

FAST-RESPONSE SPRINKLER TECHNOLOGY

Arthur E. Cote and Russell P. Fleming

The ability to measure and control sprinkler sensitivity was the single most significant development in sprinkler technology in the 1980s. This ability has led to the development of new fast-response sprinkler technology that is demonstrating improved fire protection for both life and property.

This chapter covers the development of residential and other fast-response sprinklers, first for the residential environment and later for other applications. It also discusses the specific types of fast-response sprinklers currently available and some of the incentives that have been considered to encourage the widespread use of residential sprinklers.

General information on fire sprinklers can be found in and Section 6, Chapter 9, "Automatic Sprinklers," and Section 6, Chapter 10, "Automatic Sprinkler Systems." A discussion of the theory of fire sprinkler performance is in Section 6, Chapter 8, "Theory of Automatic Sprinkler Performance."

MEASURING SPRINKLER SENSITIVITY

Much of the original work in the area of measuring sprinkler sensitivity was done at Factory Mutual Research Corporation (FMRC) under the sponsorship of the United States Fire Administration (USFA) during the development of the residential sprinkler.^{1,2} Important contributing research was also performed at the British Fire Research Station and the National Institute of Standards and Technology (NIST).^{3,4,5,6}

The decade of progress in this area climaxed late in 1990, when agreement was reached within the working group on sprinkler and water spray equipment of the International Standards Organization (ISO) for a standardized approach to sprinkler sensitivity requirements and testing. The agreement, included in ISO 6182/1, "Requirements and Methods of Test for Sprinklers," uses a combination of sprinkler test procedures developed by laboratories in the United States and Europe and establishes the three ranges of sprinkler sensitivity characteristics shown in Figure 6-13A.

These ranges of sensitivity are based both on the response time index (RTI) of the device and on its conductivity (C). RTI is a measure of pure thermal sensitivity, which indicates how fast the sprinkler can absorb heat from its surroundings sufficient to cause

activation. The conductivity factor is important in measuring how much of the heat picked up from the surrounding air will be lost to the sprinkler fittings and waterway.

Figure 6-13A shows three broad ranges of sprinkler sensitivity: standard, special, and fast response. Traditional sprinkler hardware falls into the standard-response category. The fast-response category is being used for new types of sprinklers for which fast response is considered important. The special-response category is being used in some countries for special types of sprinklers that may be installed in conformance with appropriate national installation standards. In the United States, this includes some of the extended coverage sprinklers.

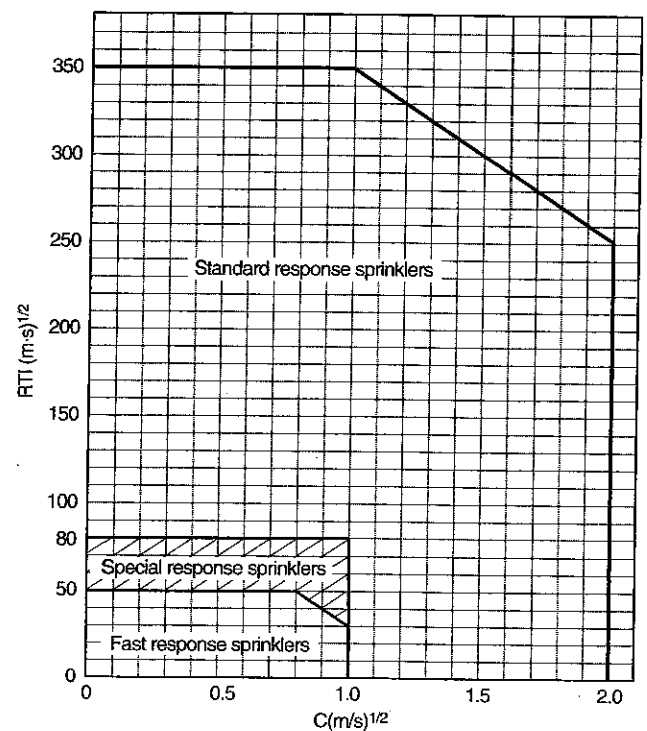


FIG. 6-13A. International sprinkler sensitivity ranges, RTI vs. conductivity. (For U.S. conversion: 1 ft = 0.305 m.)

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Sprinkler response time as a function of the temperature rating of the operating element is well understood, that is, a 165°F (74°C) rated sprinkler would operate when its temperature reaches 165°F (74°C), plus or minus a few degrees. Because of the "thermal lag" of the link or bulb mass, however, the air temperature may be as high as 1000°F (538°C) before the element operates. The smaller mass of the operating element of a fast-response sprinkler permits it to follow a temperature rise in the surrounding air more rapidly, resulting in faster operation. The actual sensitivity requirements of the first fast-response sprinklers, intended as residential sprinklers, were arrived at somewhat by trial and error during developmental test work. To measure sensitivity, FMRC researchers first applied the concept of the "tau" factor and later developed the RTI.

Both the tau factor and RTI refer to the performance of a sprinkler or its operating element in a standardized air oven tunnel test. The test is known as a "plunge" test because a sprinkler at room temperature is plunged into a heated air stream of known constant temperature and velocity.^{1,2} In the plunge test, the tau factor is the time at which the excess temperature of the sensing element of the sprinkler is approximately 63 percent of the excess gas temperature. In other words, the tau factor is the time at which the temperature of the sprinkler thermal element has risen 63 percent of the way to the higher temperature of the heated air. The smaller the tau factor, the faster the sprinkler sensing element heats up and operates.

The tau factor is independent of the air temperature used in the plunge test, but is inversely proportional to the square root of the air velocity. During the early development of the residential sprinkler, a tau factor of 21 sec was considered to indicate the needed level of sensitivity, but this was associated with the specific velocity of 5 ft/sec (1.52 m/s) used in the FMRC plunge test. Since the tau factor changes with the velocity of heated air moving past the sprinkler, it is a fairly inconvenient measure of sprinkler sensitivity.

The RTI has replaced the tau factor as the measure of sensitivity and is determined simply by multiplying the tau factor by the square root of the air velocity at which it is found. The RTI is therefore practically independent of both air temperature and air velocity. Comparisons of RTI give a good indication of relative sprinkler sensitivity.

The smaller the RTI, the faster the sprinkler operation. Standard response sprinklers have RTIs in the range of 180 to 650 $\text{sec}^{1/2}\text{ft}^{1/2}$ (100 to 350 $\text{s}^{1/2}/\text{m}^{1/2}$), while the RTI range for residential sprinklers is about 50 to 90 $\text{sec}^{1/2}\text{ft}^{1/2}$ (28 to 50 $\text{s}^{1/2}/\text{m}^{1/2}$).

The need to add a conductivity term to the model of sprinkler response was recognized in 1986.^{7,8} This term accounts for the loss of heat from the sprinkler operating element to the sprinkler frame, its mounting, and even the water in the pipe. These losses can become significant under low-velocity conditions, particularly for some of the flush-type sprinkler designs with little insulation between the operating element and the sprinkler body.

HISTORICAL DEVELOPMENT

Sensitivity was recognized as a key attribute of automatic sprinklers almost from the start. An evaluation of "sensitiveness" was included among the first comprehensive tests ever performed by C.J.H. Woodbury of the Factory Mutual Fire Insurance Companies in 1884. Many of the refinements to the automatic sprinkler during its first century of use were made with thermal sensitivity in mind.

Yet the standard sprinkler of the 1970s was really little changed from its ancestors. Except for the introduction of the spray sprinkler in the early 1950s to improve the sprinkler discharge pattern, sprinkler design, including the sensitivity of release mechanisms, remained about the same. Sprinklers were essentially

devices intended to protect property, although their effectiveness in providing life safety from fires was outstanding.

Development of NFPA 13D

In 1973, in response to recommendations in the Presidential Commission report, "America Burning," the NFPA Committee on Automatic Sprinklers appointed a Subcommittee on Residential and Light-Hazard Occupancies to prepare a residential sprinkler standard. In 1975, the first edition of NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes* (hereinafter referred to as NFPA 13D), was published, based on expert judgment and the best information available at that time. (Note the first several editions of NFPA 13D used the term "Mobile Home" in the title).

The purpose of the standard was "to provide a sprinkler system that will aid in the detection and control of dwelling fires and thus provide improved protection against injury, life loss, and property damage." The standard required the use of an NFPA 13, *Standard for the Installation of Sprinkler Systems* (hereinafter referred to as NFPA 13), light-hazard water application density of 0.10 gpm/ft^2 [4 mm/min], but it permitted other concessions. The water supply could be based on the area of the largest room or 25 gpm (95 L/min), whichever was less; the total water supply required was to be only 250 gal (946 L); and sprinkler spacing of 256 sq ft (23.7 m^2) was permitted, even though NFPA 13 allowed only 225 sq ft (20.9 m^2). Further, NFPA 13D permitted sprinklers to be omitted from certain areas where the incidence of life loss from fires was shown statistically to be low. NFPA 13 had always required complete sprinkler protection in order to safeguard property properly. In departing from this ideal, the 1975 edition of NFPA 13D became the first attempt at a "life safety" sprinkler standard. In spite of these concessions, actual installations based on this standard were rare, primarily due to cost.

Residential Sprinkler Research

Beginning in 1976, the National Fire Prevention and Control Administration (NFPCA), which was later renamed the U.S. Fire Administration (USFA), acted on its mandate to reduce the nation's fire losses and funded research programs focusing on the residential fire problem in general and residential sprinkler protection in particular. The NFPCA/USFA programs included studies to assess the impact sprinklers would have on reducing deaths and injuries in residential fires.⁹ Other studies evaluated the design, installation, practical usage, and water acceptance factors that would have an impact on achieving reliable and acceptable systems¹⁰; the minimum water discharge rates and automatic sprinkler flow required, and response sensitivity and design criteria¹¹⁻¹³; and full-scale tests of prototype residential sprinkler systems.¹⁴⁻¹⁸

The research showed that a more sensitive sprinkler was needed to respond faster to both smoldering and fast-developing residential fires for two reasons. First, fires had to be controlled quickly in order to prevent the development of lethal conditions in small residential compartments. In addition, fires had to be attacked while still small if they were to be controlled with the water supplies typically available in residences, i.e., 20 to 30 gpm (76 to 114 L/min), and if low costs were to be achieved.

Full-scale tests conducted by FMRC resulted in the development of a prototype fast-response sprinkler that could control or suppress typical residential fires with the operation of not more than two sprinklers. It could also operate fast enough to maintain survivable conditions within the room of fire origin.¹⁴ Survivable conditions were established as follows:

1. Maximum gas temperature at eye level of 200°F (93°C).



FIG. 6-13B. The Grinnell R-1 (right) pena

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2. Maximum ceiling surface temperature of 500°F (260°C).
3. Maximum carbon monoxide concentration of 1,500 parts per million.

Thus, the sprinkler concept expanded from the traditional role of property protection to include life safety. Full-scale field tests were then conducted in Los Angeles to establish system design parameters using the new prototype fast-response "residential sprinkler."¹⁵⁻¹⁸

The data from these tests were studied by the National Fire Protection Association Technical Committee on Automatic Sprinklers and used to establish the criteria for the 1980 edition of NFPA 13D.

Revised NFPA 13D Design Requirements

The design criteria in the 1980 edition of NFPA 13D included for the first time the requirement that all sprinklers be "listed residential sprinklers." Figure 6-13B shows the first two listed residential sprinklers.

Other initial basic design requirements in the revamped NFPA 13D were as follows.

Performance criteria: To prevent flashover in the room of fire origin, when sprinklered, and to improve the chance for occupants to escape or be evacuated.

Design criteria:

1. Only listed residential sprinklers to be used.
2. Minimum 18 gpm (68 L/min) to any single operating sprinkler and 13 gpm (49 L/min) to all operating sprinklers in the design area up to a maximum of two sprinklers.
3. Maximum area protected by a single sprinkler of 144 sq ft (13.4 m²).
4. Maximum distance between sprinklers of 12 ft (3.7 m).
5. Minimum distance between sprinklers of 8 ft (2.4 m).
6. Maximum distance from a sprinkler to a wall or partition of 6 ft (1.8 m).

Application rates, design areas, areas of coverage, and minimum design pressures other than those specified above were permitted to be used with special sprinklers listed for such special residential installation conditions.

Sprinkler coverage: Sprinklers to be installed in all areas with the following exceptions.

Exception No. 1: Sprinklers allowed to be omitted from bathrooms no larger than 55 sq ft (5.1 m²).

Exception No. 2: Sprinklers allowed to be omitted from closets where the least dimension does not exceed 3 ft (0.9 m), the area does not exceed 24 sq ft (2.2 m²), and the walls and ceiling are surfaced with noncombustible materials.

Exception No. 3: Sprinklers allowed to be omitted from open-attached porches, garages, carports, and similar structures.

Exception No. 4: Sprinklers allowed to be omitted from attics and crawl spaces that are not used or intended for living purposes or storage.

Exception No. 5: Sprinklers allowed to be omitted from entrance foyers that are not the only means of egress.

TYPES OF FAST-RESPONSE SPRINKLERS

Today, fast-response sprinkler technology has been incorporated into several different types of sprinklers, each with unique attributes and applications.

Residential Sprinklers

In the sixteen years following the development of the residential sprinkler, special listings involving expanded protection areas and reduced flows proliferated to the point that the original flow and spacing criteria have become all but obsolete. Residential sprinklers are now listed for coverage areas up to 400 sq ft (37.2 m²) per sprinkler. Table 6-13A contains a 1995 compilation of residential sprinklers listed by Underwriters Laboratories Inc. (UL), along with their pressure and flow requirements.

It is important to recognize that, in addition to their fast-response characteristics, residential sprinklers have a special water distribution pattern. Because the effective control of residential fires often depends on a single sprinkler in the room of fire origin, the distribution of residential sprinklers is required to be more uniform than that of standard spray sprinklers, which in large areas can rely upon the overlapping patterns of several sprinklers to make up for voids. Additionally, residential sprinklers are required to protect sofas, drapes, and similar furnishings at the periphery of the room. In their discharge patterns, therefore, the sprinklers must not only be capable of delivering water to the walls of their assigned areas, but high enough up on the walls to prevent the fire from getting "above" the sprinklers. The water delivered close to the ceiling not only protects the portion of the wall close to the ceiling, but also enhances the capacity of the spray to cool gases at the ceiling level, thus reducing the likelihood of excessive sprinkler openings.

Because of their differences, residential sprinklers are not listed by product evaluation organizations under the same product standards as standard sprinklers. Underwriters Laboratories Inc., for example, has developed UL 1626 for residential sprinklers, and FMRC has published its Approval Standard FM 2030 for residential sprinklers. Both of these standards include a plunge test with specific sensitivity requirements and a distribution test that checks the spray pattern in the vertical plane, as well as the horizontal plane. The product standards for standard spray sprinklers contain neither test.

Both UL 1626 and FM 2030 also include a fire test that is intended to simulate a residential fire in the corner of a room containing combustible materials representative of a living room environment. The fire test arrangements for UL 1626 are shown in Figure 6-13C.

The UL 1626 test procedure contains a time-temperature curve that is reproducible in actual tests. The curve parallels the time-temperature relationship developed during the tests of the prototype residential sprinkler in Los Angeles that was part of the ongoing residential sprinkler research effort.^{15, 17, 18}

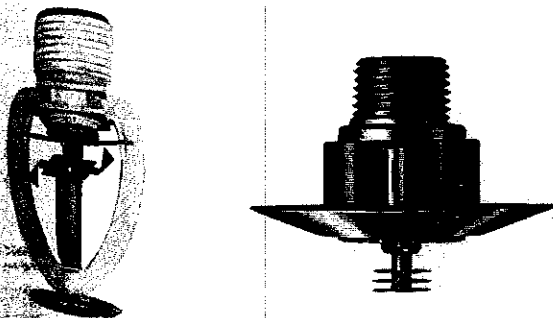


FIG. 6-13B. The first two listed residential sprinklers. Shown are the Grinnell Model F954 (left) and Central "Omega" Model 8-1 (right) pendent sprinklers.

TABLE 6-13A. 1996 Residential Sprinkler Listings

The following updated roster of residential sprinkler listings of NFSA member manufacturers was prepared with data provided from the manufacturers. All temperatures are in degrees Fahrenheit, spacings in feet, flows in gallons per minute (gpm) and pressure in pounds per square inch (psi). Second (multiple) sprinkler flows have been increased in some cases to accommodate the new NFPA 13/13R/13D requirement for 7 psi minimum pressures.

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
<i>Badger Fire Protection Systems - Charlottesville, Virginia (804-973-4361)</i>									
HR-1	Pendent	4.3	155	12x12	14	(10.6)	11.5	(7.1)	
				14x14	14	(10.6)	11.5	(7.1)	
				16x16	16	(13.8)	12	(7.8)	
				18x18	18	(17.5)	16	(13.8)	
HR-1	Recessed pendent	4.3	155	12x12	14	(10.6)	11.5	(7.1)	
				14x14	15	(12.2)	12	(7.8)	
				16x16	16	(13.8)	12	(7.8)	
HR	Pendent or recessed	4.2	155	14x14	18	(18.0)	13	(10.0)	
				16x16	21	(25.0)	15	(13.0)	
HR	Horizontal sidewall	5.5	155	14x14	25	(21.0)	18	(11.0)	
				14Wx16L	30	(30.0)	21	(15.0)	
HR	Recessed sidewall	5.5	155	14x14	25	(21.0)	18	(11.0)	
<i>Central Sprinkler Corporation - Lansdale, Pennsylvania (800-523-6512)</i>									
R-1M	Flush pendent	3.9	160	12x12	10.5	(7.2)	10.5	(7.2)	
				14x14	10.5	(7.2)	10.5	(7.2)	
				16x16	14	(12.9)	11	(8.0)	
				18x18	14	(12.9)	12	(9.5)	
				20x20	16	(16.8)	16	(16.8)	
EC-20A	Flush pendent	5.6	160	12x12	19	(11.5)	16	(8.1)	
				14x14	25	(19.9)	18	(10.3)	
				16x16	30	(28.7)	21	(14.1)	
				18x18	32	(32.7)	29	(26.8)	
HEC-12 RES	Flush sidewall	5.6	160	12x12	26	(21.6)	18	(10.3)	
				14x14	27	(23.2)	21	(14.1)	
GBR	Pendent	4.3	155	14x14	14	(10.6)	11.5	(7.1)	
				16x16	16	(13.8)	12	(7.8)	
				18x18	19	(19.5)	14	(10.6)	
GBR	Recessed pendent	4.3	155	14x14	14	(10.6)	11.5	(7.1)	
				16x16	16	(13.8)	12	(7.8)	
				18x18	19	(19.5)	16	(13.8)	
GBR-2	Pendent or recessed	4.3	155	12x12	13	(9.1)	11.5	(7.1)	
				14x14	18	(17.5)	14	(10.6)	
				16x16	18	(17.5)	14	(10.6)	
				18x18	20	(21.6)	16	(13.8)	
				20x20	20	(21.6)	16	(13.8)	

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TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
GBR	Concealed pendent	4.3	155	12x12	13	(9.1)	11.5	(7.1)	
				14x14	16	(13.8)	13.5	(9.8)	
				16x16	21	(23.8)	15	(12.2)	
GBRS/W	Horizontal sidewall or recessed	5.4	155	12x12	20	(13.7)	18	(11.1)	
				16Wx18L	22	(16.6)	20	(13.7)	
				16Wx20L	30	(30.9)	25	(21.4)	
ROC	Concealed pendent	4.2	165	12x12	18	(18.4)	13	(9.6)	
				14x14	18	(18.4)	13	(9.6)	
				16x16	18	(18.4)	13	(9.6)	
				18x18	24	(32.7)	17	(16.4)	
				20x20	24	(32.7)	17	(16.4)	
GBR-LF	Sidewall or recessed sidewall	3.0	155&175	12x12	14	(16.0)	11	(9.9)	Deflector distance 4-12 in. below ceiling for spacings 14x14 and smaller
				14x14	14	(16.0)	12	(11.8)	
				16x16	16	(20.9)	13	(13.8)	
GBR-LF	Pendent or recessed pendent	3.0	155	12x12	10	(11.1)	8	(7.1)	
				14x14	10	(11.1)	8	(7.1)	
				16x16	10	(11.1)	8	(7.1)	
				18x18	14	(21.8)	10.5	(12.3)	
				20x20	16	(28.4)	13.5	(20.3)	
GBR-LF	Pendent or recessed pendent	3.0	175	12x12	10	(11.1)	8	(7.1)	
				14x14	12	(16.0)	8.5	(8.0)	
				16x16	12	(16.0)	8.5	(8.0)	
				18x18	15	(25.0)	10.5	(12.3)	
				20x20	16	(28.4)	13.5	(20.3)	
GBR-LP	Pendent "extended"	3.0	155&175	12x12	11	(13.4)	8	(7.1)	Deflector distance extended 4-8 in. below ceiling
				14x14	12	(16.0)	9	(9.0)	
				16x16	14	(21.8)	10.5	(12.3)	
				18x18	14	(21.8)	12	(16.0)	
				20x20	16	(28.4)	15	(25.0)	
Globe Fire Sprinkler - Standish, Michigan (800-248-0278)									
JUN	Pendent	4.2	155	12x12	13	(9.6)	11.5	(7.5)	
				14x14	20	(22.7)	14	(11.1)	
				16x16	20	(22.7)	14	(11.1)	
				20x20	19	(20.5)	16	(14.5)	
JUN	Recessed pendent	4.2	155	12x12	13	(9.6)	11.5	(7.5)	
				14x14	18	(18.4)	13	(9.6)	
				16x16	18	(18.4)	13	(9.6)	
				18x18	18	(18.4)	14	(11.1)	
				20x20	19	(20.5)	16	(14.5)	

TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
J/JN	Concealed pendent	4.2	155	12x12	13	(9.6)	11.5	(7.5)	
				14x14	17	(16.4)	13	(9.6)	
				16x16	22	(27.4)	16	(14.5)	
J/JN	Horizontal sidewall or recessed sidewall	4.2	155	12x12	19	(20.5)	14	(11.1)	
				14x14	21	(25.0)	16	(14.5)	FR-1
				16x16	24	(32.7)	19	(20.5)	
	Horizontal sidewall or recessed sidewall	5.6	155	12x12	20	(12.8)	15	(7.2)	
				14x14	23	(16.9)	17	(9.2)	F984
				16x16	24	(18.4)	20	(12.8)	
JRES2/ JNRES2	Horizontal sidewall or recessed sidewall	5.6	155	12x12	18	(10.3)	15	(7.2)	F974
				16Wx18L	30	(28.7)	22	(15.4)	
				16Wx20L	35	(39.1)	26	(21.6)	F993
<i>Grinnell Corporation - Exeter, New Hampshire (603-778-9200)</i>									
83	Pendent	4.4	155	12x12	12	(7.4)	12	(7.4)	
				14x14	15	(11.6)	12	(7.4)	A
				16x16	15	(11.6)	12	(7.4)	
				18x18	8	(16.7)	14	(10.1)	
				20x20	20	(20.7)	17	(14.9)	
			175	12x12	12	(7.4)	12	(7.4)	A
				14x14	16	(13.2)	12	(7.4)	
F973	Recessed pendent	4.4	155	12x12	12	(7.4)	12	(7.4)	
				14x14	15	(11.6)	12	(7.4)	
				16x16	15	(11.6)	12	(7.4)	A
				18x18	18	(16.7)	14	(10.1)	
				20x20	20	(20.7)	17	(14.9)	
F990	Flush pendent	4.2	160	12x12	12	(8.2)	11.5	(7.5)	
				14x14	14	(11.1)	11.5	(7.5)	A/FZ
				16x16	16	(14.5)	12	(8.2)	
				18x18	18	(18.4)	14	(11.1)	ZX-RES
				20x20	22	(27.4)	18	(18.4)	
F992	Flush pendent	5.6	160	12x12	17	(9.2)	15	(7.2)	
				14x14	20	(12.8)	17	(9.2)	
				16x16	22	(15.4)	19	(11.5)	
				18x18	31	(30.6)	24	(18.4)	ZX RES/2
978	Concealed pendent	4.2	155	12x12	16	(14.5)	12	(8.2)	
				14x14	16	(14.5)	12	(8.2)	

TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
FR-1	Horizontal sidewall	5.6	165	16x16	16	(14.5)	12	(8.2)	
				18x18	24	(32.7)	17	(16.4)	
				20x20	25	(35.4)	18	(18.4)	
		8.1	140&165	12x12	21	(14.1)	17	(9.2)	
				16Wx20L	40	(51.0)	37	(43.7)	
				12x12	26	(10.3)	24	(8.8)	
F984	Horizontal sidewall	4.4	55	16Wx20L	50	(38.1)	45	(30.9)	
				12x12	13	(8.7)	12	(7.4)	
				14x14	21	(22.8)	15	(11.6)	
F974	Recessed horizontal sidewall	4.4	155	16x16	21	(22.8)	15	(11.6)	
				12x12	13	(8.7)	12	(7.4)	
				14x14	21	(22.8)	15	(11.6)	
F993	Flush sidewall	5.6	160	12x12	22	(15.4)	15.5	(7.7)	
				14x14	30	(28.7)	21	(14.1)	
				16x16	22	(22.8)	15	(11.6)	

The Reliable Automatic Sprinkler Company—Mount Vernon, New York (800-431-1588)

A	Pendent	4.15	165	14x14	18	(18.8)	13	(9.8)	
				16x16	25	(36.3)	18	(18.8)	
		5.5	165	12x12	21	(14.6)	15	(7.4)	
				14x14	24	(19.0)	17	(9.6)	
A	Recessed pendent	4.15	165	14x14	19	(21.0)	13.5	(10.6)	
				16x16	25	(36.3)	18	(18.8)	
		5.5	165	12x12	21	(14.6)	15	(7.4)	
				14x14	24	(19.0)	17	(9.6)	
A	Horizontal sidewall	4.15	165	12x12	21	(25.6)	15	(13.1)	
				14x14	25	(36.3)	18	(18.8)	
A/Z	Recessed sidewall	4.15	165	12x12	21	(25.6)	15	(13.1)	
				14x14	25	(36.3)	18	(18.8)	
A/BES	Flush pendent	4.1	165	14x14	18	(19.3)	13	(10.1)	
				16x16	24	(34.3)	17	(17.2)	
				14x14	26	(23.2)	18	(11.1)	
	Flush pendent	5.4	165	16x16	30	(30.9)	21	(15.1)	
				18x18	32.5	(36.2)	23	(18.1)	
A	Flush pendent	4.1	165	12x12	12	(8.6)	11	(7.2)	
				14x14	13	(10.1)	11	(7.2)	
				16x16	14	(11.7)	12	(8.6)	
				18x18	16	(15.2)	14	(11.7)	
				20x20	18	(19.3)	16	(15.2)	

TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non- Standard Notes
ZX-RES	Horizontal sidewall	5.4	165	14x14	24	(19.8)	17	(10.0)	
F1/RES	Pendent	5.6	155	14x14	20	(12.8)	15	(7.2)	
				16x16	20	(12.8)	20	(12.8)	
				18x18	28	(25.0)	22	(15.4)	
F1/RES	Horizontal sidewall	5.6	155	12x12	25	(19.9)	18	(10.3)	
				14x14	25	(19.9)	18	(10.3)	
				16x16	30	(28.7)	21	(14.1)	
				16x18	34	(36.9)	24	(18.4)	
				16x20	37	(43.7)	26	(21.6)	
F1/RES/2	Pendent and recessed pendent*	4.2	155	12x12	12	(8.2)	11	(7.0)	
				14x14	13	(9.6)	11	(7.0)	
				16x16	15	(12.8)	12	(8.2)	
				18x18	17	(16.4)	15	(12.8)	
				20x20	19	(20.5)	17	(16.4)	
F1/RES /F2	Recessed pendent	5.6	155	14x14	20	(12.8)	15	(7.2)	
				16x16	20	(12.8)	20	(12.8)	
F1/RES /F2	Recessed horizontal sidewall	5.6	155	12x12	25	(19.9)	18	(10.3)	
				14x14	25	(19.9)	18	(10.3)	
F1/RES/3	Pendent and recessed pendent **	3.9	155&175	12x12	10.5	(7.2)	10.5	(7.2)	9-ft minimum spacing between sprinklers
			155&175	14x14	12	(9.5)	10.5	(7.2)	
			155&175	16x16	12	(9.5)	10.5	(7.2)	
			155	18x18	15	(14.8)	10.5	(7.2)	
			155	20x20	18	(21.3)	18	(21.3)	
F1/RES/3	Concealed pendent	3.9	155	12x12	11	(8.0)	10.5	(7.2)	
				14x14	12	(9.5)	10.5	(7.2)	
				16x16	15	(14.8)	12	(9.5)	
				18x18	16	(16.8)	13	(11.1)	
				20x20	18	(21.3)	14	(12.9)	
F1/RES/3	Horizontal sidewall	3.9	155	12x12	13	(11.1)	11	(7.9)	
				14x14	14	(12.9)	12	(9.5)	
				16x16	17	(19.0)	14	(12.9)	
				16x18	18	(21.3)	16.5	(17.9)	
				16x20	25	(41.1)	19.5	(25.0)	
				18x18	22	(31.8)	21	(29.0)	
				12x12	13	(11.1)	13	(11.1)	Deflector 6-12 in. distance below ceiling
				14x14	17	(19.0)	16	(16.8)	
16x16	20	(26.3)	17	(19.0)					

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/F.

F4/RE

Star Sp

LD-2

LD-2

SG-R

TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
			175	12x12	14	(12.9)	11	(7.9)	
				14x14	14	(12.9)	12	(9.5)	
				16x16	17	(19.0)	14	(12.9)	
				16x18	19	(23.7)	16.5	(17.9)	
				16x20	25	(41.1)	20	(26.3)	
				12x12	13	(11.1)	13	(11.1)	Deflector
				14x14	17	(19.0)	16	(16.8)	distance 6-12 in.
				16x16	20	(26.3)	17	(19.0)	below ceiling
F1/RES/3	Recessed	3.9	155	12x12	13	(11.1)	11	(7.9)	
F2	horizontal sidewall			14x14	14	(12.9)	12	(9.5)	
				16x16	17	(19.0)	14	(12.9)	
				16x18	18	(21.3)	16.5	(17.9)	
				16x20	25	(41.1)	19.5	(25.0)	
				18x18	22	(31.8)	21	(29.0)	
				12x12	13	(11.1)	13	(11.1)	
				14x14	17	(19.0)	16	(16.8)	
				16x16	20	(26.3)	17	(19.0)	
			175	12x12	14	(12.9)	11	(7.9)	
				14x14	14	(12.9)	12	(9.5)	
				16x16	17	(19.0)	14	(12.9)	
				16x18	19	(23.7)	16.5	(17.9)	
				16x20	25	(41.1)	20	(26.3)	
				12x12	13	(11.1)	13	(11.1)	Deflector
				14x14	17	(19.0)	16	(16.8)	distance 6-12 in.
				16x16	20	(26.3)	17	(19.0)	below ceiling
	F4/RES	5.5	135	12x12	22	(16.0)	20	(13.2)	
				14x14	27	(24.1)	22.5	(16.7)	
				16x16	30	(29.8)	23	(17.5)	
Sprinkler Corporation—Milwaukee, Wisconsin (800-558-5236; in Wisconsin 414-570-5000)									
	Pendent or recessed	4.5	165	12x12	18	(16.0)	13	(8.3)	
				14x14	20	(19.8)	14	(9.7)	
				16x16	20	(19.8)	15	(11.1)	
	Horizontal sidewall or recessed sidewall	4.5	165	12x12	17	(14.3)	12	(7.1)	
				14x14	21	(21.8)	15	(11.1)	
				16x16	25	(30.9)	18	(16.0)	
		4.8	165	12x12	17	(12.5)	13	(7.3)	
				16Wx20L	38	(62.7)	27	(31.6)	
	Pendent	4.3	155	12x12	16	(13.8)	11.5	(7.1)	
				14x14	16	(13.8)	11.5	(7.1)	
				16x16	17	(15.6)	13	(9.1)	
				18x18	19	(19.5)	14	(10.6)	
				20x20	20	(21.6)	17	(15.6)	

Non-Standard Notes

minimum spacing between sprinklers

deflector 6-12 in. distance below

TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
SG-R	Recessed	4.3	155	12x12	13	(9.1)	11.5	(7.1)	
				14x14	16	(13.8)	11.5	(7.1)	
				16x16	17	(15.6)	13	(9.1)	
				18x18	17	(15.6)	13	(9.1)	
				20x20	21	(23.9)	17	(15.6)	
SG-RES	Horizontal sidewall or recessed sidewall	4.3	155	12x12	15	(12.2)	12	(7.8)	
				12x12	17	(15.6)	12	(7.8)	6-12 in.
				14x14	16	(13.8)	14	(10.6)	
				14x14	19	(19.5)	15	(12.2)	6-12 in.
				16x16	18	(17.5)	14	(10.6)	
		5.8	155	12x12	18	(9.6)	15.5	(7.1)	
				12x12	17	(8.6)	15.5	(7.1)	6-12 in.
				16Wx18L	28	(23.3)	23	(15.7)	
				16Wx20L	29	(25.0)	26	(20.1)	
Q	Concealed	4.3	155	12x12	13	(9.1)	11.5	(7.5)	
				14x14	17	(15.6)	13	(9.1)	
				16x16	20	(21.6)	15	(12.2)	
Viking Corporation—Hastings, Michigan (616-945-9501)									
M	Pendent or recessed†	4.2	155&175	12x12	15	(12.8)	11.5	(7.0)	
				14x14	18	(18.4)	13	(9.6)	
				16x16	24	(32.7)	17	(16.4)	
M-2	Pendent or recessed†	5.5	155&175	12x12	23	(17.5)	16	(8.5)	
				14x14	24	(19.0)	17	(9.6)	
M	Horizontal sidewall or recessed sidewall†	5.5	155&175	12x12	21	(14.6)	17	(9.6)	
				14x14	25	(20.7)	18	(10.7)	
M	Horizontal sidewall	5.5	155	16x16	27	(24.1)	23	(17.5)	
				16x16	28	(25.9)	23	(17.5)	6-10 in.
				16x18	28	(25.9)	23	(17.5)	4-10 in.
				16x20	37	(45.2)	30	(29.7)	
				16x20	38	(47.7)	31	(31.7)	6-10 in.
				18x16	29	(27.8)	25	(20.6)	4-10 in.
H	Flush pendent	4.2	165	12x12	14	(11.1)	11.5	(7.5)	
				16x16	17	(16.4)	12	(8.2)	
				18x18	20	(22.7)	14	(11.1)	
				20x20	29	(47.7)	21	(25.0)	

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 ** Recessed p
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In summa
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TABLE 6-13A. (Continued)

Model	Style	K	Temp °F	Maximum Spacing (ft)	1-spr Flow (gpm)	(Pres) (psi)	Multiple Sprinkler Flow (gpm)	(Pres) (psi)	Non-Standard Notes
		5.5	165	12x12	18	(10.7)	14.5	(7.0)	
				16x16	22	(16.0)	16	(8.5)	
				18x18	22	(16.0)	18	(10.7)	
				20x20	30	(29.8)	21	(14.6)	
H-2, H-3	Flush pendent	3.8	165	12x12	10	(7.0)	10	(7.0)	
				14x14	11	(8.4)	10	(7.0)	
				16x16	13	(11.7)	11	(8.4)	
				18x18	16	(17.7)	13	(11.7)	
				20x20	19	(25.0)	17	(20.0)	
H-3	Flush pendent	3.8	165	16x16	16	(17.7)	12	(10.0)	Listed for sloped ceilings to pitch of 6 in 12
A-1	Concealed	4.2	155	14x14	18	(18.4)	13	(9.6)	
				16x16	25	(35.4)	19	(20.5)	
				14x14	24	(19.0)	17	(9.6)	
M-4	Pendent or recessed pendent ††	4.3	155	12x12	11.5	(7.1)	11.5	(7.1)	
				14x14	13	(9.1)	11.5	(7.1)	
				16x16	13	(9.1)	11.5	(7.1)	
				18x18	16	(13.8)	13.5	(9.9)	
				20x20	19	(19.5)	17	(15.6)	
M-4	Horizontal sidewall or recessed sidewall	4.3	155	12x12	19	(19.5)	15	(12.2)	6-12 in. below
				14x14	22	(26.2)	17	(15.6)	sloped ceilings to
				16x16	22	(26.2)	17	(15.6)	pitch of 4 in 12
M-5	Horizontal sidewall or recessed sidewall	5.5	155	12x12	21	(14.6)	15	(7.4)	6-12 in. below
				14x14	24	(19.0)	21	(14.6)	sloped ceilings to
				16x16	24	(19.0)	21	(14.6)	pitch of 6 in 12

† Recessed pendent is model F1/RES/2/F2
 †† Recessed pendent is model F1/RES/3/F2
 ††† Escutcheon for recessed version
 †††† Escutcheon for recessed version

In summary, to meet the UL 1626 test criteria, residential sprinklers, installed in a fire test enclosure with an 8-ft (2.4-m) ceiling height, are required to control a fire for 10 min with the following conditions:

- 1. The maximum gas or air temperature adjacent to the sprinkler—6.2 mm (0.25 in.) below the ceiling and 8 in. (203 mm) horizontally from the sprinkler—must not exceed 600°F (316°C).
- 2. The maximum temperature—5 ft, 3 in. (1.6 m) above the floor and 10 ft (3 m) from the room length away from each wall—must be less than 300°F (93°C) during the entire test. This temperature must not exceed 130°F (54°C) for more than a 2-min period.

3. The maximum temperature 1/4 in. (6.3 mm) behind the finished surface of the ceiling material directly above the test fire must not exceed 500°F (260°C).
4. No more than two residential sprinklers in the test enclosure can operate.

The test enclosure is built to be twice the size of the proposed maximum spacing of the residential sprinkler. In a typical test, the walls of one corner of the test enclosure are covered with combustible cellulosic acoustical panels 1/8-in. (3.2-mm) thick. Two combustible structures with urethane foam, representing stuffed furniture, are positioned at the same corner. (See Figure 6-13C.) The enclosure is kept at an initial ambient temperature of 80°F (27°C) ±

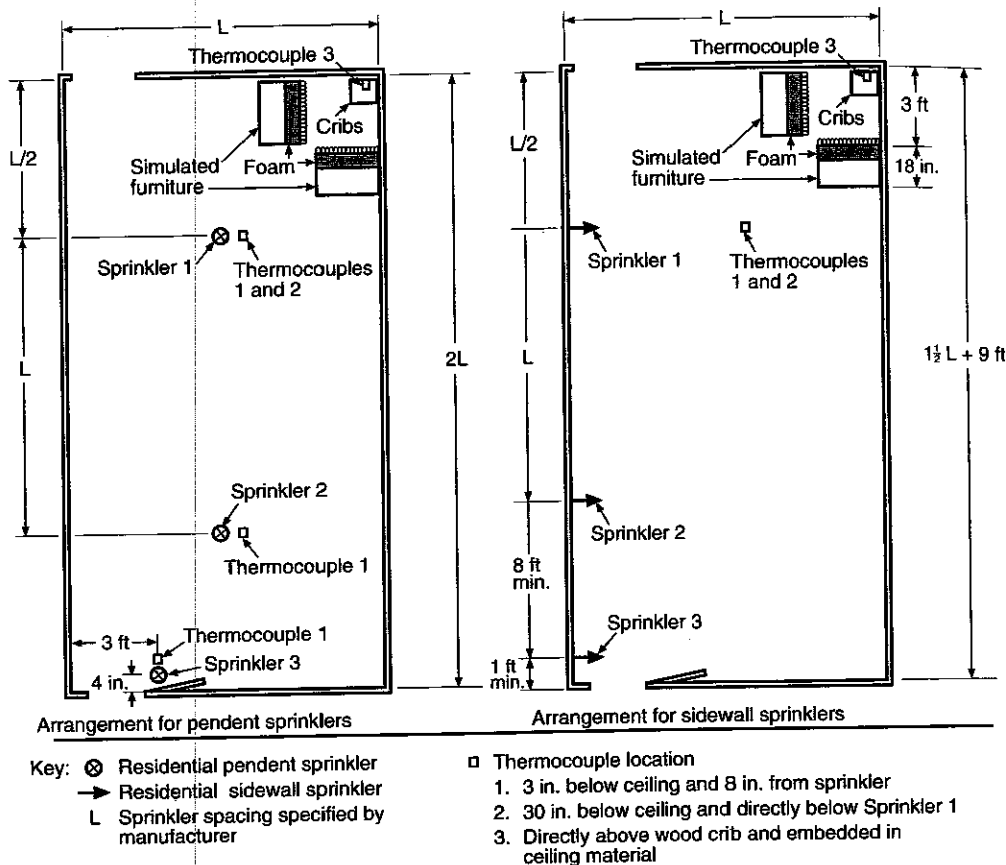


FIG. 6-13C. Fire test arrangements for UL 1626 for pendent sprinklers (left) and sidewall sprinklers (right). The simulated furniture consists of 3 in. (76 mm) thick uncovered urethane foam cushions 30 in. (762 mm) high by 30 in. (762 mm) wide. The foam has a density of 1.25 lb/sq ft (6.1 kg/m³) and is attached to a wood frame. The walls of the test room are covered with 4 by 8 ft × 1/8 in. (1.2 × 2.4 m × 3.2 mm) decorative plywood paneling (flame spread rating 200) attached to wood furring strips. The fire source consists of 12 × 12 × 12 in. (0.3 × 0.3 × 0.3 m) wood cribs weighing 12 to 13 lb (5.4 to 5.9 kg). The ceiling of the test room is 8 ft (2.4 m) high and covered with 2 × 4 ft × 1/2 in. (6.1 × 1.2 m × 12.7 mm) thick acoustical panels attached to wood furring strips. (For SI units: 1 in = 25.4 mm; 1 ft = 0.305 m.)

5°F (3°C), and it is ventilated through two door openings on opposite walls. The fire source is a wood crib of 12 to 13 lb (5.4 to 5.9 kg) mass, measuring approximately 12 by 12 by 12 in. (0.3 by 0.3 by 0.3 m).

The wood crib is ignited by 8 oz. (24 mL) of N-heptane in a pan directly below the crib. Forty sec after ignition, the excelsior [1/4 lb (0.11 kg)] on the floor next to the simulated furniture is ignited.

The fire test is conducted for 10 min after the ignition of the wood crib. The water flow to the first sprinkler that operates and the total water flow when the second sprinkler operates are specified as part of the listing limitations for the sprinklers in the test. The total water flow for two sprinklers must be a minimum of 1.2 times the minimum flow for a single sprinkler.

The water distribution test requirements are based on the distribution pattern of the prototype residential sprinkler used in the Los Angeles test fires.¹⁸ The distribution requirements involve collections in both the horizontal and vertical planes.

All residential sprinklers in the test must discharge water at the flow rate specified by the manufacturer for a 10-min period simulating one sprinkler operating and two sprinklers operating. The quantity of water collected on both the horizontal and vertical surfaces is measured and recorded.

Sprinklers being tested are required to discharge a minimum of 0.02 gpm per sq ft [0.8(L/min)/m²] at both flow rates over the entire design area, plus an area 2 ft (0.61 m) beyond the listed coverage area in each direction (only three directions for horizontal sidewall-type sprinklers). They must also wet the walls of the test enclosure to a height not less than 28 in. (711 mm) below the ceiling with one sprinkler operating and not less than 36 in. (914 mm) with two sprinklers operating. Each wall surrounding the coverage area is required to be wetted with a minimum of 5 percent of the sprinkler application densities at both flow rates.

Since 1985, the use of residential sprinklers has also been permitted under some conditions in accordance with NFPA 13. Essentially, NFPA 13 allows residential sprinklers in dwelling units located in any occupancy, provided they are installed in conformance with the requirements of their listing and the positioning requirements of NFPA 13D. A dwelling unit is defined as one or more rooms arranged for the use of one or more individuals living together, as in a single housekeeping unit normally having cooking, living, sanitary, and sleeping facilities. Dwelling units include hotel rooms, dormitory rooms, sleeping rooms in nursing homes, and similar living units. Occupancies encompassing dwelling units include apartment buildings, board and care facilities, dormitories, condominiums, lodging and rooming houses, and other multiple-family dwellings.

FIG. 6-13D
NFPA 13 oc

For NFPA 13 applications involving residential sprinklers in dwelling units, the design area is required to consist of the four most hydraulically demanding sprinklers. (See Figure 6-13D).

Other areas, such as attics, basements, or other types of occupancies outside of dwelling units but within the same structure, are required to be protected in accordance with regular provisions of NFPA 13, including the appropriate water supply requirements. The decision as to which areas are to be protected with sprinklers is also regulated in accordance with the normal provisions of NFPA 13. This means, for example, that combustible concealed spaces generally require sprinklers. Although the four-sprinkler design area can be used in the dwelling units when protected with residential sprinklers, any sprinklers installed within such concealed spaces would have to use a different design approach.

Residential sprinklers installed in systems designed to NFPA 13 requirements are spaced and positioned in accordance with their residential listings, not with the spacing requirements of NFPA 13. The water demands for the residential sprinklers are the same as in NFPA 13 applications, except that the multiple sprinkler flow requirement is extended to four sprinklers rather than the two stipulated for one- and two-family dwellings and manufactured homes in NFPA 13D. The more liberal piping, component, hanger location, and water supply duration allowances of NFPA 13D are not permitted in these systems.

Beginning in 1996, NFPA 13 requires residential sprinklers or quick-response sprinklers in residential areas.

In 1989, a new standard was developed to bridge the gap between NFPA 13 and NFPA 13D. The new standard is NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height* (hereinafter referred to as NFPA 13R).

Like NFPA 13D, NFPA 13R is oriented toward economical life safety protection. Sprinklers are omitted from building areas that have been found to have a low incidence of fatal fires originating in them, including combustible concealed spaces, small bathrooms and closets, and attached porches. As with NFPA 13D, residential sprinklers are required throughout dwelling units, with some minor exceptions. A four-sprinkler design area is required unless the largest compartment contains fewer sprinklers.

In recognition of the greater risk associated with multifamily occupancies, however, NFPA 13R is more conservative than NFPA 13D, in some areas. Requirements for plans, hydraulic calculations, and system acceptance certificates parallel those of NFPA 13. Unlike NFPA 13D, NFPA 13R requires a consideration of the likelihood that simultaneous domestic flows might occur through combined service piping. In addition, pumps and other key equipment are required to be listed.

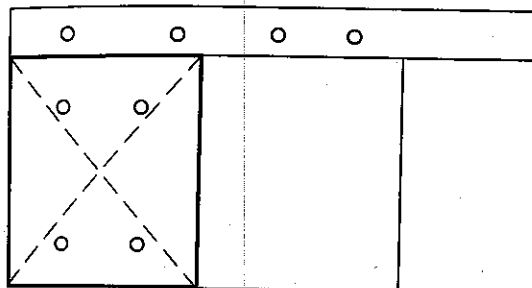
In NFPA 13R systems, areas outside dwelling units can be protected with standard spray sprinklers, using NFPA 13 design criteria.

Quick-Response Sprinklers

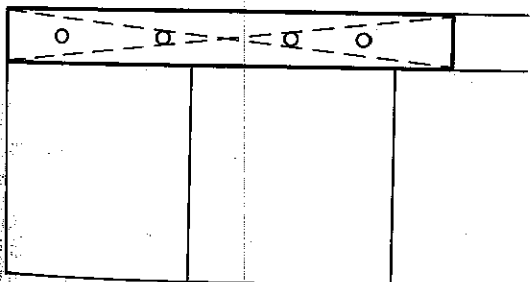
Quick-response sprinklers are designed to be used in hotels, motels, offices, and other buildings where faster sprinkler operation could enhance life safety. UL first listed these sprinklers as quick-response sprinklers based on performance comparable to a standard response sprinkler equipped with a quick-response electronic squib actuator, a device marketed by one sprinkler manufacturer in the 1970s.

Quick-response sprinklers, which are essentially standard spray sprinklers equipped with fast-response operating mechanisms, were first introduced in 1983. They were developed by manufacturers in two different ways. One was to replace the actuating mechanism of standard spray sprinklers with the more sensitive heat-responsive element used in residential sprinklers. This sprinkler was then resubmitted to a testing laboratory for testing and listing under the product standard for standard spray sprinklers. The other way was to simply submit a residential sprinkler to a testing laboratory for testing and listing under the provisions of a product standard for standard spray sprinklers.

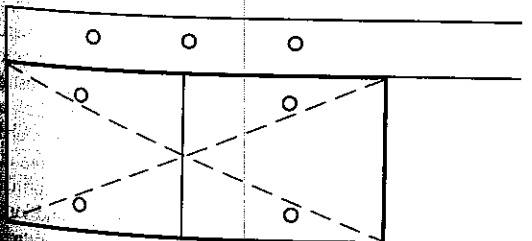
It was not until 1988 that full-scale testing showed that quick-response sprinklers could be used effectively with the traditional area/density design approaches found in sprinkler installation standards.^{19,20} In "control-mode" testing of a 6-ft, 8-in. (2.0-m) arrangement of a standard plastic commodity under a 20-ft (6.1-m) ceiling, multiple tests involving sprinklers identical in all respects except sensitivity indicated that on average fewer quick-response



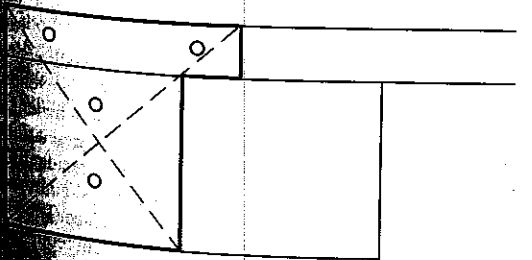
(a)



(b)



(c)



(d)

Figure 6-13D: Examples of design areas for dwelling units within occupancies.

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