).	$r = 6.5$ *1.41 = 9.2 = S (m) $Q = 1,523$ kW $t_d = 180$ sec
4.	Using equation (15), calculate the nondimensional time (t_{2f}^*) at which the initial heat front reaches the detector.	$t_{2f}^* = 0.861 (1 + \frac{r}{H})$ $t_{2f}^* = 2.26$
5.	Calculate the factor A defined in equation (14).	$A = \frac{g}{C_p T_a \rho_0}$ $A = 0.030$
6.	Use the required response time along with equation (14) and $p = 2$ to calculate the corresponding value of t_2^* .	$t_2^* = \frac{t}{A^{-1/(3+p)} \alpha^{-1/(3+p)} H^{4/(3+p)}}$ $t_2^* = 16$
7.	If $t_2^* > t_{2f}^*$ continue to step 8. If not, try a new detector position (r) and return to step 4.	
8.	Calculate the ratio $\frac{u}{u_p}$ using equation (18).	$\frac{u}{u_p} = A^{1/(3+p)} \alpha^{1/(3+p)} H^{(p-1)/(3+p)}$ $\frac{u}{u_p} = 0.356$
9.	Calculate the ratio $\frac{\Delta T}{\Delta T_2^*}$ using equation (19).	$\frac{\Delta T}{\Delta T_2^*} = A^{2/(3+p)} (T_a/g) \alpha^{2/(3+p)} H^{-(5-p)/(3+p)}$ $\frac{\Delta T}{\Delta T_2^*} = 0.913$
10.	Use equation (15) to calculate ΔT_2^* .	$\Delta T_2^* = \left[\frac{t_2^* - t_{2f}^*}{(0.146 + 0.242r/H)} \right]^{4/3}$ $\Delta T_2^* = 75.01$
11.	Use equation (17) to calculate the ratio $\frac{u_2^*}{(\Delta T_2^*)^{1/2}}$.	$\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.59 \left(\frac{r}{H} \right)^{-0.63}$ $\frac{u_2^*}{(\Delta T_2^*)^{1/2}} = 0.435$
12.	Use equations (16) and (17) to calculate Y .	$Y = \left(\frac{3}{4} \right) \left(\frac{u}{u_2^*} \right)^{1/2} \left[\frac{u_2^*}{\Delta T_2^*} \right]^{1/2} \left(\frac{\Delta T_2^*}{RTI} \right) \left(\frac{t}{t_2^*} \right) D$ $Y = 1.37$
13.	<i>Fixed Temperature HD</i> — Use equation (16) to calculate the resulting temperature of the detector.	$T_d(t) = \left(\frac{\Delta T}{\Delta T_2^*} \right) \Delta T_2^* \left[1 - \frac{(1-e^{-Y})}{Y} \right] + T_d(0)$ $T_d(t) = 41$
14.	<i>Rate of Rise HD</i> — Use equation (16).	$dT_d = \left[\left(\frac{4}{3} \right) \left(\frac{\Delta T}{\Delta T_2^*} \right) (\Delta T_2^*)^{1/4} \frac{(1-e^{-Y})}{(t/t_2^*)D} \right] dT_d$ $dT_d =$
15.	If: 1. $T_d < T_s$ 2. $T_d > T_s$ 3. $T_d = T$	Repeat Procedure Using Design 1. a larger r 2. a smaller r 3. $s = 1.41 \times r =$ m Analysis 1. a larger t_r 2. a smaller t_r 3. $t_r =$ sec

B-3.3.8.3.5 Using a radial distance of 6.5 m (21 ft) from the axis of this fire, the temperature of the detector is calculated to be 41°C (106°F) after 3 minutes of exposure. The detector actuation temperature is 57°C (135°F). Thus, the detector response time is more than the estimated 3 minutes. If the calculated temperature were more than the actuation temperature, then a smaller t would be used. As in the previous example, calculations should be repeated varying the time to response until the calculated detector temperature is approximately equal to the actuation temperature. For this example, the response time is estimated to be 213 seconds. This corresponds to a fire size at response of 2132 kW.

B-3.3.8.4 The above examples assume that the fire continues to follow the t-squared fire growth relationship up to detector activation. These calculations do not check whether this will happen, nor do they show how the detector temperature varies once the fire stops following the power law relationship. The user should therefore determine that there will be sufficient fuel, as the above correlations do not perform this analysis. If there is not a sufficient amount of fuel, then there is the possibility that the heat release rate curve will flatten out or decline before the heat release rate needed for actuation is reached.

B-3.3.8.5 Tables B-3.3.8.5(a) through (k) provide a comparison of heat release rates, response times, and spacings when variables characteristic of the fires, detectors, and room are changed from the analysis example.

Table B-3.3.8.5(a) Operating Temperature Versus Heat Transfer Rate ($S = 30$ ft)

Operating Temperature		Heat Release Rate (kW)/Response Time (sec)
°C	°F	
57	135	2132/213
74	165	2798/244
93	200	3554/275

Table B-3.3.8.5(b) Operating Temperature Versus Spacing ($Q_d = 1000$ kW)

Operating Temperature		Spacing (m)
°C	°F	
57	135	4.7
74	165	3.5
93	200	2.5

Table B-3.3.8.5(c) RTI Versus Heat Release Rate ($S = 30$ ft)

RTI		Heat Release Rate (kW)/Response Time (sec)
$m^{1/2} \text{ sec}^{1/2}$	$ft^{1/2} \text{ sec}^{1/2}$	
50	93	1609/185
150	280	2640/237
300	560	3898/288

Table B-3.3.8.5(d) RTI Versus Spacing ($Q_d = 1000$ kW)

RTI		Spacing (m)
$m^{1/2} \text{ sec}^{1/2}$	$ft^{1/2} \text{ sec}^{1/2}$	
50	93	6.1
150	280	3.7
300	560	2.3

Table B-3.3.8.5(e) Ambient Temperature Versus Heat Release Rate ($S = 30$ ft)

Ambient Temperature		Heat Release Rate (kW)/Response Time (sec)
°C	°F	
0	32	2552/233
20	68	1751/193
38	100	1058/150

Table B-3.3.8.5(f) Ambient Temperature Versus Spacing ($Q_d = 1000$ kW)

Ambient Temperature		Spacing (m)
°C	°F	
0	32	3.8
20	68	5.7
38	100	8.8

Table B-3.3.8.5(g) Ceiling Height Versus Heat Release Rate ($S = 30$ ft)

Ceiling Height		Heat Release Rate (kW)/Response Time (sec)
m	ft	
2.4	8	1787/195
4.9	16	2358/224
7.3	24	3056/255

Table B-3.3.8.5(h) Ceiling Height Versus Spacing ($Q_d = 1000$ kW)

Ceiling Height		Spacing (m)
m	ft	
2.4	8	5.8
4.9	16	4.0
7.3	24	2.1

Table B-3.3.8.5(i) Detector Spacing Versus Heat Release Rate ($S = 30$ ft)

Detector Spacing		Heat Release Rate (kW)/Response Time (sec)
m	ft	
4.6	15	1000/146
9.1	30	2132/213
15.2	50	4146/297

Table B-3.3.6.1.3(j) Fire Growth Rate Versus Heat Release Rate ($S = 30$ ft)

Fire Growth Rate	Heat Release Rate (kW)/Response Time (sec)
Slow $t_g = 400$ sec	1250/435
Medium $t_g = 250$ sec	1582/306
Fast $t_g = 100$ sec	2769/162

Table B-3.3.6.1.3(k) Fire Growth Rate Versus Spacing $Q_d = 1000$ kW)

Fire Growth Rate	Spacing (m)
Slow $t_g = 400$ sec	8.2
Medium $t_g = 250$ sec	6.5
Fast $t_g = 100$ sec	3.7

B-3.3.9 Rate-of-Rise Heat Detector Spacing. The procedure presented above can be used to estimate the response of rate-of-rise heat detectors for either design or analysis purposes. In this case, it is necessary to assume that the heat detector response can be modeled using a lumped mass heat transfer model.

B-3.3.9.1 The user must determine the rate of temperature rise at which the detector will respond from the manufacturer's data. [Note that listed rate-of-rise heat detectors are designed to activate at a nominal rate of temperature rise of 15°F (8°C) per minute.] The user must use equation (17) instead of equation (16) in order to calculate the rate of change of the detector temperature. This value is then compared to the rate of change at which the chosen detector is designed to respond.

NOTE: The assumption that heat transfer to a detector can be modeled as a lumped mass might not hold for rate-of-rise heat detectors. This is due to the operating principle of this type of detector, in that most rate-of-rise detectors operate when the expansion of air in a chamber expands at a rate faster than it can vent through an opening. To accurately model the response of a rate-of-rise detector would require modeling the heat transfer from the detector body to the air in the chamber, as well as the air venting through the hole.

B-3.3.9.2 Rate Compensation-Type Heat Detectors. Rate-compensated detectors are not specifically covered by

Appendix B. However, a conservative approach to predicting their performance is to use the fixed-temperature heat detector guidance contained herein.

B-4 Smoke Detector Spacing for Flaming Fires.

B-4.1 Introduction.

B-4.1.1 The listing investigation for smoke detectors does not yield a "listed spacing" as it does for heat detectors. Instead, the manufacturers recommend a spacing. Because the largest spacing that can be evaluated in the full-scale fire test room is 30 ft (9.1 m), it has become common practice to recommend this 30-ft (9.1-m) spacing for smoke detectors when they are installed on flat, smooth ceilings. Reductions in smoke detector spacing are made empirically to address factors that can affect response, including ceiling height, beamed or joisted ceilings, and areas that have high rates of air movement.

B-4.1.1.1 The placement of smoke detectors, however, should be based on an understanding of fire plume and ceiling jet flows, smoke production rates, particulate changes due to aging, and the operating characteristics of the particular detector being used. The heat detector spacing information presented in Section B-3 is based on knowledge of plume and jet flows. An understanding of smoke production and aging lags considerably behind an understanding of heat production. In addition, the operating characteristics of smoke detectors in specific fire environments are not often measured or made generally available for other than a very few number of combustible materials. Therefore, the existing knowledge base precludes the development of complete engineering design information for smoke detector location and spacing.

B-4.1.1.2 In design applications where predicting the response of smoke detectors is not critical, the spacing criteria presented in Chapter 2 should provide sufficient information to design a very basic smoke detection system. However, if the goals and objectives established for the detection system require detector response within a certain amount of time, optical density, heat release rate, or temperature rise, then additional analysis might be needed. For these situations, information regarding the expected fire characteristics (fuel and its fire growth rate), transport characteristics, detector characteristics, and compartment characteristics is required. The following information regarding smoke detector response and various performance-based approaches to evaluating smoke detector response is therefore provided.

B-4.1.2 Response Characteristics of Smoke Detectors.

B-4.1.2.1 General.

B-4.1.2.1.1 In order to determine whether a smoke detector will respond to a given Q_{CR} , a number of factors need to be evaluated. These factors include smoke characteristics, smoke transport, and detector characteristics.

B-4.1.2.2 Smoke Characteristics.

B-4.1.2.2.1 Smoke characteristics are a function of the fuel composition, the mode of combustion (smoldering or flaming), and the amount of mixing with the ambient air (dilution). These factors are important for determining the characteristics of the products of combustion, such as particle size, distribution, composition, concentration, refractive index, etc. The significance of these features with regard to smoke detector response are well documented. [29,30]

B-4.1.2.2.2 Whether smoke detectors detect by sensing scattered light, loss of light transmission (light extinction), or reduction of ion current, they are particle detectors. Thus, particle concentration, size, color, size distribution, and so on, affect each sensing technology differently. It is generally accepted that a flaming, well-ventilated, energetic fire produces smoke having a larger proportion of the sub-micron diameter particulates as opposed to a smoldering fire that produces smoke with a predominance of large, super-micron particulates. It is also known that as the smoke cools the smaller particles agglomerate, forming larger ones as they age, and are carried away from the fire source. More research is necessary to provide sufficient data to allow the prediction of smoke characteristics at the source, as well as during transport. Furthermore, response models must be developed that can predict the response of a particular detector to different kinds of smoke as well as smoke that has aged during the flow from the fire to the detector location.

B-4.1.2.3 Transport Considerations.

B-4.1.2.3.1 General. All smoke detection relies on the plume and ceiling jet flows to transport the smoke from the locus of the fire to the detector. Various considerations must be addressed during this transport time, including changes to the characteristics of the smoke that occur with time and distance from the source, and transport time of smoke from the source to the detector.

B-4.1.2.3.2 The smoke characteristic changes that occur during transport relate mainly to the particle size distribution. Particle size changes during transport occur mainly as a result of sedimentation and agglomeration.

B-4.1.2.3.3 Transport time is a function of the characteristics of the travel path from the source to the detector. Important characteristics that should be considered include ceiling height and configuration (for example, sloped, beamed), intervening barriers such as doors and beams, as well as dilution and buoyancy effects such as stratification that might delay or prevent smoke in being transported to the detector.

B-4.1.2.3.4 In smoldering fires, thermal energy provides a force for transporting smoke particles to the smoke sensor. However, usually in the context of smoke detection, the rate of energy (heat) release is small and the rate of growth of the fire is slow. Consequently, other factors such as ambient airflow from HVAC systems, differential solar heating of the structure, and wind cooling of the structure can have a dominant influence on the transport of smoke particles to the smoke sensor when low-output fires are considered.

B-4.1.2.3.5 In the early stages of development of a growing fire, the same interior environmental effects, including ambient airflow from HVAC systems, differential solar heating of the structure, and wind cooling of the structure, can have a dominant influence on the transport of smoke. This is particularly important in spaces having high ceilings. Greater thermal energy release from the fire is necessary to overcome these interior environmental effects. Because the fire must attain a sufficiently high level of heat release before it can overcome the interior environmental airflows and drive the smoke to the ceiling-mounted detectors, the use of closer spacing of smoke detectors on the ceiling might not significantly improve the response of the detectors to the fire. Therefore, when considering ceiling height alone, smoke detector spacing closer than 30 ft (9.1 m) might not be warranted, except

in instances where an engineering analysis indicates additional benefit will result. Other construction characteristics also should be considered. (Refer to the appropriate sections of Chapter 2 dealing with smoke detectors and their use for the control of smoke spread.)

B-4.1.2.3.6 Smoke Dilution. Smoke dilution causes a reduction in the quantity of smoke per unit of air volume of smoke reaching the detector. Dilution typically occurs either by entrainment of air in the plume or the ceiling jet or by effects of HVAC systems. Forced ventilation systems with high air change rates typically cause the most concern, particularly in the early stages of fire development, when smoke production rate and plume velocity are both low. Airflows from supply as well as return vents can create defined air movement patterns within a compartment, which can either keep smoke away from detectors that are located outside of these paths or can inhibit smoke from entering a detector that is located directly in the airflow path. [26]

B-4.1.2.3.7 There currently are no quantitative methods for estimating either smoke dilution or airflow effects on locating smoke detectors. These factors should therefore be considered qualitatively. The designer should understand that the effects of airflow become larger as the fire size at detection (Q_{CR}) gets smaller. Depending on the application, the designer might find it useful to obtain airflow and velocity profiles within the room or to even conduct small-scale smoke tests under various conditions to assist in the design of the system.

B-4.1.2.3.8 Stratification.

B-4.1.2.3.8.1 The potential for the stratification of smoke is another concern in designing and analyzing the response of detectors. This is of particular concern with the detection of low-energy fires and fires in compartments with high ceilings.

B-4.1.2.3.8.2 The upward movement of smoke in the plume depends on the smoke being buoyant relative to the surrounding air. Stratification occurs when the smoke or hot gases flowing from the fire fail to ascend to the smoke detectors mounted at a particular level (usually on the ceiling) above the fire due to the loss of buoyancy. This phenomenon occurs due to the continuous entrainment of cooler air into the fire plume as it rises, resulting in cooling of the smoke and fire plume gases. The cooling of the plume results in a reduction in buoyancy. Eventually the plume cools to a point where its temperature equals that of the surrounding air and its buoyancy diminishes to zero. Once this point of equilibrium is reached, the smoke will cease its upward flow and form a layer, maintaining its height above the fire, regardless of the ceiling height, unless and until sufficient additional thermal energy is provided from the fire to raise the layer due to its increased buoyancy. The maximum height to which plume fluid (smoke) will ascend, especially early in the development of a fire, depends on the convective heat release rate of the fire and the ambient temperature in the compartment.

B-4.1.2.3.8.3 Because warm air rises, there will usually be a temperature gradient in the compartment. Of particular interest are those cases where the temperature of the air in the upper portion of the compartment is greater than at the lower level before the ignition. This can occur as a result of solar load where ceilings contain glazing materials. Computational methods are available to assess the potential for intermediate stratification for the following two cases, depicted in Figure B-4.1.2.3.8.3(a).

Case 1. The temperature of the ambient is relatively constant up to a height above which there is a layer of warm air at uniform temperature. This situation can occur if the upper portion of a mall, atrium, or other large space is unoccupied and the air is left unconditioned.

Case 2. The ambient interior air of the compartment has a constant and uniform temperature gradient (temperature change per unit height) from floor to ceiling. This case is generally encountered in industrial and storage facilities that are normally unoccupied.

The analysis of intermediate stratification is presented in Figure B-4.1.2.3.8.3(b). Plume centerline temperatures from two fires, 1000 kW and 2000 kW, are graphed based on estimates from correlations presented in this section. In Case 1, a step function is assumed to indicate a 30°C/m change in temperature 15 m above the floor due to the upper portion of the atrium being unconditioned. For Case 2, a temperature gradient of 1.5°C/m is arbitrarily assumed in an atrium that has a ceiling height of 20 m.

Figure B-4.1.2.3.8.3(a) Pre-fire temperature profiles.

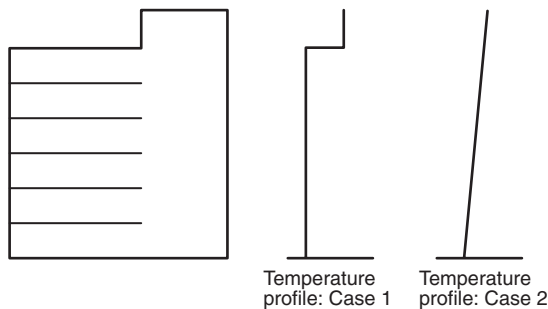
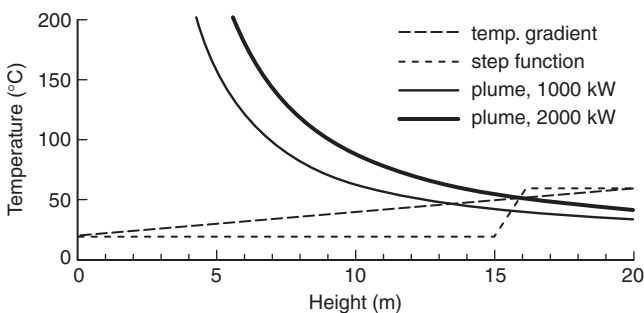


Figure B-4.1.2.3.8.3(b) Indoor air and plume temperature profiles with potential for intermediate stratification.



B-4.1.2.3.8.4 Step Function Temperature Gradient Spaces. If the interior air temperature exhibits a discrete change at some elevation above the floor, the potential for stratification can be assessed by applying the plume centerline temperature correlation. If the plume centerline temperature is equal to the ambient temperature, the plume is no longer buoyant, loses its upward momentum, and stratifies at that

height. The plume centerline temperature can be calculated by using the following equation:

$$T_c = 316 Q_c^{2/3} z^{-5/3} + 70 \text{ (°F)} \quad (23)$$

or

$$T_c = 25 Q_c^{2/3} z^{-5/3} + 20 \text{ (°C)}$$

where:

- T_c = plume centerline temperature (°F or °C)
- Q_c = convective portion of fire heat release rate (Btu/sec or kW)
- z = height above the top of the fuel package involved (ft or m)

B-4.1.2.3.8.5 Linear Temperature Gradient Spaces. To determine whether or not the rising smoke or heat from an axisymmetric fire plume will stratify below detectors, the following equation can be applied where the ambient temperature increases linearly with increasing elevation:

$$Z_m = 14.7 Q_c^{1/4} \left(\frac{\Delta T_0}{dZ} \right)^{-3/8} \text{ (ft)} \quad (24)$$

or

$$Z_m = 5.54 Q_c^{1/4} \left(\frac{\Delta T_0}{dZ} \right)^{-3/8} \text{ (m)}$$

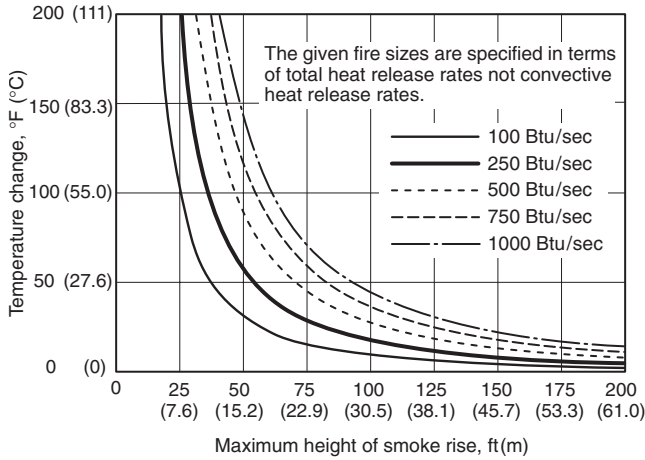
where:

- Z_m = maximum height of smoke rise above the fire surface (ft or m)
- ΔT_0 = difference between the ambient temperature at the location of detectors and the ambient temperature at the level of the fire surface (°F or °C)
- Q_c = convective portion of the heat release rate (Btu/sec or kW)

B-4.1.2.3.8.6 The convective portion of the heat release rate (Q_c) can be estimated as 70 percent of the heat release rate.

B-4.1.2.3.8.7 As an alternative to using the noted expression to directly calculate the maximum height to which the smoke or heat will rise, Figure B-4.1.2.3.8.7 can be used to determine Z_m for given fires. Where Z_m as calculated or determined graphically, is greater than the installed height of detectors, smoke or heat from a rising fire plume is predicted to reach the detectors. Where the compared values of Z_m and the installed height of detectors are comparable heights, the prediction that smoke or heat will reach the detectors might not be a reliable expectation.

Figure B-4.1.2.3.8.7 Temperature change and maximum height of smoke rise for given fire sizes.



B-4.1.2.3.8.8 Assuming the ambient temperature varies linearly with the height, the minimum Q_c required to overcome the ambient temperature difference and drive the smoke to the ceiling ($Z_m = H$) may be determined from the following equation:

$$Q_c = 2.39 \times 10^{-5} H^{5/2} \Delta T_0^{3/2} \text{ (Btu/sec)} \quad (25)$$

or

$$Q_c = 0.0018 H^{5/2} \Delta T_0^{3/2} \text{ (kW)}$$

Note that variables are identified in Section B-7.

B-4.1.2.3.8.9 The theoretical basis for the stratification calculation is based on the works of Morton, Taylor, and Turner [15] and Heskestad [9]. For further information regarding the derivation of the expression defining Z_m , the user is referred to the work of Klote and Milke [13] and NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas*.

B-4.1.2.4 Detector Characteristics.

B-4.1.2.4.1 General. Once smoke is transported to the detector, additional factors become important in determining whether response will occur. These include the aerodynamic characteristics of the detector and the type of sensor within the detector. The aerodynamics of the detector relate to how easily smoke can pass through the detector housing and enter the sensor portion of the unit. Additionally, the location of the entry portion to the sensor with respect to the velocity profile of the ceiling jet is also an important factor. Finally, different sensing methods (for example, ionization or photoelectric) will respond differently, depending on the smoke characteristics (smoke color, particle size, optical density, and so on). Within the family of photoelectric devices, there will be variations depending on the wavelengths of light and the scattering angles employed. The following paragraphs discuss some of these issues and various calculation methods.

B-4.1.2.4.2 Resistance to Smoke Entry.

B-4.1.2.4.3 All spot-type smoke detectors require smoke to enter the detection chamber in order to be sensed. This requires additional factors to be taken into consideration

when attempting to estimate smoke detector response, as smoke entry into the detection chamber can be affected in several ways, for example, insect screens, sensing chamber configuration, and location of the detector with respect to the ceiling.

B-4.1.2.4.4 In trying to quantify this, Heskestad [32] developed the idea of smoke detector lag to explain the difference in optical density outside (D_{ur}) versus inside (D_{uo}) of a detector when the detector activates. It was demonstrated that this difference could be explained by the use of a correction factor D_{uc} using the following relationship:

$$D_{uc} = \frac{L \frac{d(D_u)}{dt}}{V} \quad (26)$$

where:

L = characteristic length for a given detector design, represents the ease of smoke entry into the sensing chamber

$\frac{d(D_u)}{dt}$ = rate of increase of optical density outside the detector

V = velocity of the smoke at the detector

B-4.1.2.4.5 Various studies regarding this correlation have provided additional insight regarding smoke entry and associated lags [33,34]; however, the difficulty in quantifying L for different detectors and relating it to spacing requirements may have limited usefulness, and the concept of critical velocity (u_c) may be more applicable. [21]

B-4.1.2.4.6 Critical Velocity. [26] A smoke detector's critical velocity refers to the minimum velocity of the smoke necessary to enter the sensing chamber to cause an alarm. Flow across a detector causes a pressure differential between the upstream and down-stream sides of the detector. This pressure differential is the principal driving force for the smoke entering the unit. Experimental work has indicated that this minimum velocity is approximately 0.15 m/sec for the detectors tested in one particular study. [21] Once velocities were reduced below this level, the smoke concentration level outside the detector before an alarm condition increased dramatically when compared to smoke concentration levels when the velocity was above the critical value. Estimating the critical velocity can therefore be useful for design and analysis. It is interesting to note that this critical velocity value (0.15 m/sec) is close to that at which a smoke detector must respond in the UL smoke detector sensitivity chamber in order to become listed. [35] The location in the ceiling jet where this velocity occurs for a given fire and ceiling height might therefore be considered as a first approximation for locating detectors. This again assumes a horizontal, smooth ceiling.

B-4.1.2.4.7 Response to Smoke Color. Smoke detectors that use an optical means to detect smoke respond differently to smokes of different colors.

B-4.1.2.4.8 Manufacturers currently provide limited information regarding the response of smoke detectors in their specifications as well as in the information contained on the labels on the backs of the detectors. This response information indicates only their nominal response values with respect to gray smoke, not to black, and is often provided with a response

range instead of an exact response value. This range is in accordance with UL 268, *Standard for Safety, Smoke Detectors for Fire Protective Signalling Systems*.

B-4.1.2.4.9 The response ranges allowable by UL for gray versus black smoke are shown in Table B-4.1.2.4.9.

Table B-4.1.2.4.9 UL 268, Smoke Detector Test Acceptance Criteria for Different Colored Smoke [35]

Color of Smoke	Acceptable Response Range		Maximum: Minimum
	%/m	%/ft	
Gray	1.6 – 12.5	0.5 – 4.0	7:8
Black	1.6 – 29.2	0.5 – 10.0	18:25

B-4.1.2.4.10 As seen in Table B-4.1.2.4.9 response levels are different for black and gray smoke. This is due to the fact that detectors respond at different optical density levels to different fuels and different types of smoke. Examples of this are shown by Heskestad and Delichatsios [10] in tests they performed as shown in Table B-4.1.2.4.10. This is why it is critical that when analyzing or designing a detection system one knows how the individual detector will respond to various types of smoke.

Table B-4.1.2.4.10 Values of Optical Density at Response (For Flaming Fires Only) [18]

Material	$10^2 D_{ur}$		Relative Smoke Color
	Ionization	Scattering	
Wood	0.5	1.5	Light
Cotton	0.05	0.8	Light
Polyurethane	5.0	5.0	Dark
PVC	10.0	10.0	Dark
Variation	200:1	12.5:1	

Note the large variations in response not only to materials producing relatively the same color of smoke, but also to smoke of different color, which is much more pronounced.

B-4.1.2.4.11 Optical Density and Temperature. During a flaming fire, smoke detector response is affected by ceiling height and the size and rate of fire growth in much the same way as heat detector response. The thermal energy of the flaming fire transports smoke particles to the sensing chamber just as it does heat to a heat sensor. While the relationship between the amount of smoke and the amount of heat produced by a fire is highly dependent on the fuel and the way it is burning, research has shown that the relationship between temperature and the optical density of smoke remains somewhat constant within the fire plume and on the ceiling in the proximity of the plume.

B-4.1.2.4.12 These results were based on the work by Heskestad and Delichatsios [10] and are indicated in Table B-4.1.2.4.12. Note that for a given fuel, the optical density to temperature rise ratio between the maximum and minimum levels is 10 or less.

Table B-4.1.2.4.12 Ratio of Optical Density to Temperature Rise for Various Fuels [18]

Material	$10^2 D_u$ (1/ft°F) (T)	Value Range	Maximum: Minimum
Wood	0.02	0.015–0.055	3:6
Cotton	0.01/0.02	0.005–0.03	6:0
Paper	0.03	Data not available	—
Polyurethane	0.4	0.2–0.55	2:8
Polyester	0.3	Data not available	—
PVC	0.5/1.0	0.1–1.0	10
Foam rubber PU	1.3	Data not available	—
Average	0.4	0.005–1.3	260

B-4.1.2.4.13 In situations where the optical density at detector response is known and is independent of particle size distribution, the detector response can be approximated as a function of the heat release rate of the burning fuel, the fire growth rate, and the ceiling height, assuming that the above correlation exists.

B-4.1.2.4.14 When Appendix C of NFPA 72E was first published in 1984, a 20°F (13°C) temperature rise was used to indicate detector response. Schifiliti and Pucci [8] have combined some of the data from Heskestad and Delichatsios to produce Table B-4.1.2.4.14 showing the temperature rise at detector response. Note that the temperature rise required for detector response varies significantly depending on the detector type and fuel.

Table B-4.1.2.4.14 Temperature Rise for Detector Response [18]

Material	Temperature Rise (°F)	
	Ionization	Scattering
Wood	25	75
Cotton	3	50
Polyurethane	13	13
PVC	13	13
Average	14	38

B-4.1.3 Methods for Predicting Smoke Detector Response.

B-4.1.3.1 Method 1 — Optical Density Versus Temperature.

B-4.1.3.1.1 It is intended to determine whether an existing fire detection system can detect a fire in part of a warehouse used to store wardrobes in sufficient time to prevent radiant ignition of adjacent wardrobes. The area under review has a large, flat ceiling, 16.5 ft (5 m) high. The ambient temperature within the compartment is 68°F (20°C). The compartment is not sprinklered. The wardrobes are constructed mainly of particleboard. The detectors are ionization-type smoke detectors spaced 20 ft (6.1 m) on center. The design objective is to keep the maximum heat release rate (Q_{DO}) below 2 MW in order to ensure that radiant ignition of the wardrobes in the adjacent aisle will not occur. There is an on-site fire brigade that can respond to and begin discharging water on the fire within 90 seconds of receiving the alarm. It can be assumed that there are no other delays between the time the detector reaches its operating threshold and the time to notification of the fire brigade. Given the above, would the existing system be sufficient?

B-4.1.3.1.2 Assumptions. The following assumptions are made for this example:

$$\alpha = 0.047$$

$$RTI = 25 \text{ m}^{1/2}\text{sec}^{1/2}$$

$$\text{Temperature rise for response} = 14^\circ\text{C} (25^\circ\text{F})$$

Refer to Table B-4.1.2.4.14 for temperature rise to response of an ionization smoke detector for a wood fire.

B-4.1.3.1.3 Using the power law equation, the design objective response time is calculated as follows:

$$\begin{aligned} Q_{DO} &= \alpha t_{DO}^2 \\ 2000 \text{ kW} &= 0.047 t_{DO}^2 \\ t_{DO} &= 210 \text{ sec} \end{aligned} \quad (27)$$

B-4.1.3.1.4 Next, subtract the time for the fire brigade to respond to determine what time after ignition that detection should occur. Note that a 30-second safety factor has been added to the fire brigade's response time.

$$t_{CR} = 210 \text{ sec} - 120 \text{ sec} = 90 \text{ sec} \quad (28)$$

B-4.1.3.1.5 Then, calculate the critical heat release rate at which detection should occur as follows:

$$\begin{aligned} Q_{CR} &= \alpha t_{CR}^2 \\ Q_{CR} &= 0.047(90)^2 = 380 \text{ kW} \end{aligned} \quad (29)$$

B-4.1.3.1.6 Using the numbers in the fire detection design and analysis worksheet at 90 seconds into the fire when the heat release rate is 380 kW, the temperature rise at the detector is calculated to be approximately 17°C. This, therefore, might be a reasonable approximation to show that the detector may respond.

B-4.1.3.2 Method 2 — Mass Optical Density.

B-4.1.3.2.1 Data regarding smoke characteristics for given fuels can be used as another method to evaluate detector response.

B-4.1.3.2.2 Example. The design objective established for this scenario is to detect the smoke from a flaming 400-g (1.0-lb) polyurethane chair cushion in less than 2 minutes. The chair is placed in a compartment that is 40 m² (431 ft²). The ceiling height is 3.0 m (10 ft). It has been determined that the burning rate of the cushion is a steady rate of 50 g/min. Determine if the design objective will be met.

B-4.1.3.2.3 The total mass loss of the cushion due to combustion at 2 minutes is 100 g. Therefore, the optical density in the room produced by the burning cushion can be calculated from the following equation. [5]

$$D = \frac{D_m M}{V_c} \quad (30)$$

where:

$$D_m = \text{mass optical density (m}^2\text{/g) [26]}$$

$$M = \text{mass}$$

$$V_c = \text{volume of the compartment}$$

$$D = [(0.22 \text{ m}^2\text{/g})(100\text{g})]/(40 \text{ m}^2)(3 \text{ m}) = 0.183 \text{ m}^{-1}$$

B-4.1.3.2.4 If it is assumed that the detector responds at the UL upper sensitivity limit of 0.14 m⁻¹ for black smoke [35], it can be assumed that the detector will respond within 2 minutes.

B-4.1.3.2.5 It should be noted that this method presents a very simplified approach, and that various assumptions would need to be made including that the smoke is confined to the room, is well mixed, can reach the ceiling, and can enter the detector.

B-5 Radiant Energy Detection.

B-5.1 General.

B-5.1.1 Electromagnetic radiation is emitted over a broad range of the spectrum during the combustion process. The portion of the spectrum in which radiant energy-sensing detectors operate has been divided into three bands: ultraviolet (UV), visible, or infrared (IR). These wavelengths are defined with the following wavelength ranges: [3]

- (1) Ultraviolet 0.1 — 0.35 microns
- (2) Visible 0.35 — 0.75 microns
- (3) Infrared 0.75 — 220 microns

B-5.1.2 These wavelength ranges correspond to the quantum-mechanical interaction between matter and energy. Photonic interactions with matter can be characterized by wavelength as shown in Table B-5.1.2:

Table B-5.1.2 Wavelength Ranges

Wavelength	Photonic Interaction
$\lambda < 50 \text{ micron}$	Gross molecular translations
$50 \mu < \lambda < 1.0 \mu$	Molecular vibrations and rotations
$1.0 \mu < \lambda < 0.05 \mu$	Valence electron bond vibrations
$0.3 \mu < \lambda < 0.05 \mu$	Electron stripping and recombinations

B-5.1.3 When a fuel molecule is oxidized in the combustion process, the combustion intermediate molecule must lose energy to become a stable molecular species. This energy is emitted as a photon with a unique wavelength determined by the following equation:

$$e = \frac{hc}{\lambda} \quad (31)$$

where:

- e = energy (joules)
- h = Planck's constant (6.63E-23 joule-sec)
- c = speed of light (m/sec)
- λ = wavelength (microns)

[1.0 joule = 5.0345E+18(λ), where λ is measured in microns.]

B-5.1.4 The choice of the type of radiant energy-sensing detector to use is determined by the type of emissions that are expected from the fire radiator.

B-5.1.4.1 Fuels that produce a flame, a stream of combustible or flammable gases involved in the combustion reaction with a gaseous oxidizer, radiate quantum emissions. These fuels include flammable gases, flammable liquids, combustible liquids, and solids that are burning with a flame.

B-5.1.4.2 Fuels that are oxidized in the solid phase or radiators that are emitting due to their internal temperature (sparks and embers) radiate Plankian emissions. These fuels include carbonaceous fuels such as coal, charcoal, wood, and cellulosic fibers that are burning without an established flame, as well as metals that have been heated due to mechanical impacts and friction.

B-5.1.4.3 Almost all combustion events produce Plankian emissions, emissions that are the result of the thermal energy in the fuel mass. Therefore, spark/ember detectors that are designed to detect these emissions are not fuel specific. Flame detectors detect quantum emissions that are the result of changes in molecular structure and energy state in the gas phase. These emissions are uniquely associated with particular molecular structures. This can result in a flame detector that is very fuel specific.

B-5.1.5 Affects of Ambient. The choice of radiant energy-sensing detector is also limited by the affect of ambient conditions. The design must take into account the radiant energy absorption of the atmosphere, presence of nonfire-related radiation sources that might cause nuisance alarms, the electromagnetic energy of the spark, ember, or fire to be detected, the distance from the fire source to the sensor, and characteristics of the sensor.

B-5.1.5.1 Ambient Non-Fire Radiators. Most ambients contain non-fire radiators that can emit at wavelengths used by radiant energy-sensing detectors for fire detection. The designer should make a thorough evaluation of the ambient to identify radiators that have the potential for producing unwarranted alarm response from radiant energy-sensing detectors. Since radiant energy-sensing detectors use electronic components that can act as antennas, the evaluation should include radio band, microwave, infrared, visible, and ultraviolet sources.

B-5.1.5.2 Ambient Radiant Absorbance. The medium through which radiant energy passes from fire source to detector has a finite transmittance. Transmittance is usually quantified by its reciprocal, absorbance. Absorbance by atmospheric species varies with wavelength. Gaseous species absorb at the same wavelengths that they emit. Particulate species can transmit, reflect, or absorb radiant emission and the proportion that is absorbed is expressed as the reciprocal of its emissivity, ϵ .

B-5.1.5.3 Contamination of Optical Surfaces. Radiant energy can be absorbed or reflected by materials contaminating the optical surfaces of radiant energy-sensing detectors. The designer should evaluate the potential for surface contamination and implement provisions for keeping these surfaces clean. Extreme caution must be employed when considering the use of surrogate windows. Common glass, acrylic, and other glazing materials are opaque at the wavelengths used by most flame detectors and some spark/ember detectors. Placing a window between the detector and the hazard area that has not been listed by a nationally recognized testing laboratory (NRTL) for use with the detector in question is a violation of the detector listing and will usually result in a system that is incapable of detecting a fire in the hazard area.

B-5.1.5.4 These factors are important for several reasons. First, a radiation sensor is primarily a line-of-sight device, and must "see" the fire source. If there are other radiation sources in the area, or if atmospheric conditions are such that a large fraction of the radiation could be absorbed in the atmosphere, the type, location, and spacing of the sensors could be affected. In addition, the sensors react to specific wavelengths, and the fuel must emit radiation in the sensor's bandwidth. For example, an infrared detection device with a single sensor tuned to 4.3 microns (the CO₂ emission peak) cannot be expected to detect a non-carbon-based fire. Furthermore, the sensor needs to be able to respond reliably within the required time, especially when activating an explosion suppression system or similar fast-response extinguishing or control system.

B-5.1.6 Detector Response Model. The response of radiant energy-sensing detectors is modeled with a modified inverse square relationship as shown in the following equation [5]:

$$S = \frac{kPe^{-\zeta d}}{d^2} \quad (32)$$

where:

- S = radiant power reaching the detector (W) sufficient to produce alarm response
- k = proportionality constant for the detector
- P = radiant power emitted by the fire (W)
- ζ = extinction coefficient of air at detector operating wavelengths
- d = distance between the fire and the detector

This relationship models the fire as a point source radiator, of uniform radiant output per steradian, some distance (d) from the detector. This relationship also models the effect of absorbance by the air between the fire and the detector as being a uniform extinction function. The designer must verify that these modeling assumptions are valid for the application in question.

B-5.2 Design of Flame Detection Systems.

B-5.2.1 Detector Sensitivity. Flame detector sensitivity is traditionally quantified as the distance at which the unit can detect a fire of given size. The fire most commonly used by the NRTLs in North America is a 1.0 ft² (0.9 m²) fire fueled with regular grade, unleaded gasoline. Some special purpose detectors are evaluated using 6.0-in. (0.015-m) diameter fires fueled with isopropanol.

B-5.2.1.1 This means of sensitivity determination does not take into account that flames can best be modeled as an optically dense radiator in which radiant emissions radiated from the far side of the flame toward the detector are re-absorbed by the flame. Consequently, the radiated power from a flame is not proportional to the area of the fire but to the flame silhouette, and hence to the height and width of the fire.

B-5.2.1.2 Because flame detectors detect the radiant emissions produced during the formation of flame intermediates and products, the radiant intensity produced by a flame at a given wavelength is proportional to the relative concentration of the specific intermediate or product in the flame and that portion of the total heat release rate of the fire resulting from the formation of that specific intermediate or product. This means that the response of a detector may vary widely as different fuels are used to produce a fire of the same surface area and flame width.

B-5.2.1.3 Many flame detectors are designed to detect specific products such as water (2.5 microns) and CO₂ (4.35 microns). These detectors cannot be used for fires that do not produce these products as a result of the combustion process.

B-5.2.1.4 Many flame detectors use time variance of the radiant emissions of a flame to distinguish between non-fire radiators and a flame. Where a deflagration hazard exists, the designer must determine the sample time period for such flame detectors and how such detectors will operate in the event of a deflagration of fuel vapor or fuel gases.

B-5.2.2 Design Fire. Using the process outlined in Section B-2, determine the fire size (kW or Btu/sec) at which detection must be achieved.

B-5.2.2.1 Compute the surface area the design fire is expected to occupy from the correlations in Table B-2.3.2.3.1(a) or other sources. Use the flame height correlation to determine the height of the flame plume:

$$h_f = 0.584(kQ)^{2/5} \quad (33)$$

where:

- h_f = flame height (ft)
- Q = heat release rate (Btu/sec)
- k = wall effect factor

Where there are no nearby walls, use $k = 1$

Where the fuel package is near a wall, use $k = 2$

Where the fuel package is in a corner, use $k = 4$

Determine the minimum anticipated flame area width (w_f). Where flammable or combustible liquids are the fuel load and are unconfined, model the fuel as a circular pool. Compute the radiating area (A_r) using the following equation:

$$A_r = 1/2 h_f w_f \quad (34)$$

where:

- A_r = radiating area (ft²)
- h_f = flame height (ft)
- w_f = flame width (ft)

B-5.2.2.2 The radiant power output of the fire to the detector can be approximated as being proportional to the radiating area (A_r) of the flame.

$$P = cA_r \quad (35)$$

where:

- A_r = radiating area (ft²)
- c = power per unit area proportionality constant
- P = radiated power (W)

B-5.2.3 Calculate Detector Sensitivity. Using equation (33) compute the radiating area of the test fire used by the NRTL in the listing process (A_t). The radiant power output of the test fire to the detector in the listing process is proportional to the radiating area (A_t) of the listing test flame.

B-5.2.4 Calculate Detector Response to Design Fire. Because the sensitivity of a flame detector is fixed during the manufacturing process, the following is the relationship that determines the radiant power reaching the detector sufficient to produce an alarm response.

$$S = \frac{kcA_t^{-\zeta}d'}{d^2} \quad (36)$$

where:

- S = radiant power reaching the detector (W) sufficient to produce alarm response
- k = proportionality constant for the detector
- A_t = radiant area of the listing test fire (W)
- ζ = extinction coefficient of air at detector operating wavelengths
- d' = distance between the fire and the detector during the listing fire test
- c = emitted power per unit flame radiating area correlation

Because the sensitivity of the detector is constant over the range of ambients for which it is listed

$$S = \frac{kcA_r^{-\zeta}d'}{d^2}$$

where:

- S = radiant power reaching the detector (W) sufficient to produce alarm response
- k = proportionality constant for the detector
- A_r = radiant area of the design fire (W)

- ζ = extinction coefficient of air at detector operating wavelengths
 d' = distance between the design fire and the detector
 c = emitted power per unit flame radiating area correlation

Therefore, use the following equation to determine the following:

$$\frac{kcA_t^{-\zeta d}}{d^2} = \frac{kcA_t^{-\zeta d'}}{d'^2} \quad (37)$$

To solve for d' use the following equation:

$$\frac{(d')^2 A_t^{-\zeta d'}}{A_t^{(-\zeta d)^{1/2}}} = d' \quad (38)$$

This relation is solved iteratively for d' , the distance at which the detector can detect the design fire.

B-5.2.5 Correction for Angular Displacement.

B-5.2.5.1 Most flame detectors exhibit a loss of sensitivity as the fire is displaced from the optical axis of the detector. This correction to the detector sensitivity is shown as a polar graph in Figure A-2-4.3.2.3.

B-5.2.5.2 When the correction for angular displacement is expressed as a reduction of normalized detection distance, the correction is made to detection distance (d').

B-5.2.5.3 When the correction for angular displacement is expressed as a normalized sensitivity (fire size increment), the correction must be made to A_r prior to calculating response distance (d').

B-5.2.6 Corrections for Fuel. Most flame detectors exhibit some level of fuel specificity. Some manufacturers provide "fuel factors" that relate detector response performance to a fire of one fuel to the response performance of a benchmark fuel. Other manufacturers provide performance criteria for a list of specific fuels. Unless the manufacturer's manual, bearing the listing mark, contains explicit instructions for the application of the detector for fuels other than those used in the listing process, the unit cannot be deemed listed for use in hazard areas containing fuels different than those employed in the listing process.

B-5.2.6.1 When the fuel factor correction is expressed as a detection distance reduction, the correction should be applied after the detection distance has been computed.

B-5.2.6.2 When the fuel factor correction is expressed as a function of normalized fire size, the correction must be made prior to calculating detection distance.

B-5.2.7 Atmospheric Extinction Factors. Because the atmosphere is not infinitely transmittant at any wavelength, all flame detectors are affected by atmospheric absorption to some degree. The effect of atmospheric extinction on the performance of flame detectors is determined to some degree by the wavelengths used for sensing and the detector electronic architecture. Values for the atmospheric extinction coefficient (ζ) should be obtained from the detector manufacturer.

B-5.3 Design of Spark/Ember Detection Systems.

B-5.3.1 Design Fire. Using the process outlined in Section B-2 determine the fire size (kW or Btu/sec) at which detection must be achieved.

B-5.3.1.1 The quantification of the fire is generally derived from the energy investment per unit time sufficient to propagate combustion of the combustible particulate solids in the fuel stream. Because energy per unit time is power, expressed in watts, the fire size criterion is generally expressed in watts or milliwatts.

B-5.3.1.2 The radiant emissions, integrated over all wavelengths, from a non-ideal Plankian radiator is expressed with the following form of the Steffan-Boltzmann equation:

$$P = \epsilon A \sigma T^4 \quad (39)$$

where:

- P = radiant power (W)
 ϵ = emissivity, a material property expressed as a fraction between 0 and 1.0
 A = area of radiator (m^2)
 σ = Steffan-Boltzmann constant $5.67E-8W/m^2K^4$
 T = temperature (K)

B-5.3.1.3 This models the spark or ember as a point source radiator.

B-5.3.2 Fire Environment. Spark/ember detectors are usually used on pneumatic conveyance system ducts to monitor combustible particulate solids as they flow past the detector(s). This environment puts large concentrations of combustible particulate solids between the fire and the detector. A value for ζ must be computed for the monitored environment. The simplifying assumption that absorbance at visible levels is equal to or greater than that at infrared wavelengths yields conservative designs and is used.

B-5.3.3 Calculate Detector Response to Design Fire. Because the sensitivity of a spark/ember detector is fixed during the manufacturing process,

$$S = \frac{kPe^{-\zeta d}}{d^2}$$

where:

- S = radiant power reaching the detector (W) sufficient to produce alarm response
 k = proportionality constant for the detector
 P = radiant power emitted by test spark (W)
 ζ = extinction coefficient of air at detector operating wavelengths
 d = distance between the fire and the detector during the listing fire test

Because the sensitivity of the detector is constant over the range of ambients for which it is listed

$$S = \frac{kP'e^{-\zeta d'}}{d'^2} \quad (40)$$

where:

- S = radiant power reaching the detector (W) sufficient to produce alarm response
- k = proportionality constant for the detector
- P' = radiant power from the design fire
- ζ = the extinction coefficient of air at detector operating wavelengths
- d' = the distance between the design fire and the detector

Therefore, use the following equation to solve for

$$\frac{kPe^{-\zeta d}}{d^2} = \frac{kP'e^{-\zeta d'}}{d'^2}$$

To solve for d' ,

$$\left[\frac{(d^2)P^{-\zeta d}}{P'^{\zeta d}} \right]^{1/2} = d'$$

This relation is solved iteratively for d' , the distance at which the detector can detect the design fire.

B-5.3.4 Correction for Angular Displacement.

B-5.3.4.1 Most spark/ember detectors exhibit a loss of sensitivity as the fire is displaced from the optical axis of the detector. This correction to the detector sensitivity is shown as a polar graph in Figure A-2-4.3.2.3.

B-5.3.4.2 When the correction for angular displacement is expressed as a reduction of normalized detection distance the correction is made to detection distance (d').

B-5.3.4.3 When the correction for angular displacement is expressed as a normalized sensitivity (fire size increment) the correction must be made to P' prior to calculating response distance (d').

B-5.3.5 Corrections for Fuel. Because spark/ember detectors respond to Plankian emission in the near infrared portion of the spectrum, corrections for fuels are rarely necessary.

B-6 Computer Fire Models. Several special application computer models are available to assist in the design and analysis of both heat detectors (for example, fixed-temperature, rate-of-rise, sprinklers, fusible links) and smoke detectors. These computer models typically run on personal computers and are available from the NIST Center for Fire Research computer bulletin board.

B-6.1 DETACT — T2. DETACT — T2 (DETECTOR ACTuation — time squared) calculates the actuation time of heat detectors (fixed-temperature and rate-of-rise) and sprinklers to user-specified fires that grow with the square of time. DETACT — T2 assumes the detector is located in a large compartment with an unconfined ceiling, where there is no accumulation of hot gases at the ceiling. Thus, heating of the detector is only from the flow of hot gases along the ceiling. Input data includes H , τ_0 , RTI, T_s , S , and α . The program calculates the heat release rate at detector activation, as well as the time to

activation. The response of a smoke detector can also be modeled by assuming the smoke detector to be a low-temperature, zero lag-time heat detector.

B-6.2 DETACT — QS. DETACT — QS (DETECTOR ACTuation — quasi-steady) calculates the actuation time of heat detectors and sprinklers in response to fires that grow according to a user-defined fire. DETACT — QS assumes the detector is located in a large compartment with unconfined ceilings, where there is no accumulation of hot gases at the ceiling. Thus, heating of the detector is only from the flow of hot gases along the ceiling. Input data includes H , τ_0 , RTI, T_s , the distance of the detector from the fire's axis, and heat release rates at user-specified times. The program calculates the heat release rate at detector activation, the time to activation, and the ceiling jet temperature. The response of a smoke detector can also be modeled by assuming the smoke detector to be a low-temperature, zero lag-time heat detector.

B-6.2.1 DETACT — QS can also be found in HAZARD I, FIREFORM, FPETOOL.

B-6.3 LAVENT. LAVENT (Link Actuated VENT) calculates the actuation time of sprinklers and fusible link-actuated ceiling vents in compartment fires with draft curtains. Inputs include the ambient temperature, compartment size, thermophysical properties of the ceiling, fire location, size and growth rate, ceiling vent area and location, RTI, and temperature rating of the fusible links. Outputs of the model include the temperatures and release times of the links, the areas of the vents that have opened, the radial temperature distribution at the ceiling, and the temperature and height of the upper layer.

B-7 Nomenclature. The nomenclature used in Appendix B is defined as follows:

α	= fire intensity coefficient (Btu/sec ³ or kW/sec ²)
A	= area (m ² or ft ²)
A_0	= $g/(C_p T_a \rho_0)$ [m ⁴ /sec ² kJ] or ft ⁴ /(sec ² Btu)]
A_r	= radiating area (ft ²)
A_t	= radiating area of test fire
C	= specific heat of detector element (Btu/lbm·°F or kJ/kg·°C)
c	= speed of light (m/sec)
C_p	= specific heat of air [Btu/lbm R or kJ/(kg K) (1.040 kJ/kg K)]
D_m	= mass optical density (m ² /g)
d	= distance between fire and radiant energy-sensing detector
d'	= distance between fire and detector
$\frac{d(D_u)}{dt}$	= rate of increase of optical density outside the detector
D	= $0.146 + 0.242r/H$

Δt	= change in time (sec)	r	= radial distance from fire plume axis (m or ft)
ΔT	= increase above ambient in temperature of gas surrounding a detector ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)	ρ_0	= density of ambient air [kg/m^3 or lb/ft^3 ($1.1 \text{ kg}/\text{m}^3$)]
Δt_d	= increase above ambient in temperature of a detector ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)	RTI	= response time index ($\text{m}^{1/2}\text{sec}^{1/2}$ or $\text{ft}^{1/2}\text{sec}^{1/2}$)
Δt_p^*	= change in reduced gas temperature	S	= spacing of detectors or sprinkler heads (m or ft)
e	= energy (joules)	S	= radiant energy
f	= functional relationship	t_{DO}	= time at which the design objective heat release rate (Q_{DO}) is reached (sec)
g	= gravitational constant [m/sec^2 or ft/sec^2 ($9.81 \text{ m}/\text{sec}^2$)]	t_{CR}	= time at which the critical heat release rate (Q_{CR}) is reached (sec)
h	= Plank's constant ($6.63\text{E-}23 \text{ joule}\cdot\text{sec}$)	t	= time (sec)
H	= ceiling height or height above fire (m or ft)	t_c	= critical time — time at which fire would reach a heat release rate of $1000 \text{ Btu}/\text{sec}$ (1055 kW) (sec)
H_c	= convective heat transfer coefficient ($\text{kW}/\text{m}^2\cdot^{\circ}\text{C}$ or $\text{Btu}/\text{ft}^2\cdot\text{sec}\cdot^{\circ}\text{F}$)	t_d	= time to detector response
ΔH_c	= heat of combustion (kJ/mol)	t_g	= fire growth time to reach $1000 \text{ Btu}/\text{sec}$ (1055 kW) (sec)
h_f	= flame height (ft)	t_r	= response time (sec)
H_f	= heat of formation (kJ/mol)	t_{respond}	= time available, or needed, for response to an alarm condition (sec)
L	= characteristic length for a given detector design	t_v	= virtual time of origin (sec)
k	= detector constant, dimensionless	t_{2f}	= arrival time of heat front (for $p = 2$ power law fire) at a point r/H (sec)
m	= mass (lbm or kg)	t_{2f}^*	= reduced arrival time of heat front (for $p = 2$ power law fire) at a point r/H (sec)
p	= positive exponent	t_p^*	= reduced time
P	= radiant power (watts)	T	= temperature ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
q	= heat release rate density per unit floor area ($\text{Btu}/\text{sec}\cdot\text{ft}^2$)	T_a	= ambient temperature ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
Q	= heat release rate (Btu/sec or kW)	T_c	= plume centerline temperature ($^{\circ}\text{F}$)
Q_c	= convection portion of fire heat release rate (Btu/sec)	T_d	= detector temperature ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
Q_{cond}	= heat transferred by conduction (Btu/sec or kW)	T_g	= temperature of fire gases ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
Q_{conv}	= heat transferred by convection (Btu/sec or kW)	T_s	= rated operating temperature of a detector or sprinkler ($^{\circ}\text{C}$ or $^{\circ}\text{F}$)
Q_d	= threshold fire size at which response must occur	u_0	= instantaneous velocity of fire gases (m/sec or ft/sec)
Q_{rad}	= heat transferred by radiation (Btu/sec or kW)	u	= velocity (m/sec)
Q_{total}	= total heat transfer (Btu/sec or kW)	u_c	= critical velocity
Q_{CR}	= critical heat release rate (Btu/sec or kW)	U_p^*	= reduced gas velocity
Q_{DO}	= design heat release rate (Btu/sec or kW)	V	= velocity of smoke at detector
Q_m	= maximum heat release rate (Btu/sec or kW)	w_f	= flame width (ft)
Q_p	= predicted heat release rate (Btu/sec or kW)	Y	= defined in equation (16)
Q_T	= threshold heat release rate at response (Btu/sec or kW)	z	= height above top of fuel package involved (ft)

λ	= wavelength (microns)
Z_m	= maximum height of smoke rise above fire surface (ft or m)
τ	= detector time constant mc/H_eA (sec)
τ_0	= detector time constant measured at reference velocity u_0 (sec)
ϵ	= emissivity, a material property expressed as a fraction between 0 and 1.0

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this code for informational purposes only and are thus not considered part of the requirements of this code unless also listed in Chapter 9. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this code.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1998 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1999 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1998 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1997 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1996 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1998 edition.

NFPA 70, *National Electrical Code*®, 1999 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1999 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1999 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1999 edition.

NFPA 92A, *Recommended Practice for Smoke-Control Systems*, 1996 edition.

NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas*, 1995 edition.

NFPA 101®, *Life Safety Code*®, 1997 edition.

NFPA 170, *Standard for Fire Safety Symbols*, 1999 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communication Systems*, 1999 edition.

C-1.2 Other Publications.

C-1.2.1 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI A17.1, *Safety Code for Elevators and Escalators*, 1998.

ANSI S3.2, *Method for Measuring the Intelligibility of Speech Over Communications Systems*, 1989.

ANSI S3.41, *Audible Emergency Evacuation Signal*, 1990.

C-1.2.2 IEC Publications. International Electrotechnical Commission; 3 rue de Varembé, P.O. Box 131, Geneva 1, Switzerland. IEC documents are available through ANSI.

IEC 60849, *Sound systems for emergency purposes*, Second Edition: 1998.

IEC 60268, Part 16, *The objective rating of speech intelligibility by speech transmission index*, Second Edition: 1998.

C-1.2.3 IES Publication. Illuminating Engineering Society of North America, 120 Wall Street, 17th floor, New York, NY 10005.

Lighting Handbook Reference and Application, 1993.

C-1.2.4 ISO Publication. Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, NY 10017-3483.

ISO 8201, *Audible Emergency Evacuation Signal*, 1990.

C-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 268, *Standard for Safety, Smoke Detectors for Fire Protective Signaling Systems*, 1999.

Visual Signaling Appliances — Private Mode Emergency and General Utility Signaling, UL 1638, 1995.

UL 1971, *Standard for Safety Signaling Devices for the Hearing Impaired*, 1992.

C-1.2.6 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 47, *Code of Federal Regulations*, Part 15.

FCC Rules and Regulations, Volume V, Part 90, March 1979.

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1. Alpert, R. "Ceiling Jets" *Fire Technology*, Aug. 1972.

2. Evaluating Unsprinklered Fire Hazards, SFPE Technology Report 83-2.

3. Babrauskas, V.; Lawson, J. R.; Walton, W. D.; and Twilley, W. H. "Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter", (NBSIR 82-2604) (Dec. 1982). National Institute of Standards and Technology (formerly National Bureau of Standards), Center for Fire Research, Gaithersburg, MD 20889.

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17. Title 47, *Code of Federal Regulations*, Communications Act of 1934 Amended.
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3-2.2	3-2.1	3-8.12.2	3-8.6.2	3-12.4.3	3-8.4.1.3.3.3
3-2.3	3-8.4.1	3-8.12.3	3-8.6.3	3-12.5	3-8.4.1.3.4
3-2.4	3-8.4.1.1	3-8.12.4	3-8.6.4	3-12.5.1	3-8.4.1.3.4.1
3-2.5	3-2.3	3-8.12.5	3-8.6.5	3-12.5.2	3-8.4.1.3.4.2
3-2.5.1	3-2.3.1	3-8.12.6	3-8.6.6	3-12.6	3-8.4.1.3.5
3-2.5.2	3-2.3.2	3-8.13	3-8.2	3-12.6.1	3-8.4.1.3.5.1
3-2.5.3	3-2.3.3	3-8.13.1	3-8.2.1	3-12.6.2	3-8.4.1.3.5.2
3-2.5.4	3-2.3.4	3-8.13.2	3-8.2.2	3-12.6.3	3-8.4.1.3.5.3
3-3	3-3	3-8.13.3	3-8.2.3	3-12.6.3.1	3-8.4.1.3.5.3.1
3-4	3-4	3-8.13.4	3-8.2.4	3-12.6.3.2	3-8.4.1.3.5.3.2
3-4.1	3-4.1	3-8.13.5	3-8.2.5	3-12.6.3.3	3-8.4.1.3.5.3.3
3-4.2	3-8.4.1	3-8.13.6	3-8.2.6	3-12.6.3.4	3-8.4.1.3.5.3.4
3-4.3	3-4.2	3-8.14	3-9.3	3-12.6.4	3-8.4.1.3.5.4
3-4.3.1	3-4.2.1	3-8.14.1	3-9.3.1	3-12.6.5	3-8.4.1.3.5.5
3-4.3.2	3-4.2.2	3-8.14.2	3-9.3.2	3-12.6.5.1	3-8.4.1.3.5.5.1
3-4.4	3-4.2.2.2	3-8.14.3	3-9.3.4	3-12.6.5.2	3-8.4.1.3.5.5.2
3-4.5	3-4.3	3-8.14.4	3-9.3.5	3-12.6.5.3	3-8.4.1.3.5.5.3
3-4.5.1	3-4.3.1	3-8.14.5	3-9.3.6	3-12.6.6	3-8.4.1.3.5.6
3-4.5.2	3-4.3.2	3-8.14.6	3-9.3.7	3-12.6.6.1	3-8.4.1.3.5.6.1
3-5	3-5	3-8.15	3-9.4	3-12.6.6.2	3-8.4.1.3.5.6.2
3-6	3-6	3-8.15.1	3-9.4.1	3-12.6.6.3	3-8.4.1.3.5.6.3
3-7	3-7	3-8.15.2	3-9.4.2	3-12.6.6.4	3-8.4.1.3.5.6.4
3-7.1	3-7	3-8.15.3	3-9.4.3	3-12.7	3-8.4.1.3.6
3-7.2	3-8.4.1.2	3-8.16	3-8.4.4.2	3-12.7.1	3-8.4.1.3.6.1
3-8	3-8	3-8.16.1	3-8.4.4.2.1	3-12.7.2	3-8.4.1.3.6.2
3-8.1	3-8.3.2	3-8.16.2	3-8.4.4.2.1	3-12.8	3-8.4.1.3.7
3-8.1.1	3-8.3.2.1 & 3-8.3.1.1	3-9	3-9	3-12.8.1	3-8.4.1.3.7.1
3-8.1.2	3-8.3.1.2	3-9.1	3-9.1	3-12.8.2	3-8.4.1.3.7.2
3-8.1.3	3-8.3.2.1	3-9.2	3-9.2	3-12.8.3	3-8.4.1.3.7.3
3-8.2	3-8.3.2.2	3-9.2.1	3-9.2.1	3-12.8.4	3-8.4.1.3.7.4
3-8.2.1	3-8.3.1.1	3-9.2.2	3-9.2.2	3-12.8.5	3-8.4.1.3.7.5
3-8.2.2	3-8.3.2.2	3-9.2.3	3-9.2.3	3-12.8.6	3-8.4.1.3.7.6
3-8.2.3	3-8.3.2.3.1	3-9.2.4	3-9.2.4	3-12.8.7	3-8.4.1.3.7.7
3-8.2.4	-	3-9.2.5	3-9.2.6	3-12.8.8	3-8.4.1.3.7.8
3-8.2.5	3-8.3.2.3.3	3-9.2.6	1-5.4.5.1	3-12.8.9	3-8.4.1.3.7.9
3-8.3	3-8.4.2.2	3-9.3.1	3-9.5.1	3-13	3-10
3-8.4	3-8.3.2.3.2	3-9.3.2	3-9.5.2	3-13.1	3-10.1
3-8.5	3-8.3.2.4	3-9.3.3	3-9.5.3	3-13.2	3-10.2
3-8.5.1	1-5.1.2 & 2-9	3-9.3.4	3-9.5.4	3-13.3	3-10.3
3-8.5.2	3-8.3.2.4.1	3-9.4	3-9.6	3-13.3.1	3-10.3.1
3-8.5.3	3-8.3.2.4.2	3-9.4.1	3-9.6.1	3-13.3.2	3-10.3.2
3-8.6	3-8.3.3	3-9.4.2	3-9.6.2	3-13.3.3	3-10.3.3
3-8.6.1	3-8.3.3.1	3-9.4.3	3-9.6.3	3-13.3.4	3-10.3.4
3-8.6.1.1	1-5.1.2 & 2-9	3-9.4.4	3-9.6.4	3-13.3.5	3-10.3.5
3-8.6.1.2	3-8.3.1.1	3-9.5	3-9.7	3-13.4	3-10.4
3-8.6.2	3-8.3.3.1.2	3-9.5.1	3-9.7.1	3-13.4.1	3-10.4.1
3-8.6.3	3-8.3.3.1.3	3-9.5.2	3-9.7.2	3-13.4.2	3-10.4.2
3-8.6.4	3-8.3.3.1.2	3-9.5.3	3-9.7.3	3-13.4.3	3-10.4.3
3-8.6.5	3-8.3.3.1.2	3-10	3-8.4.3	3-13.4.4	3-10.4.4
3-8.6.6	-	3-10.1	3-8.4.3.1	3-13.4.5	3-10.4.5
3-8.6.7	3-8.3.3.1.2	3-10.2	3-8.4.3.2	3-13.4.6	3-10.4.6
3-8.6.8	3-8.3.3.1.2	3-10.3	3-8.4.3.3		
3-8.7	3-2.2	3-10.4	3-8.4.3.4		
3-8.8	3-8.3.2.5	3-10.5	3-8.4.3.5		
3-8.8.1	3-8.3.2.5.1	3-10.6	3-8.4.3.6		
3-8.8.2	3-8.3.2.5.2	3-10.7	3-8.4.3.7		
3-8.8.3	3-8.3.2.5.2	3-11	3-8.1		
3-8.9	3-8.3.3.2	3-11.1	3-8.1.1		
3-8.9.1	3-8.3.3.2.1	3-11.2	3-8.1.2		
3-8.9.2	3-8.3.3.2.2	3-11.2.1	3-8.1.2.1		
3-8.10	3-8.3.4	3-11.2.2	3-8.1.2.2		
3-8.10.1	3-8.3.4.1	3-11.3	3-8.1.3		
3-8.10.2	3-8.3.3.1.2	3-12	3-8.4.1.3		
3-8.11	3-8.5	3-12.1	3-8.4.1.3		
3-8.11.1	3-8.5.1	3-12.2	3-8.4.1.3.1		
3-8.11.2	3-8.5.2	3-12.3	3-8.4.1.3.2		