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.

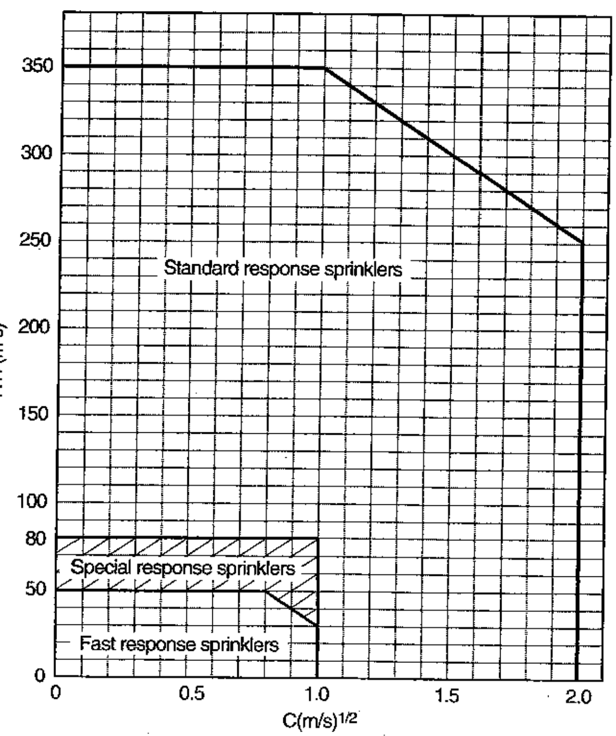


FIG. 6-13A. International sprinkler sensitivity ranges, RTI vs. conductivity. (For U.S. conversion: 1 ft = 0.305 m.)

Arthur E. Cote, P.E., is senior vice president, operations, of the NFPA. Russell P. Fleming, P.E., is vice president of engineering of the National Fire Sprinkler Association.

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 $sec^{1/2}ft^{1/2}$ (100 to 350 $s^{1/2}/m^{1/2}$), while the RTI range for residential sprinklers is about 50 to 90 $sec^{1/2}ft^{1/2}$ (28 to 50 $s^{1/2}/m^{1/2}$).

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/ft² [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 m²) was permitted, even though NFPA 13 allowed only 225 sq ft (20.9 m²). 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 systems[10]; the minimum water discharge rates and automatic sprinkler flow required, and response sensitivity and design criteria[11-13]; 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).

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 m^2).
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 m^2).

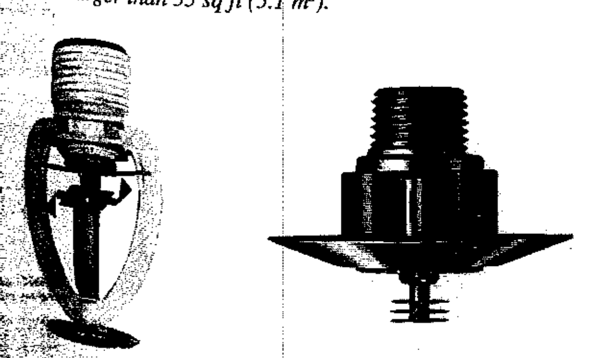


FIG. 6-13B. The first two listed residential sprinklers. Shown are the Grinnell Model F954 (left) and Central "Omega" Model R-1 (right) pendent sprinklers.

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 m^2), 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 m^2) 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]

TABLE 6-13A. ***1996 Residential Sprinkler Listings***

…e 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
Badger Fire Protection Systems - Charlottesville, Virginia (804-973-4361)									
HR-1	Pendent	4.3	155	12×12	14	(10.6)	11.5	(7.1)	
				14×14	14	(10.6)	11.5	(7.1)	
				16×16	16	(13.8)	12	(7.8)	
				18×18	18	(17.5)	16	(13.8)	
HR-1	Recessed pendent	4.3	155	12×12	14	(10.6)	11.5	(7.1)	
				14×14	15	(12.2)	12	(7.8)	
				16×16	16	(13.8)	12	(7.8)	
HR	Pendent or recessed	4.2	155	14×14	18	(18.0)	13	(10.0)	
				16×16	21	(25.0)	15	(13.0)	
HR	Horizontal sidewall	5.5	155	14×14	25	(21.0)	18	(11.0)	
				14W×16L	30	(30.0)	21	(15.0)	
HR	Recessed sidewall	5.5	155	14×14	25	(21.0)	18	(11.0)	
Central Sprinkler Corporation - Lansdale, Pennsylvania (800-523-6512)									
R-1M	Flush pendent	3.9	160	12×12	10.5	(7.2)	10.5	(7.2)	
				14×14	10.5	(7.2)	10.5	(7.2)	
				16×16	14	(12.9)	11	(8.0)	
				18×18	14	(12.9)	12	(9.5)	
				20×20	16	(16.8)	16	(16.8)	
EC-20A	Flush pendent	5.6	160	12×12	19	(11.5)	16	(8.1)	
				14×14	25	(19.9)	18	(10.3)	
				16×16	30	(28.7)	21	(14.1)	
				18×18	32	(32.7)	29	(26.8)	
HEC-12 RES	Flush sidewall	5.6	160	12×12	26	(21.6)	18	(10.3)	
				14×14	27	(23.2)	21	(14.1)	
GBR	Pendent	4.3	155	14×14	14	(10.6)	11.5	(7.1)	
				16×16	16	(13.8)	12	(7.8)	
				18×18	19	(19.5)	14	(10.6)	
GBR	Recessed pendent	4.3	155	14×14	14	(10.6)	11.5	(7.1)	
				16×16	16	(13.8)	12	(7.8)	
				18×18	19	(19.5)	16	(13.8)	
GBR-2	Pendent or recessed	4.3	155	12×12	13	(9.1)	11.5	(7.1)	
				14×14	18	(17.5)	14	(10.6)	
				16×16	18	(17.5)	14	(10.6)	
				18×18	20	(21.6)	16	(13.8)	
				20×20	20	(21.6)	16	(13.8)	

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	12×12	13	(9.1)	11.5	(7.1)	
				14×14	16	(13.8)	13.5	(9.8)	
				16×16	21	(23.8)	15	(12.2)	
GBRS/W	Horizontal sidewall or recessed	5.4	155	12×12	20	(13.7)	18	(11.1)	
				16W×18L	22	(16.6)	20	(13.7)	
				16W×20L	30	(30.9)	25	(21.4)	
ROC	Concealed pendent	4.2	165	12×12	18	(18.4)	13	(9.6)	
				14×14	18	(18.4)	13	(9.6)	
				16×16	18	(18.4)	13	(9.6)	
				18×18	24	(32.7)	17	(16.4)	
				20×20	24	(32.7)	17	(16.4)	
GBR-LF	Sidewall or recessed sidewall	3.0	155&175	12×12	14	(16.0)	11	(9.9)	Deflector distance 4–12 in. below ceiling for spacings 14×14 and smaller
				14×14	14	(16.0)	12	(11.8)	
				16×16	16	(20.9)	13	(13.8)	
GBR-LF	Pendent or recessed pendent	3.0	155	12×12	10	(11.1)	8	(7.1)	
				14×14	10	(11.1)	8	(7.1)	
				16×16	10	(11.1)	8	(7.1)	
				18×18	14	(21.8)	10.5	(12.3)	
				20×20	16	(28.4)	13.5	(20.3)	
GBR-LF	Pendent or recessed pendent	3.0	175	12×12	10	(11.1)	8	(7.1)	
				14×14	12	(16.0)	8.5	(8.0)	
				16×16	12	(16.0)	8.5	(8.0)	
				18×18	15	(25.0)	10.5	(12.3)	
				20×20	16	(28.4)	13.5	(20.3)	
GBR-LP	Pendent "extended"	3.0	155&175	12×12	11	(13.4)	8	(7.1)	Deflector distance extended 4–8 in. below ceiling
				14×14	12	(16.0)	9	(9.0)	
				16×16	14	(21.8)	10.5	(12.3)	
				18×18	14	(21.8)	12	(16.0)	
				20×20	16	(28.4)	15	(25.0)	
Globe Fire Sprinkler - Standish, Michigan (800-248-0278)									
J/JN	Pendent	4.2	155	12×12	13	(9.6)	11.5	(7.5)	
				14×14	20	(22.7)	14	(11.1)	
				16×16	20	(22.7)	14	(11.1)	
				20×20	19	(20.5)	16	(14.5)	
J/JN	Recessed pendent	4.2	155	12×12	13	(9.6)	11.5	(7.5)	
				14×14	18	(18.4)	13	(9.6)	
				16×16	18	(18.4)	13	(9.6)	
				18×18	18	(18.4)	14	(11.1)	
				20×20	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	12×12	13	(9.6)	11.5	(7.5)	
				14×14	17	(16.4)	13	(9.6)	
				16×16	22	(27.4)	16	(14.5)	
J/JN	Horizontal sidewall or recessed sidewall	4.2	155	12×12	19	(20.5)	14	(11.1)	
				14×14	21	(25.0)	16	(14.5)	
				16×16	24	(32.7)	19	(20.5)	
	Horizontal sidewall or recessed sidewall	5.6	155	12×12	20	(12.8)	15	(7.2)	
				14×14	23	(16.9)	17	(9.2)	
				16×16	24	(18.4)	20	(12.8)	
JRES2/ JNRES2	Horizontal sidewall or recessed sidewall	5.6	155	12×12	18	(10.3)	15	(7.2)	
				16W×18L	30	(28.7)	22	(15.4)	
				16W×20L	35	(39.1)	26	(21.6)	
Grinnell Corporation - Exeter, New Hampshire (603-778-9200)									
83	Pendent	4.4	155	12×12	12	(7.4)	12	(7.4)	
				14×14	15	(11.6)	12	(7.4)	
				16×16	15	(11.6)	12	(7.4)	
				18×18	8	(16.7)	14	(10.1)	
				20×20	20	(20.7)	17	(14.9)	
			175	12×12	12	(7.4)	12	(7.4)	
				14×14	16	(13.2)	12	(7.4)	
F973	Recessed pendent	4.4	155	12×12	12	(7.4)	12	(7.4)	
				14×14	15	(11.6)	12	(7.4)	
				16×16	15	(11.6)	12	(7.4)	
				18×18	18	(16.7)	14	(10.1)	
				20×20	20	(20.7)	17	(14.9)	
F990	Flush pendent	4.2	160	12×12	12	(8.2)	11.5	(7.5)	
				14×14	14	(11.1)	11.5	(7.5)	
				16×16	16	(14.5)	12	(8.2)	
				18×18	18	(18.4)	14	(11.1)	
				20×20	22	(27.4)	18	(18.4)	
F992	Flush pendent	5.6	160	12×12	17	(9.2)	15	(7.2)	
				14×14	20	(12.8)	17	(9.2)	
				16×16	22	(15.4)	19	(11.5)	
				18×18	31	(30.6)	24	(18.4)	
978	Concealed pendent	4.2	155	12×12	16	(14.5)	12	(8.2)	
				14×14	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
				16×16	16	(14.5)	12	(8.2)	
				18×18	24	(32.7)	17	(16.4)	
				20×20	25	(35.4)	18	(18.4)	
FR-1	Horizontal sidewall	5.6	165	12×12	21	(14.1)	17	(9.2)	
				16W×20L	40	(51.0)	37	(43.7)	
		8.1	140&165	12×12	26	(10.3)	24	(8.8)	
				16W×20L	50	(38.1)	45	(30.9)	
F984	Horizontal sidewall	4.4	55	12×12	13	(8.7)	12	(7.4)	
				14×14	21	(22.8)	15	(11.6)	
				16×16	21	(22.8)	15	(11.6)	
F974	Recessed horizontal sidewall	4.4	155	12×12	13	(8.7)	12	(7.4)	
				14×14	21	(22.8)	15	(11.6)	
				16×16	22	(22.8)	15	(11.6)	
F993	Flush sidewall	5.6	160	12×12	22	(15.4)	15.5	(7.7)	
				14×14	30	(28.7)	21	(14.1)	
The Reliable Automatic Sprinkler Company—Mount Vernon, New York (800-431-1588)									
A	Pendent	4.15	165	14×14	18	(18.8)	13	(9.8)	
				16×16	25	(36.3)	18	(18.8)	
		5.5	165	12×12	21	(14.6)	15	(7.4)	
				14×14	24	(19.0)	17	(9.6)	
A	Recessed pendent	4.15	165	14×14	19	(21.0)	13.5	(10.6)	
				16×16	25	(36.3)	18	(18.8)	
		5.5	165	12×12	21	(14.6)	15	(7.4)	
				14×14	24	(19.0)	17	(9.6)	
A	Horizontal sidewall	4.15	165	12×12	21	(25.6)	15	(13.1)	
				14×14	25	(36.3)	18	(18.8)	
[illegible]FZ	Recessed sidewall	4.15	165	12×12	21	(25.6)	15	(13.1)	
				14×14	25	(36.3)	18	(18.8)	
[illegible]XRES	Flush pendent	4.1	165	14×14	18	(19.3)	13	(10.1)	
				16×16	24	(34.3)	17	(17.2)	
		5.4	165	14×14	26	(23.2)	18	(11.1)	
				16×16	30	(30.9)	21	(15.1)	
				18×18	32.5	(36.2)	23	(18.1)	
[illegible]	Flush pendent	4.1	165	12×12	12	(8.6)	11	(7.2)	
				14×14	13	(10.1)	11	(7.2)	
				16×16	14	(11.7)	12	(8.6)	
				18×18	16	(15.2)	14	(11.7)	
				20×20	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	14×14	24	(19.8)	17	(10.0)	
F1/RES	Pendent	5.6	155	14×14	20	(12.8)	15	(7.2)	
				16×16	20	(12.8)	20	(12.8)	
				18×18	28	(25.0)	22	(15.4)	
F1/RES	Horizontal sidewall	5.6	155	12×12	25	(19.9)	18	(10.3)	
				14×14	25	(19.9)	18	(10.3)	
				16×16	30	(28.7)	21	(14.1)	
				16×18	34	(36.9)	24	(18.4)	
				16×20	37	(43.7)	26	(21.6)	
F1/RES/2	Pendent and recessed pendent*	4.2	155	12×12	12	(8.2)	11	(7.0)	
				14×14	13	(9.6)	11	(7.0)	
				16×16	15	(12.8)	12	(8.2)	
				18×18	17	(16.4)	15	(12.8)	
				20×20	19	(20.5)	17	(16.4)	
F1/RES /F2	Recessed pendent	5.6	155	14×14	20	(12.8)	15	(7.2)	
				16×16	20	(12.8)	20	(12.8)	
F1/RES /F2	Recessed horizontal sidewall	5.6	155	12×12	25	(19.9)	18	(10.3)	
				14×14	25	(19.9)	18	(10.3)	
F1/RES/3	Pendent and recessed pendent **	3.9	155&175	12×12	10.5	(7.2)	10.5	(7.2)	
			155&175	14×14	12	(9.5)	10.5	(7.2)	9-ft minimum spacing between sprinklers
			155&175	16×16	12	(9.5)	10.5	(7.2)	
			155	18×18	15	(14.8)	10.5	(7.2)	
			155	20×20	18	(21.3)	18	(21.3)	
F1/RES/3	Concealed pendent	3.9	155	12×12	11	(8.0)	10.5	(7.2)	
				14×14	12	(9.5)	10.5	(7.2)	
				16×16	15	(14.8)	12	(9.5)	
				18×18	16	(16.8)	13	(11.1)	
				20×20	18	(21.3)	14	(12.9)	
F1/RES/3	Horizontal sidewall	3.9	155	12×12	13	(11.1)	11	(7.9)	
				14×14	14	(12.9)	12	(9.5)	
				16×16	17	(19.0)	14	(12.9)	
				16×18	18	(21.3)	16.5	(17.9)	
				16×20	25	(41.1)	19.5	(25.0)	
				18×18	22	(31.8)	21	(29.0)	
				12×12	13	(11.1)	13	(11.1)	Deflector 6–12 in. distance below ceiling
				14×14	17	(19.0)	16	(16.8)	
				16×16	20	(26.3)	17	(19.0)	

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	12×12	14	(12.9)	11	(7.9)	
				14×14	14	(12.9)	12	(9.5)	
				16×16	17	(19.0)	14	(12.9)	
				16×18	19	(23.7)	16.5	(17.9)	
				16×20	25	(41.1)	20	(26.3)	
				12×12	13	(11.1)	13	(11.1)	Deflector
				14×14	17	(19.0)	16	(16.8)	distance 6–12 in.
				16×16	20	(26.3)	17	(19.0)	below ceiling
F1/RES/3 /F2	Recessed horizontal sidewall	3.9	155	12×12	13	(11.1)	11	(7.9)	
				14×14	14	(12.9)	12	(9.5)	
				16×16	17	(19.0)	14	(12.9)	
				16×18	18	(21.3)	16.5	(17.9)	
				16×20	25	(41.1)	19.5	(25.0)	
				18×18	22	(31.8)	21	(29.0)	
				12×12	13	(11.1)	13	(11.1)	
				14×14	17	(19.0)	16	(16.8)	
				16×16	20	(26.3)	17	(19.0)	
			175	12×12	14	(12.9)	11	(7.9)	
				14×14	14	(12.9)	12	(9.5)	
				16×16	17	(19.0)	14	(12.9)	
				16×18	19	(23.7)	16.5	(17.9)	
				16×20	25	(41.1)	20	(26.3)	
				12×12	13	(11.1)	13	(11.1)	Deflector
				14×14	17	(19.0)	16	(16.8)	distance 6–12 in.
				16×16	20	(26.3)	17	(19.0)	below ceiling
F4/RES	Concealed	5.5	135	12×12	22	(16.0)	20	(13.2)	
				14×14	27	(24.1)	22.5	(16.7)	
				16×16	30	(29.8)	23	(17.5)	
Star Sprinkler Corporation—Milwaukee, Wisconsin (800-558-5236; in Wisconsin 414-570-5000)									
LD-2	Pendent or recessed	4.5	165	12×12	18	(16.0)	13	(8.3)	
				14×14	20	(19.8)	14	(9.7)	
				16×16	20	(19.8)	15	(11.1)	
[illegible]	Horizontal sidewall or recessed sidewall	4.5	165	12×12	17	(14.3)	12	(7.1)	
				14×14	21	(21.8)	15	(11.1)	
				16×16	25	(30.9)	18	(16.0)	
		4.8	165	12×12	17	(12.5)	13	(7.3)	
				16W×20L	38	(62.7)	27	(31.6)	
[illegible]	Pendent	4.3	155	12×12	16	(13.8)	11.5	(7.1)	
				14×14	16	(13.8)	11.5	(7.1)	
				16×16	17	(15.6)	13	(9.1)	
				18×18	19	(19.5)	14	(10.6)	
				20×20	20	(21.6)	17	(15.6)	

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	12×12	13	(9.1)	11.5	(7.1)		
				14×14	16	(13.8)	11.5	(7.1)		
				16×16	17	(15.6)	13	(9.1)		
				18×18	17	(15.6)	13	(9.1)		
				20×20	21	(23.9)	17	(15.6)		
SG-RES	Horizontal sidewall or recessed sidewall	4.3	155	12×12	15	(12.2)	12	(7.8)		H-2,
				12×12	17	(15.6)	12	(7.8)	6–12 in.	
				14×14	16	(13.8)	14	(10.6)		
				14×14	19	(19.5)	15	(12.2)	6–12 in.	
				16×16	18	(17.5)	14	(10.6)		
				16W×18L	21	(23.9)	19	(19.5)		
		5.8	155	12×12	18	(9.6)	15.5	(7.1)		H-3
				12×12	17	(8.6)	15.5	(7.1)	6–12 in.	
				16W×18L	28	(23.3)	23	(15.7)		
				16W×20L	29	(25.0)	26	(20.1)		A-1
Q	Concealed	4.3	155	12×12	13	(9.1)	11.5	(7.5)		
				14×14	17	(15.6)	13	(9.1)		
				16×16	20	(21.6)	15	(12.2)		M-4
Viking Corporation—Hastings, Michigan (616-945-9501)										
M	Pendent or recessed†	4.2	155&175	12×12	15	(12.8)	11.5	(7.0)		
				14×14	18	(18.4)	13	(9.6)		
				16×16	24	(32.7)	17	(16.4)		
M-2	Pendent or recessed†	5.5	155&175	12×12	23	(17.5)	16	(8.5)		M-4
				14×14	24	(19.0)	17	(9.6)		
M	Horizontal sidewall or recessed sidewall†	5.5	155&175	12×12	21	(14.6)	17	(9.6)		M-5
				14×14	25	(20.7)	18	(10.7)		
M	Horizontal sidewall	5.5	155	16×16	27	(24.1)	23	(17.5)		
				16×16	28	(25.9)	23	(17.5)	6–10 in.	
				16×18	28	(25.9)	23	(17.5)	4–10 in.	
				16×20	37	(45.2)	30	(29.7)		
				16×20	38	(47.7)	31	(31.7)	6–10 in.	
				18×16	29	(27.8)	25	(20.6)	4–10 in.	
				18×18	31	(31.7)	26	(22.3)	4–10 in.	
H	Flush pendent	4.2	165	12×12	14	(11.1)	11.5	(7.5)		
				16×16	17	(16.4)	12	(8.2)		
				18×18	20	(22.7)	14	(11.1)		
				20×20	29	(47.7)	21	(25.0)		

*Recessed p
**Recessed p
†F-1 escutche
††E-1 escutch

In summa
sprinklers, inst
ceiling are requ
limits:

1. The maximu
3 in. (76.2 m
tally away fr
2. The maximu
and half the
than 200°F (9.
not exceed 13

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	12×12	18	(10.7)	14.5	(7.0)	
				16×16	22	(16.0)	16	(8.5)	
				18×18	22	(16.0)	18	(10.7)	
				20×20	30	(29.8)	21	(14.6)	
H-2, H-3	Flush pendent	3.8	165	12×12	10	(7.0)	10	(7.0)	
				14×14	11	(8.4)	10	(7.0)	
				16×16	13	(11.7)	11	(8.4)	
				18×18	16	(17.7)	13	(11.7)	
				20×20	19	(25.0)	17	(20.0)	
H-3	Flush pendent	3.8	165	16×16	16	(17.7)	12	(10.0)	Listed for sloped ceilings to pitch of 6 in 12
A-1	Concealed	4.2	155	14×14	18	(18.4)	13	(9.6)	
				16×16	25	(35.4)	19	(20.5)	
		5.5	155	14×14	24	(19.0)	17	(9.6)	
M-4	Pendent or recessed pendent ††	4.3	155	12×12	11.5	(7.1)	11.5	(7.1)	
				14×14	13	(9.1)	11.5	(7.1)	
				16×16	13	(9.1)	11.5	(7.1)	
				18×18	16	(13.8)	13.5	(9.9)	
				20×20	19	(19.5)	17	(15.6)	
M-4	Horizontal sidewall or recessed sidewall	4.3	155	12×12	19	(19.5)	15	(12.2)	6–12 in. below sloped ceilings to pitch of 4 in 12
				14×14	22	(26.2)	17	(15.6)	
				16×16	22	(26.2)	17	(15.6)	
M-5	Horizontal sidewall or recessed sidewall	5.5	155	12×12	21	(14.6)	15	(7.4)	6–12 in. below sloped ceilings to pitch of 6 in 12
				14×14	24	(19.0)	21	(14.6)	
				16×16	24	(19.0)	21	(14.6)	

[illegible] Recessed pendent is model F1/RES/2/F2
[illegible] Recessed pendent is model F1/RES/3/F2
[illegible] E-1 escutcheon for recessed version
[illegible] E-1 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) [illegible] are required to control a fire for 10 min with the following [illegible]

1. [illegible] maximum gas or air temperature adjacent to the sprinkler—[illegible] (76.2 mm) below the ceiling and 8 in. (203 mm) horizon[illegible] away from the sprinkler—must not exceed 600°F (316°C).
2. [illegible] maximum temperature—5 ft, 3 in. (1.6 m) above the floor [illegible] the room length away from each wall—must be less [illegible] 200°F (93°C) during the entire test. This temperature must [illegible] 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) ±

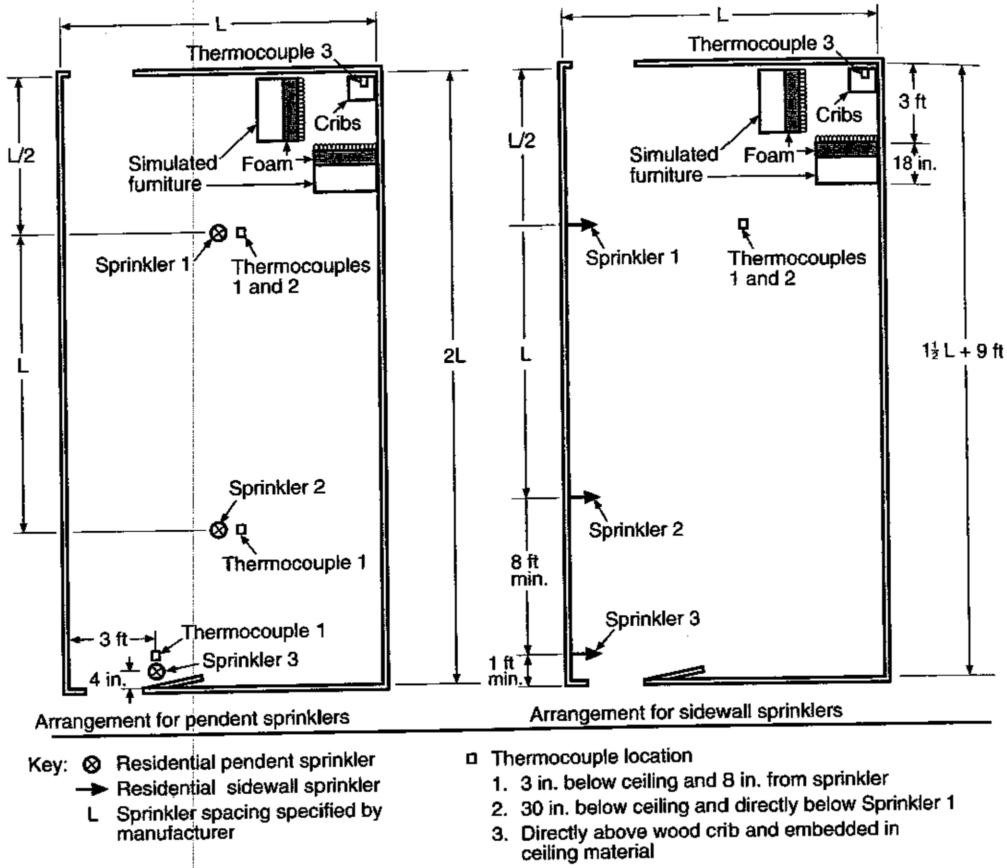


FIG. 6-13C. Fire test arrangements for UL 1626 for pendent sprinklers (left) and sidewall sprinklers (right). The simulated furniture consists of 3 in. (76 mm) thick uncovered urethane foam cushions 30 in. (762 mm) high by 30 in. (762 mm) wide. The foam has a density of 1.25 lb/sq ft (6.1 kg/m³) and 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.

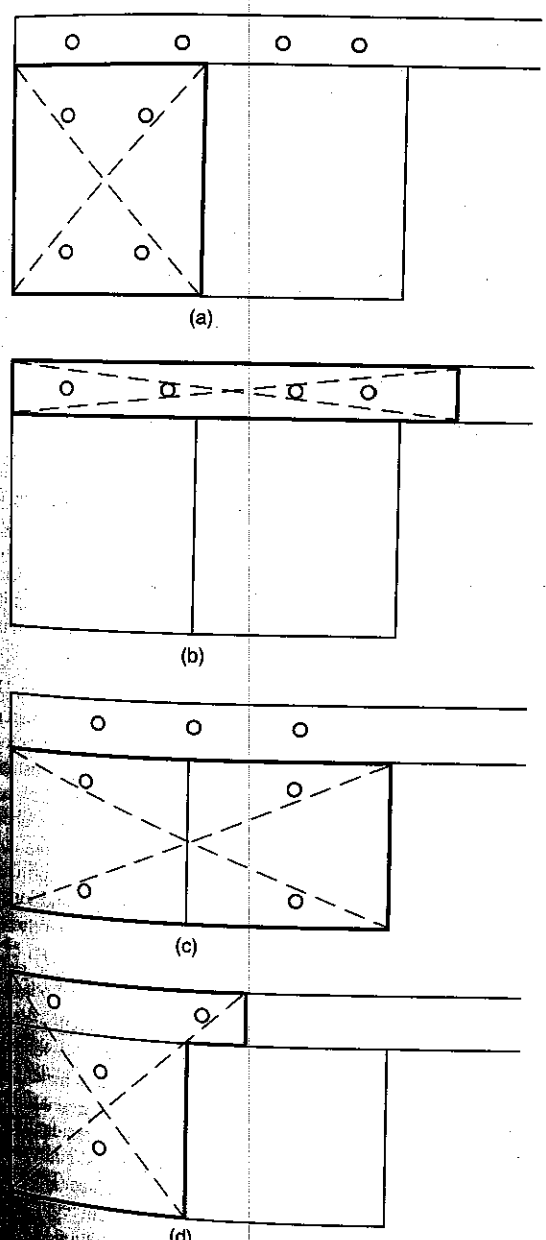
All residential sprinklers in the test must discharge water at the flow rate specified by the manufacturer for a 10-min period simulating one sprinkler operating and two sprinklers operating. The quantity of water collected on both the horizontal and vertical surfaces is measured and recorded.

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.

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.



[illegible] *Examples of design areas for dwelling units within [illegible] occupancies.*

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 sprinklers activated to control the fire than standard response sprinklers.

Current NFPA standards require the use of quick-response sprinklers throughout buildings of light-hazard occupancy. They are also permitted for use in ordinary hazard occupancies but have not yet been recognized for use in extra-hazard occupancies or for use as ceiling sprinklers in occupancies involving high-piled storage. Beginning with the 1995 edition of NFPA 231C, *Standard for Rack Storage of Materials*, quick-response sprinklers were permitted for use as in-rack sprinklers. Research is currently underway to determine if quick-response sprinklers can be used successfully in dry systems as well as wet systems.

Early Suppression Fast-Response Sprinklers

The early suppression fast-response (ESFR) sprinklers were first envisioned by the Factory Mutual Research Corporation.[21,22] Working with FMRC, the National Fire Protection Research Foundation funded full-scale testing to prove that fast-response sprinklers made suppression of a high-challenge fire feasible.[23]

Like its predecessor, the large-drop sprinkler, the ESFR sprinkler is intended to prevail against the strong fire plumes associated with fires in industrial and warehouse occupancies. However, its delivery of water to the burning fuel surfaces is accomplished by means of spray momentum rather than the gravitational effects of large droplets.

Operating at a minimum pressure of 50 psi (7.25 kPa) so as to produce a minimum flow per sprinkler of 100 gpm (380 L/min), the original ESFR sprinkler could protect challenges up to and including 25 ft (7.6 m) of plastics storage under a 30-ft (9.1-m) ceiling, without the use of in-rack sprinklers. Subsequent research and development has expanded the use of the ESFR sprinkler to protect commodities up to 35 ft (10.6 m) high under a 40-ft (12.2-m) ceiling without the use of in-rack sprinklers, and has also extended the application of the sprinkler for the protection of aerosols and other special hazards.

"Quick-Response, High-Challenge" Large-Drop Sprinklers

The "quick-response, high-challenge" sprinkler resulted from one manufacturer's insertion of a fast-response link into an approved large-drop sprinkler. The large-drop sprinkler concept, pioneered during the 1970s by FMRC, was based on the theory that larger spray droplets would be more capable of achieving gravitational penetration of a strong upward fire plume.

Product approval and installation standards were developed, and specialized system design criteria found its way into NFPA standards beginning with the 1985 edition of NFPA 13. The large-drop sprinkler has a characteristic large deflector and is an upright sprinkler with a 0.64-in. (16-mm) diameter orifice.

The concept of combining the penetration capabilities of the large-drop sprinkler with fast response was basic to the development of the ESFR sprinkler program. In tests of the large-drop sprinklers with and without fast-response links, the addition of fast response to the penetration abilities of the sprinkler provided superior protection against a high-challenge fire.

This particular sprinkler, however, later referred to as the "quick-response, high-challenge" sprinkler, fell by the wayside during the screening for the ESFR prototype sprinkler, due to its inability to provide sufficient water directly under the sprinkler. As an upright sprinkler, it could not handle the scenario in which a fire is started directly under a single sprinkler with 5 to 15 ft (1.5 to 4.6 m) of clearance below a 30-ft (9.1-m) ceiling. The sprinkler's water penetration capability was considered insufficient, due to an op[...] ing of the spray umbrella. The ESFR prototype eventually sele[...] was a pendent with a larger orifice.

Nevertheless, this sprinkler had already established its wort[h in] the eyes of many. A variation of that sprinkler was listed by UL [as a] "specific application" sprinkler, permitted to protect commodi[ties] up to 20 ft (6.1 m) high under a 25-ft (7.6-m) ceiling with ceili[ng] sprinklers only. Beginning with the 1994 edition of NFPA 13, [the] NFPA Committee on Automatic Sprinklers expanded the allowab[le] types of ESFR sprinklers to permit such sprinklers to fall within [one] category of ESFR sprinklers.

Quick-Response, Early Suppression Sprinklers

Quick-response, early suppression (QRES) sprinklers are considered a future area of product development within NFPA 13. With the QRES sprinkler, the same principles used in the development of the ESFR sprinkler could be applied to a smaller-orifice sprinkler, which could be used in a wide variety of business, mercantile, public assembly, educational, and other applications. The proposed NFPA definition of QRES sprinklers is "fast-response sprinklers that are listed for their ability to provide fire suppression of specific hazards." It is expected that the final development of such sprinklers is still several years away.

INCENTIVES TO MORE WIDESPREAD USE OF RESIDENTIAL SPRINKLERS

There are certain incentives that can stimulate interest in residential sprinklers. These incentives are discussed in the following paragraphs.

Reduction in Government Spending

Reduction in all forms of government spending, resulting from public pressure to reduce property taxes, is a prime factor in the future growth of the residential sprinkler concept. Many fire departments are forced to protect larger areas and more subdivisions with the same number of or even fewer people since financial restrictions hamper a fire department's ability to grow with the community. As a result, alternates to traditional fire-fighting techniques must be found. One of them is the use of residential sprinklers.

San Clemente, CA, was the first community in the United States to pass a residential sprinkler ordinance in 1980 as part of the fire department's master plan. This ordinance requires automatic sprinkler systems to be installed in all new residential construction. The prime motivation for the passage of this ordinance was San Clemente's cutbacks in government spending brought about by Proposition 13, the state's tax-capping measure. Many communities across the country face similar situations. Automatic sprinklers in residences may be the answer to fewer fire fighters and longer response times from the fire department.

Insurance Savings

Although the greatest benefit from widespread installation of residential sprinklers will be the lives saved and injuries prevented, lower property losses will be a secondary and substantial benefit. An ad-hoc committee from the insurance industry sponsored a number of the test fires in Los Angeles and concluded that residential sprinklers have the potential for reducing homeowners' claim payment expenses.[24] As a result, the Insurance Services Office (ISO) Personal Lines Committee recommended that a 15-percent reduction in the homeowner's policy premium be given for installation of an NFPA 13D residential sprinkler system. While this would not pay for the system over a short period of time, as is the case in many commer-

Beitel, J. J., "Quick-Response Sprinkler Tests, Group 2 Performance Tests," National Fire Protection Research Foundation, Quincy, MA, Dec. 1988.

Budnick, E. K., "Estimating Effectiveness of State-of-the-Art Detectors and Automatic Sprinklers on Life Safety in Residential Occupancies," NBSIR 84-2819, Jan. 1984, National Bureau of Standards, Washington, DC.

Carey, W. M., "Report of the Quick-Response Sprinkler Project, Group 2 Performance Tests," National Fire Protection Research Foundation, Quincy, MA, Mar. 1988.

Casaccio, E. K., "ESFR Installation Guidelines Set," *Building Standards*, Vol. 57, No. 2, Mar.–Apr. 1988, pp. 20–21.

Chopra, I. S., "Subject 1626: Residential Automatic Sprinklers," *Lab Data*, Underwriters Laboratories, Northbrook, IL, Vol. 15, No. 2, 1984.

Coleman, R. F., "Sprinklers in the Home—The Evolution of an Idea," *Fire International*, Vol. 11, No. 102, 1987, pp. 43, 46–47.

Cote, A. E., "Final Report on Field Test of a Retrofit Sprinkler System," National Fire Protection Research Foundation, Washington, DC, Feb. 1983.

Cote, A. E., "QRS: Do You Understand the Technology?" *Fire Journal*, Vol. 81, No. 1, Jan. 1987, p. 27.

Cote, A. E., "Behind the Technology of Quick-Response Sprinklers," *Consulting Specifying Engineer*, Vol. 1, No. 5, 1987, pp. 68–71.

Cote, A. E., "Use of Quick-Response Sprinklers in Residential Occupancies—What You Should Know," *Sprinkler Quarterly*, Spring 1985.

Cote, A. E., "Highlights of a Field Test of a Retrofit Sprinkler System," *Fire Journal*, Vol. 77, No. 3, May 1983.

Cote, A. E., "Update on Residential Sprinkler Protection," *Fire Journal*, Vol. 77, No. 6, Nov. 1983, p. 69.

Cote, A. E., "Field Test and Evaluation of Residential Sprinkler Systems, Part I," *Fire Technology*, Vol. 19, No. 4, Nov. 1983, pp. 221-232.

Cote, A. E., "Field Test and Evaluation of Residential Sprinkler Systems," Part II, *Fire Technology*, Vol. 20, No. 1, Feb. 1984, pp. 48-58.

Cote, A. E., "Field Test and Evaluation of Residential Sprinkler Systems, Part III," *Fire Technology*, Vol. 120, No. 2, May 1984, pp. 41–46.

"Development of an Experimental Prototype Low-Cost Electronic Sensor/Actuator for a Residential Automatic Sprinkler Head," Battelle Columbus Laboratories, Columbus, OH, 1982.

Evans, D. D., "Calculating Sprinkler Activation Time in Compartments," National Bureau of Standards, Washington, DC, 1984.

Fleming, R. P., "Applications/Limitations of QRS Technology," *Fire Safety Journal*, Vol. 14, Nos. 1&2, July 1988, pp. 75–88.

Fleming, R. P., "Quick-Response Sprinklers—A State-of-the-Art Technical Report," National Fire Protection Research Corporation, Quincy, MA, 1985.

Fleming, R. P., "The Special Listings," *Sprinkler Quarterly*, No. 52, Spring 1985.

Fleming, R. P., "Understanding the New Sprinklers," *Sprinkler Quarterly*, National Fire Sprinkler Association, No. 47, Fall 1983.

FM 2030, *Approval Standard for Residential Sprinklers*, Factory Mutual Research Corp., Norwood, MA, 1983.

Foehl, J. M., "In Quest of an Economical Automatic Fire Suppression System for Multi-Family Residential Complexes," *Fire Journal*, Vol. 70, No. 1, Jan. 1976, pp. 48-57.

Fuller, S. K., and Ruegg, R. T., "Economics of Fast-Response Residential Sprinkler Systems," *Fire Journal*, Vol. 79, No. 3, May–June 1985, pp. 18–22, 115.

Goodfellow, D. G., "Apparatus and Procedure for Measuring the Actual Delivered Density (ADD) of Sprinklers in Simulated Rack Storage Fires," Factory Mutual Research Foundation, Norwood, MA, Jan. 1985.

Hall, J. R., Jr., "The U.S. Experience with Sprinklers: Who Has Them? How Well Do They Work?" *NFPA Journal*, Nov./Dec. 1993, p. 44.

Hammerman, D. M., "Project Home—A Pilot Program for a Low-Cost Residential Sprinkler System," *Fire Journal*, Vol. 75, No. 2, Mar. 1981, pp. 66–69.

Harmathy, T. Z., "On the Economics of the Mandatory Sprinklering of Dwellings," *Fire Technology*, Vol. 24, No. 3, 1988, pp. 245–261.

Isner, M. S., "Successful Residential Sprinkler Activation," *Fire Command*, Vol. 53, No. 1, Jan. 1986, pp. 22–27.

Kung, H. C., Spaulding, R. D., and Hill, E. E., "Sprinkler Performance in Living-Room Fire Tests: Effect of Link Sensitivity and Room Size," Factory Mutual Research Corporation, July 1983.

Kung, H. C., "Low-Cost Residential Sprinkler Protection," *Fire Technology*, Vol. 12, No. 2, May 1976, pp. 85.

Miller, C., "Early Suppression-Fast Response Sprinklers: A New Level of Industrial Fire Protection," *National Engineer*, Vol. 93, No. 9, Sept. 1989, pp. 18–19.

Moore, D. A., "Field Test and Evaluation of Residential Sprinkler Systems," *Fire Journal*, Vol. 74, No. 6, Nov. 1980.

O'Neil, J. G., "Fast-Response Sprinklers in Patient Room Fires," *Fire Technology*, Vol. 17, No. 4, Nov. 1981.

O'Rourke, G. W., "Automatic Sprinkler Systems: What's New?" *Heating/Piping/AirCondition*, Vol. 55, No. 4, April 1983, pp. 37–41.

"Outline of Proposed Investigation for Residential Automatic Sprinklers for Fire Protection Service," Subject 1626, Underwriters Laboratories, Oct. 27, 1980.

Pepi, J. S., "Design Characteristics of Quick-Response Sprinklers," TR 86-3, 1986, Society of Fire Protection Engineers, Boston, MA.

Pepi, J. S., "Concept and Development of the Residential and Fast-Response Sprinklers," *Sprinkler Quarterly*, No. 52, Spring 1985.

Proceedings of the Fourth Conference on Low-Cost Residential Sprinkler Systems, Sept. 26–27, 1979, Federal Emergency Management Agency/U.S. Fire Administration, Aug. 1980.

Proceedings of the Third Conference on Low-Cost Residential Sprinklers, November 29–30, 1977, National Fire Prevention and Control Administration, June 1978.

Ruegg, R. T., and Fuller, S. K., "A Benefit-Cost Model of Residential Fire Sprinkler Systems," NBS Technical Note 1203, Nov. 1984, National Bureau of Standards, Washington, DC,.

Shaw, H., "Fast-Response Sprinklers—The Answer to the Toxicity Problem," *Sprinkler Quarterly*, No. 47, Fall 1983.

Teague, P. E., "Residential Sprinklers: An Idea Whose Time Has Almost Come," *Fire Journal*, Vol. 82, No. 5, Sept.–Oct., 1988, p. 46.

UL 1626, *Standard for Safety Residential Sprinklers for Fire-Protection Service*, Underwriters Laboratories Inc., Northbrook, IL, 1988.

Viniello, J. A., "Residential and Quick-Response Fire Sprinklers—You Need to Know the Difference!" *Sprinkler Quarterly*, No. 52, Spring 1985.

Walton, W. D., and Budnick, E. K., "Quick-Response Sprinklers in Office Configurations: Fire Test Results," NBSIR 88-3695, 1988, National Institute of Standards and Technology, Gaithersburg, MD.

Weber, R. A., and Smith, D. T., "Evaluation of Residential Sprinklers for Use in Military Housing," Technical Report, Sept. 1987, U.S. Army Corps of Engineers, Champaign, IL., p. 28.

"What Residential Sprinklers Can Do," *Fire Journal*, Vol. 82, No. 5, Sept.–Oct. 1985, p. 60.

Yoa, C., "Development of the ESFR Sprinkler System," *Fire Safety Journal*, Vol. 14, Nos. 1&2, July 1988, pp. 73–75.

Yao, C., "Early Fire Suppression with Fast-Response Sprinklers," *Sprinkler Quarterly*, Winter 1983–84, pp. 19–23.

cial installations, the continuing increases in the cost of insuring a single-family home make this a significant incentive nonetheless.

Real Estate Tax Reductions

In 1981, the State of Alaska enacted into law a significant piece of legislation that has a dramatic impact on the installation of sprinkler systems throughout that state. The law provides that 2 percent of the assessed value of any structure is exempt from taxation if the structure is protected with a fire protection system. The word "structure" is significant in the law, since it also applies to homes. In effect, if a home were assessed at $100,000 for purposes of taxation, the assessed value would be computed at $98,000, provided that it contained a fire protection system.

Buyers' Attitude

While one study indicated that 30 percent of the people interviewed perceived no need for a residential sprinkler system,[10] a 1980 survey published by the National Association of Home Builders on luxury features that buyers want in a new home showed that 14.3 percent indicated "fire suppression systems" as a choice. For potential buyers with incomes over $50,000, the percentage rose to over 20 percent.

Zoning

Greater land use may be possible with zoning changes that would permit fully sprinklered residences to be built on smaller parcels of land. The assumption is that the space between houses will not be as important from a fire protection standpoint if an entire street or neighborhood is fully sprinklered. One could argue, however, that if the sprinkler system fails, the resultant fire involving a number of residences could be much greater.

Sprinkler Legislation

In addition to the San Clemente ordinance, a number of other California communities have passed residential sprinkler legislation, including Orange County and Los Angeles County. By 1993, more than 4 million Californians lived in communities in which residential sprinklers were mandated in all new homes.[25]

Since 1982, Greenburgh, NY, and several surrounding communities have enacted sprinkler ordinances that require the installation of automatic sprinklers in virtually all new construction, including all new multiple- and one- and two-family dwellings. A similar law went into effect in Prince Georges County, MD, in 1992.

The State of Florida in 1983 passed a law requiring that all public lodging and time-share units three stories or more high in the [illegible] be sprinklered. It also required that all existing units be sprinklered by 1988.

In 1983, the City of Honolulu, HI, adopted legislation that required all new and existing high-rise hotels, which are those more than [illegible] ft (23 m) above grade, to be sprinklered.

In the late 1980s, additional jurisdictions, including Atlanta, the State of Connecticut, and the Commonwealth of Massachusetts, moved to retroactively require the installation of sprinkler systems in high-rise residential buildings.

In 1990, the federal government enacted the Hotel and Motel Fire Safety Act, which contains strong incentives for complete fire protection of hotels, since only hotels with satisfactory fire protection are eligible for federal employee travel.

The Federal Fire Safety Act of 1992 requires automatic sprinklers or an equivalent level of safety in all federally assisted housing four or more stories in height, as well as in office buildings leased for more than 25 federal employees.

Perhaps the most significant legislation promoting the use of sprinkler systems, however, is the 1990 Americans with Disabilities Act. In 1991, the U.S. Department of Justice published criteria that became mandatory for places of public accommodation and commercial facilities designed for first occupation after January 26, 1993. Alterations to existing buildings must also comply. A key feature of the criteria is the need for areas of refuge. Floors of buildings that do not have direct access to the exterior at grade must provide areas of rescue assistance, except those buildings that have a supervised automatic sprinkler system.

Construction Incentives

Many Authorities Having Jurisdiction have used building code modifications as an incentive to install sprinklers. Cobb County, GA, was one of the first communities to amend its Buildings and Construction Code include to such an approach for multifamily structures equipped with residential sprinkler systems.

While these construction alterations can be a major incentive to install residential sprinklers, the disaster potential must always be considered if a fire, for whatever reason, should overpower the sprinkler system. This is especially true if the system is designed with the minimal water supplies required by NFPA 13D.

The City of Dallas, TX, adopted a building code that requires all new buildings or those undergoing major renovation, having an area greater than 7,500 sq ft (697 m^2), to have automatic sprinklers. At the same time, this building code encourages the installation of sprinkler systems by allowing design options that may allow different levels of "passive" fire protection features in exchange for "active" automatic sprinkler alternatives.

Performance

Since 1983, Operation Life Safety, a project of the International Association of Fire Chiefs, has been collecting incident reports of residential sprinkler activations in systems installed in accordance with NFPA 13D or NFPA 13R as of July 31, 1995. A total of 551 incidents have been reported. Of this total, 35.2 percent of the fires that activated sprinklers were reported to have originated in kitchens, and 14.9 percent in bedrooms, with 20.3 percent listed as "not reported." Table 6-13B shows the reported activations by room of origin. Figure 6-13E shows activations of residential sprinklers by occupancy, as well as the number of sprinkler activations per fire.[26]

TABLE 6-13B. ***Room of Origin of Residential Sprinkler Activation***

Kitchen	35.2%
Bedroom	14.9%
Living room	7.8%
Closet	3.6%
Laundry room	2.7%
Basement	2.2%
Bathroom	1.5%
Storeroom	2.4%
Garage	4.4%
Others	5.1%
Not reported	20.3%

Note: Data as of July 31, 1995.

Code Requirements

Beginning with the 1991 edition, NFPA *101®*, *Life Safety Code®*, required the use of quick-response or residential sprinklers in new

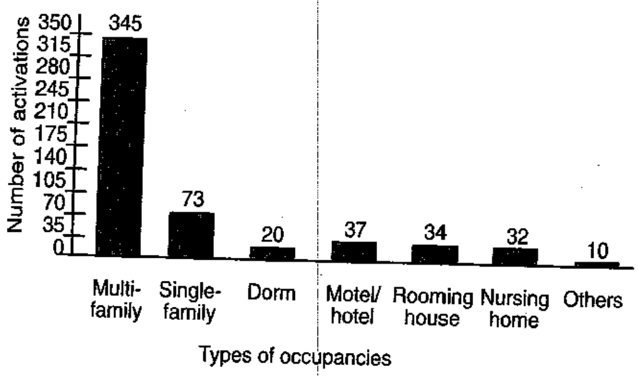


FIG. 6-13E. Residential sprinkler activations.

health care occupancies in smoke compartments containing patient sleeping rooms. This generally means all patient rooms and their adjacent corridors. Beginning with the 1994 edition, quick-response or residential sprinklers were also required in all new hotel and dormitory guest rooms and guest room suites.

Because of these and other incentives the use of residential and quick-response sprinklers nearly tripled in the United States between 1987 and 1994, even though the total number of sprinklers installed increased only slightly. There is growing recognition of the enhanced ability of fast-response sprinklers to protect life and property from fires.

BIBLIOGRAPHY

References Cited

1. Heskestad, G., and Smith, H., "Investigation of a New Sprinkler Sensitivity Approval Test: The Plunge Test," FMRC No. 22485, Dec., 1976, Factory Mutual Research Corp., Norwood, MA.
2. Heskestad, G., and Smith, H., "Plunge Test for Determination of Sprinkler Sensitivity," FMRC J.I.3A1E2.RR, 1980, Factory Mutual Research Corp., Norwood, MA.
3. Pickard, R. W., Hird, D., and Nash, P., "The Thermal Testing of Heat-Sensitive Fire Detectors," F.R. Note No. 247, Jan. 1957, Fire Research Station, Borehamwood, Herts, U.K.
4. Evans, D. D., and Madrzykowski, D., "Characterizing the Thermal Response of Fusible-Link Sprinklers," NBSIR 81–2329, Aug. 1981, National Bureau of Standards, Washington, DC.
5. Theobald, C. R., "FRS Ramp Test for Thermal Sensitivity of Sprinklers," *Journal of Fire Protection Engineering*, Vol. 1, No. 1, Jan.–Mar. 1989, p. 23.
6. Beever, P. F., "Estimating the Response of Thermal Detectors," *Journal of Fire Protection Engineering*, Vol. 2, No. 1, Jan.-Mar. 1990, p. 11.
7. Pepi, J. S., "Design Characteristics of Quick-Response Sprinklers," Grinnell Fire Protection Systems Co., Providence, RI, May 1986.
8. Heskestad, G., and Bill, R. G., "Conduction Heat-Loss Effects on Thermal Response of Automatic Sprinklers," FMRC J.I. OMOJ5.RU, Sept. 1987, Factory Mutual Research Corp., Norwood, MA.
9. Halpin, B. M., Dinan, J. J., and Deters, O. J., "Assessment of the Potential Impact of Fire Protection Systems on Actual Fire Incidents," Johns Hopkins University—Applied Physics Laboratory (JHU/APL), Laurel, MD, Oct. 1978.
10. Yurkonis, P., "Study to Establish the Existing Automatic Fire Suppression Technology for Use in Residential Occupancies," Rolf Jensen & Associates, Inc., Deerfield, IL., Dec. 1980.
11. Kung, H. C., Haines, D., and Green, R., Jr., "Development of Low-Cost Residential Sprinkler Protection," Factory Mutual Research Corp., Norwood, MA, Feb. 1978.
12. Henderson, N. C., Riegel, P. S., Patton, R. M., and Larcomb, D. B., "Investigation of Low-Cost Residential Sprinkler Systems," Battelle Columbus Laboratories, Columbus, OH, June 1978.
13. Clark, G., "Performance Specifications for Low-Cost Residential Sprinkler System," Factory Mutual Research Corp., Norwood, MA, Jan. 1978.
14. Kung, H. C., Spaulding, R. D., and Hill, E. E., Jr., "Sprinkler Performance in Residential Fire Tests," Factory Mutual Research Corp., Norwood, MA, Dec. 1980.
15. Cote, A. E., and Moore, D., "Field Test and Evaluation of Residential Sprinkler Systems," Los Angeles Test Series (A report for the NFPA 13D Subcommittee), National Fire Protection Association, Quincy, MA, Apr. 1980.
16. Moore, D., "Data Summary of the North Carolina Test Series of USFA Grant 79027 Field Test and Evaluation of Residential Sprinkler Systems, (a report for the NFPA 13D Subcommittee)," National Fire Protection Association, Quincy, MA, Sept. 1980.
17. Kung, H. C., Spaulding, R. D., Hill, E. E., Jr., and Symonds, A. P., "Technical Report, Field Evaluation of Residential Prototype Sprinkler Los Angeles Fire Test Program," Feb. 1982, Factory Mutual Research Corp., Norwood, MA.
18. Cote, A. E., "Final Report on Field Test and Evaluation of Residential Sprinkler Systems," July 1982, National Fire Protection Association, Quincy, MA.
19. Vincent, B. G., Stavrianidis, P., and Kung, H. C., "Large-Scale Fire Testing of Fast-Response Sprinklers and Conventional Response Sprinklers in a Fire-Control-Mode Scenario," FMRC J.I. OQ2P6.RA,070(A), June 1989, Factory Mutual Research Corp., sponsored by National Fire Sprinkler Association.
20. Budnick, E., and Fleming, R., "Developing an Early Suppression Design Procedure For Quick-Response Sprinklers," *Fire Journal*, Vol. 83, No. 6, Nov. 1989.
21. Yao, C., and Marsh, W., "Early Suppression—Fast Response: A Revolution in Sprinkler Technology," *Fire Journal*, Vol. 78, No. 1, Jan. 1984.
22. Yao, C., "ESFR Sprinkler System—A New Approach to High-Challenge Storage Protection," *Fire Journal*, Vol. 79, No. 2, Mar. 1985.
23. Chicarello, P., Troup, J., and Dean, R., "Large-Scale Fire Test Evaluation of Early Suppression Fast-Response (ESFR) Automatic Sprinklers," FMRC J.I. OM2R5.RR/OMJ7.RR, May 1986, Factory Mutual Research Corp., sponsored by National Fire Protection Research Foundation.
24. Jackson, R. J., "Report of 1980 Property Loss Comparison Fires," 1980, FEMA/USFA, Washington, DC.
25. Hart, S., "Executive Summary Report on the 1993 Fire Sprinkler Ordinance Survey," May 31, 1993, Fire Sprinkler Advisory Board of Southern California, Cerritos, CA.
26. "Residential Sprinkler Activations—Annual Report," *Operation Life Safety Newsletter*, International Association of Fire Chiefs, Vol. 10, No. 9–10, Sept.–Oct., 1995.

NFPA Codes, Standards, and Recommended Practices

Reference to the following NFPA codes, standards, and recommended practices will provide further information on fast-response sprinkler technology discussed in this chapter. (See the latest version of *The NFPA Catalog* for availability of current editions of the following documents.)

NFPA 13, *Standard for the Installation of Sprinkler Systems*
NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*
NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*
NFPA *101®*, *Life Safety Code®*
NFPA 231C, *Standard for Rack Storage of Materials*

Additional Reading

Anderson, N., "Sprinklers in the Home—A Life Saver," *Fire International*, Vol. 12, No. 108, Dec.–Jan. 1988, pp. 54–55.

Beitel, J. J., "Quick-Response Sprinkler Tests, Group 2 Performance Tests," National Fire Protection Research Foundation, Quincy, MA, Dec. 1988.

Benjamin/Clarke Associates, "Operation San Francisco Smoke/Sprinkler Test Technical Report," International Association of Fire Chiefs, Washington, DC, Apr. 1984.