# Chapter 6

# Residential Sprinkler Systems

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## Chapter Contents



## Key Terms

automatic sprinkler system, Home Fire Sprinkler Coalition, quick-response (QR) sprinkler, residential sprinkler system, response time index (RTI)

Automatic sprinkler systems have been successfully used to protect industrial and commercial buildings and their occupants for more than 100 years. Historically, the place that has offered the least amount of fire protection to occupants was and still is their own home. This situation was brought to light in 1973 by the Report of the National Commission on Fire Prevention and Control, *America Burning.*[1] At the time of the report, approximately 8000 people died in fires every year in the United States. Eight out of ten of those victims died in their homes.

In the more than 30 years since *America Burning* was published, the number of lives lost in fires in the United States has decreased to less than 4000 per year. Unfortunately, 8 out of 10 victims still die in home structure fires.[2] Although residential sprinkler installations are increasing, it is estimated that less than 3 percent of all residential dwellings in the United States have them installed.[3]

In response to the information from the *America Burning* report, the National Fire Protection Association's Technical Committee on Automatic Sprinklers assigned a subcommittee to develop a standard for residential sprinkler systems in 1973. NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes,* was adopted in May 1975, based on expert judgment and the best information available at that time.

Significant testing and development of residential sprinkler systems has continued since then, resulting in the evolution of NFPA 13D and the development of NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height.*

The purpose of a residential sprinkler system built to the standard is to "provide a sprinkler system that aids in detection and control of residential fires, and thus provides improved protection against injury, life loss, and property damage."[4] From a performance perspective, if the room of fire origin is sprinklered, a sprinkler system designed and installed in accordance with the residential sprinkler standards is expected to prevent flashover and improve the occupant's opportunity to escape or to be rescued.[4]

Residential sprinkler systems designed and installed in accordance with NFPA 13D or NFPA 13R have significantly different requirements than those for residential occupancies designed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.* NFPA 13D and NFPA 13R systems have been optimized for certain types of residential occupancy buildings in an effort to minimize the cost of the system while improving the degree of fire safety.

New developments in residential sprinkler system technology continue to be made in an effort to increase the ease of installation and reduce the cost of installation while maintaining the effectiveness and reliability of the system. Residential sprinkler systems have been required in dwellings in several communities for more than a decade. Information from these communities is providing compelling data concerning the effectiveness of residential sprinkler systems. These data, in addition to code requirements and other incentives, are increasing the numbers of sprinkler installations around the country.

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For related topics, see Section 3, Chapter 1, "An Overview of the Fire Problem and Fire Protection"; and Section 16, Chapter 8, "Water Mist Fire Suppression Systems."

## DEVELOPING A SPRINKLER SYSTEM IN RESPONSE TO THE HOME FIRE PROBLEM

The development of a residential sprinkler standard with the main focus on life safety required a multifaceted approach. Fire incident data had to be collected and analyzed to obtain an understanding of the nature of the residential fire safety problem. In addition, technical challenges had to be overcome to develop an effective, practical, and economically acceptable residential sprinkler system design.

The more common home fire hazards had to be characterized in terms of leading areas of origin. The rankings and percentages have changed little since then, and more recent data are shown in Table 16.6.1, which demonstrates the number of fire fatalities and injuries based on the area of origin. Over 50 percent of home fires, over 70 percent of home fire fatalities, and over 70 percent of home fire injuries are the result of

**TABLE 16.6.1** Structure Fires in Homes by Area of Origin, 1999–2002 Annual Averages

| *Area of Origin* | *Fires* | | *Civilian Deaths* | | *Civilian Injuries* | | *Direct Property Damage (in Millions of Dollars)* | |
|---|---|---|---|---|---|---|---|---|
| Kitchen or cooking area | 95,200 | (26%) | 460 | (16%) | 4620 | (30%) | 761 | (14%) |
| Bedroom | 44,800 | (12%) | 760 | (26%) | 3820 | (25%) | 928 | (17%) |
| Confined cooking fire | 29,800 | (8%) | 0 | (0%) | 470 | (3%) | 10 | (0%) |
| Common room, living room, family room, lounge, or den | 23,600 | (6%) | 870 | (29%) | 1900 | (12%) | 596 | (11%) |
| Laundry room or area | 15,800 | (4%) | 30 | (1%) | 390 | (3%) | 170 | (3%) |
| Exterior wall surface | 13,300 | (4%) | 10 | (0%) | 140 | (1%) | 168 | (3%) |
| Attic or ceiling/roof assembly or concealed space | 10,600 | (3%) | 10 | (0%) | 110 | (1%) | 290 | (5%) |
| Confined chimney fire | 10,600 | (3%) | 0 | (0%) | 10 | (0%) | 7 | (0%) |
| Garage or vehicle storage area | 9,900 | (3%) | 40 | (1%) | 340 | (2%) | 314 | (6%) |
| Heating equipment room | 9,600 | (3%) | 30 | (1%) | 270 | (2%) | 128 | (2%) |
| Chimney | 9,600 | (3%) | 10 | (0%) | 30 | (0%) | 57 | (1%) |
| Lavatory or bathroom | 9,400 | (3%) | 40 | (1%) | 350 | (2%) | 107 | (2%) |
| Crawl space or substructure space | 8,600 | (2%) | 50 | (2%) | 300 | (2%) | 202 | (4%) |
| Wall assembly or concealed space | 7,600 | (2%) | 30 | (1%) | 120 | (1%) | 146 | (3%) |
| Exterior balcony or open porch | 7,100 | (2%) | 30 | (1%) | 210 | (1%) | 180 | (3%) |
| Unclassified structural area | 5,100 | (1%) | 70 | (2%) | 150 | (1%) | 162 | (3%) |
| Unclassified | 4,800 | (1%) | 50 | (2%) | 140 | (1%) | 141 | (3%) |
| Closet | 4,400 | (1%) | 20 | (1%) | 180 | (1%) | 71 | (1%) |
| Unclassified function area | 4,200 | (1%) | 110 | (4%) | 300 | (2%) | 102 | (2%) |
| Ceiling/floor assembly or concealed space | 4,000 | (1%) | 30 | (1%) | 90 | (1%) | 107 | (2%) |
| Hallway, corridor, or mall | 3,100 | (1%) | 40 | (1%) | 160 | (1%) | 39 | (1%) |
| Confined fuel burner or boiler fire or malfunction | 2,900 | (1%) | 0 | (0%) | 10 | (0%) | 2 | (0%) |
| Exterior roof surface | 2,600 | (1%) | 0 | (0%) | 20 | (0%) | 61 | (1%) |
| Dining room, bar, or beverage area | 2,600 | (1%) | 40 | (1%) | 160 | (1%) | 59 | (1%) |
| Unclassified storage area | 2,600 | (1%) | 10 | (0%) | 80 | (1%) | 44 | (1%) |
| Storage of supplies or tools or dead storage | 2,500 | (1%) | 20 | (1%) | 100 | (1%) | 50 | (1%) |
| Multiple areas of origin | 2,100 | (1%) | 30 | (1%) | 60 | (0%) | 68 | (1%) |
| Trash or rubbish chute, area, or container | 2,000 | (1%) | 0 | (0%) | 30 | (0%) | 15 | (0%) |
| Other known means of egress | 5,700 | (2%) | 50 | (2%) | 220 | (1%) | 96 | (2%) |
| Other known outside area | 4,200 | (1%) | 10 | (0%) | 70 | (0%) | 64 | (1%) |
| Other known service or equipment area | 3,400 | (1%) | 0 | (0%) | 50 | (0%) | 64 | (1%) |
| Other known area | 6,600 | (2%) | 100 | (3%) | 350 | (2%) | 171 | (3%) |
| Contained trash or rubbish fire | 4,600 | (1%) | 0 | (0%) | 20 | (0%) | 1 | (0%) |
| Other confined or contained area | 200 | (0%) | 0 | (0%) | 0 | (0%) | 1 | (0%) |
| Total | 372,900 | (100%) | 2,960 | (100%) | 15,300 | (100%) | 5,383 | (100%) |

Source: Marty Ahrens, *U.S. Fires in Selected Occupancies: Homes,* National Fire Protection Association, Quincy, MA, Mar. 2006, Table 8.

fires starting in a living room, bedroom, or kitchen. The impact sprinklers would have in these locations was clear. Analysis of this data was used to determine those rooms of a residence in which sprinkler protection would have the most positive impact on life safety. Table 16.6.2 shows the first items ignited in home fires.[4] It shows that over one-fourth of all home fire deaths involved the initial ignition of furniture or bedding. Other data showed that these ignitions were most often caused by a smoldering heat source (e.g., cigarette) or a small open flame source (e.g., match or lighter). This information provided a sense of the types of fire hazards that residential sprinklers would have to mitigate.

Another aspect of the residential fire problem concerns those who typically die in residential fires. Figure 16.6.1 presents the number of fire deaths per million people of a given age range, and Figure 16.6.2 presents the relative risk of dying in a fire by age.[3] Both figures show the trends that children 4 years of age and under and adults 65 years of age and older are more likely to die in a residential fire than are other segments of the population. For adults 65 and older, the risk increases significantly with age. Because these high-risk groups may depend on assistance to exit the dwelling, anything less than automatic suppression may not be enough to save them.[5]

**TABLE 16.6.2** Structure Fires in Homes by Item First Ignited, 1999–2002 Annual Averages

| *Item First Ignited* | *Fires* | | *Civilian Deaths* | | *Civilian Injuries* | | *Direct Property Damage (in Millions of Dollars)* | |
|---|---|---|---|---|---|---|---|---|
| Cooking materials, including food | 59,600 | (16%) | 140 | (5%) | 3110 | (20%) | 296 | (6%) |
| Confined cooking fire | 29,800 | (8%) | 0 | (0%) | 470 | (3%) | 10 | (0%) |
| Structural member or framing | 29,300 | (8%) | 210 | (7%) | 610 | (4%) | 917 | (17%) |
| Electrical wire or cable insulation | 23,500 | (6%) | 90 | (3%) | 480 | (3%) | 297 | (6%) |
| Mattress or bedding | 18,000 | (5%) | 410 | (14%) | 2000 | (13%) | 358 | (7%) |
| Rubbish, trash, or waste | 17,400 | (5%) | 50 | (2%) | 360 | (2%) | 135 | (3%) |
| Unclassified | 16,700 | (4%) | 120 | (4%) | 550 | (4%) | 171 | (3%) |
| Exterior wall covering or finish | 14,900 | (4%) | 30 | (1%) | 190 | (1%) | 281 | (5%) |
| Interior wall covering, excluding drapes | 13,100 | (4%) | 140 | (5%) | 510 | (3%) | 321 | (6%) |
| Clothing | 13,000 | (3%) | 200 | (7%) | 780 | (5%) | 160 | (3%) |
| Confined chimney fire | 10,600 | (3%) | 0 | (0%) | 10 | (0%) | 7 | (0%) |
| Flammable or combustible liquid or gas, filter, or piping | 10,500 | (3%) | 170 | (6%) | 980 | (6%) | 244 | (5%) |
| Multiple items first ignited | 10,500 | (3%) | 190 | (6%) | 480 | (3%) | 350 | (6%) |
| Upholstered furniture or vehicle seat | 10,200 | (3%) | 560 | (19%) | 1130 | (7%) | 283 | (5%) |
| Floor covering, rug, carpet, or mat | 8,100 | (2%) | 110 | (4%) | 350 | (2%) | 159 | (3%) |
| Unclassified structural component or finish | 7,500 | (2%) | 60 | (2%) | 200 | (1%) | 245 | (5%) |
| Cabinetry, including built-in | 6,900 | (2%) | 40 | (1%) | 400 | (3%) | 136 | (3%) |
| Unclassified furniture or utensils | 6,000 | (2%) | 130 | (5%) | 530 | (3%) | 136 | (3%) |
| Insulation within structural area | 5,200 | (1%) | 10 | (0%) | 90 | (1%) | 71 | (1%) |
| Appliance housing or casing | 4,900 | (1%) | 20 | (1%) | 180 | (1%) | 50 | (1%) |
| Magazine, newspaper, or writing paper | 4,600 | (1%) | 60 | (2%) | 230 | (2%) | 71 | (1%) |
| Contained trash or rubbish fire | 4,600 | (1%) | 0 | (0%) | 20 | (0%) | 1 | (0%) |
| Box, carton, bag, basket, or barrel | 4,300 | (1%) | 30 | (1%) | 190 | (1%) | 64 | (1%) |
| Dust, fiber, lint, sawdust, or excelsior | 4,300 | (1%) | 0 | (0%) | 70 | (0%) | 26 | (0%) |
| Unclassified soft goods or wearing apparel | 3,900 | (1%) | 60 | (2%) | 200 | (1%) | 66 | (1%) |
| Exterior roof covering or finish | 3,700 | (1%) | 0 | (0%) | 40 | (0%) | 118 | (2%) |
| Curtains, blinds, drapes, or tapestry | 3,600 | (1%) | 20 | (1%) | 280 | (2%) | 57 | (1%) |
| Exterior trim, including doors | 3,400 | (1%) | 10 | (0%) | 40 | (0%) | 51 | (1%) |
| Linen other than bedding | 3,400 | (1%) | 20 | (1%) | 140 | (1%) | 33 | (1%) |
| Confined fuel burner or boiler fire or malfunction | 2,900 | (1%) | 0 | (0%) | 10 | (0%) | 2 | (0%) |
| Interior ceiling cover or finish | 2,500 | (1%) | 10 | (0%) | 60 | (0%) | 56 | (1%) |
| Light vegetation, including grass | 2,000 | (1%) | 0 | (0%) | 20 | (0%) | 25 | (0%) |
| Other known item | 13,800 | (4%) | 60 | (2%) | 570 | (4%) | 186 | (3%) |
| Other confined fire | 200 | (0%) | 0 | (0%) | 0 | (0%) | 1 | (0%) |
| Total | 372,900 | (100%) | 2,960 | (100%) | 15,300 | (100%) | 5,383 | (100%) |

Source: Marty Ahrens, *U.S. Fires in Selected Occupancies: Homes,* National Fire Protection Association, Quincy, MA, Mar. 2006, Table 9.

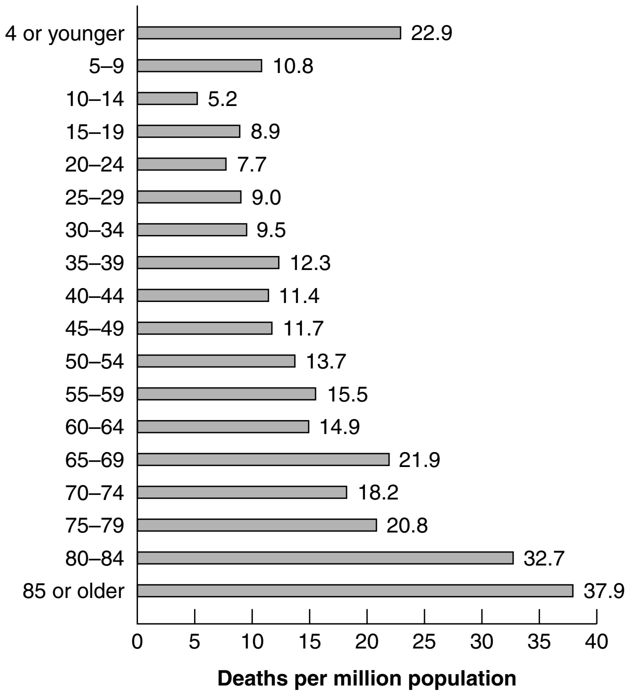


**FIGURE 16.6.1** Home Fire Deaths per Million Population by Age from 1992 to 2001. Note: Data have been adjusted to account for unknown or unspecified ages. (Source: Data from NFIRS, NFPA, and U.S. Census Bureau; in *Fire in the United States 1992–2001,* 13th ed., Federal Emergency Management Agency, United States Fire Administration, National Fire Data Center, FA-286, Oct. 2004, Figure 10, p. 42.)

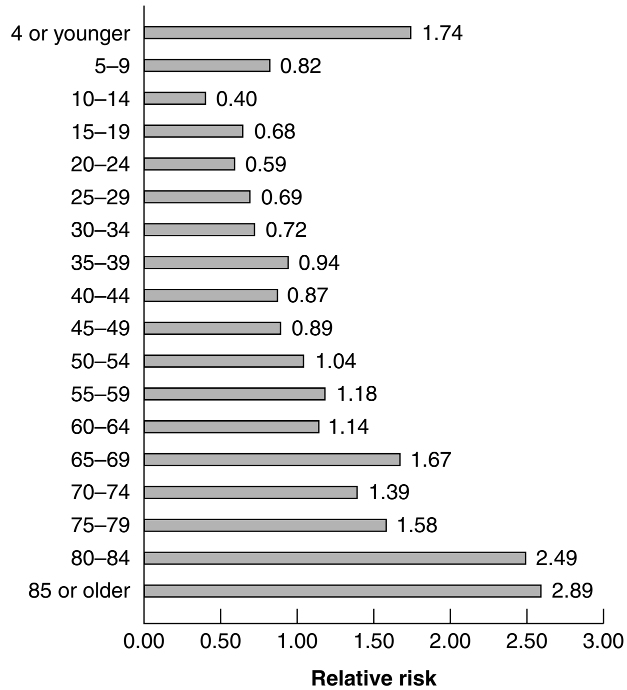


**FIGURE 16.6.2** Relative Risk of Home Fire Deaths by Age from 1992 to 2001. Notes: 1. *Relative risk* compares the per capita rate (Figure 16.6.1) for a particular group (here, an age group) to the overall per capita rate (i.e., the general population). For the general population, the relative risk is set at 7. 2. Data have been adjusted to account for unknown or unspecified ages. (Source: Data from NFIRS, NFPA, and U.S. Census Bureau; in *Fire in the United States 1992–2001,* 13th ed., Federal Emergency Management Agency, United States Fire Administration, National Fire Data Center, FA-286, Oct. 2004, Figure 11, p. 43.)

Once it was determined where sprinklers in a home would be most effective in reducing life loss, the technical challenge of developing an effective and economically viable sprinkler system was pursued. The sprinkler system would have to activate automatically while a fire was small and the smoke and heat conditions in the home were survivable. Once the system was activated, it needed to control the fire with a smaller amount of water relative to a commercial sprinkler system, because the water supply to a home is typically less than the water supply to a commercial or industrial occupancy.

## NFPA 13D, First Edition, 1975

Based on the review of then-available fire incident data, NFPA's Technical Committee on Sprinkler Systems developed a residential sprinkler installation standard that covered the principally occupied areas of a dwelling and that met the goals of (1) preventing flashover, (2) providing sufficient time for safe egress or rescue, and (3) economic viability.

As specified in the initial version of NFPA 13D, a residential sprinkler system would use a ½ in. (12.7 mm) orifice, standard response sprinkler, with a maximum of 256 $ft^2$ (23.8 $m^2$) coverage, and a spray density of 0.10 $gpm/ft^2$ (4.1 $L/m^2$), yielding a flow rate of 25 gpm (94.6 $L/m^2$). If the system was not supplied by an adequate public water source, a 250 gal (946.3 L) stored water supply was required to provide a 10-minute water supply.

To keep costs down, it was proposed that sprinklers be located only in principally occupied rooms. For this reason, sprinklers were not required in bathrooms 40 $ft^2$ (3.7 $m^2$) or less, small closets 24 $ft^2$ (2.2 $m^2$) or less, attics not used as a living space, porches, carports, garages, and foyers. Table 16.6.1 shows how much of the home fire problem begins in these excluded spaces, as well as in or on concealed spaces and exterior surfaces, which were also excluded. The system was to have a local waterflow alarm. NFPA 13D permitted sprinklers to be omitted from certain areas where the incidence of life loss from fires was statistically shown to be low. NFPA 13 had always required complete sprinkler protection in order to safeguard property adequately. In departing from the concept of complete coverage, the 1975 edition of NFPA 13D became the first "life safety" sprinkler standard. In spite of these concessions, actual installations based on this standard were rare, primarily due to cost.

The initial residential sprinkler system was crafted from existing technology and improvements were needed. Jensen noted that "much of this first edition was based on the collective experience of the committee members; little was based on real-world fire testing."[6]

## Residential Sprinkler Research

Beginning in 1976, the National Fire Prevention and Control Administration, renamed the United States Fire Administration (USFA) in 1979, supported a significant number of research programs on a wide variety of topics relating to residential sprinkler systems. The objective of the USFA research program was to assess the impact sprinklers would have on reducing deaths and injuries in residential fires.[7] The USFA—working in conjunction with the National Fire Protection Association, Factory Mutual Research Corporation, Underwriters Laboratories, and many other groups and individuals—evaluated the design, installation, practical usage, and water acceptance factors that would have an impact on achieving reliable and acceptable systems,[8] the minimum water discharge rates and automatic sprinkler flow required; and response sensitivity and design criteria.[9–11] Full-scale fire experiments were conducted to develop residential sprinkler designs and validate their effectiveness.[12–16] In addition, standards for testing and evaluating residential sprinklers were developed. These included tenability criteria for occupants that the sprinklers were required to maintain in the room of fire origin.

## Residential Sprinkler Sensitivity and Response

Although researchers at the Factory Mutual Fire Insurance Companies recognized the need for "faster" or more "sensitive" sprinklers in 1884, it was not until the late 1960s that a "quick-response sprinkler" subcommittee was formed within the NFPA 13 technical committee.

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

## Measuring Sprinkler Sensitivity

Much of the original work in the area of measuring sprinkler sensitivity was done at FM Global Research under the sponsorship of the United States Fire Administration (USFA) during the development of the residential sprinkler.[17,18] Important contributing research was also performed at the British Fire Research Station and the National Institute of Standards and Technology (NIST).[19–22]

The progress in this area climaxed late in 1990, when an 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 16.6.3.

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.[23] Figure 16.6.3 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 used for new types of sprinklers for which fast response is considered important. The special-response category is 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 category includes some of the extended coverage sprinklers.

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 will 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 significantly higher before the element operates. The

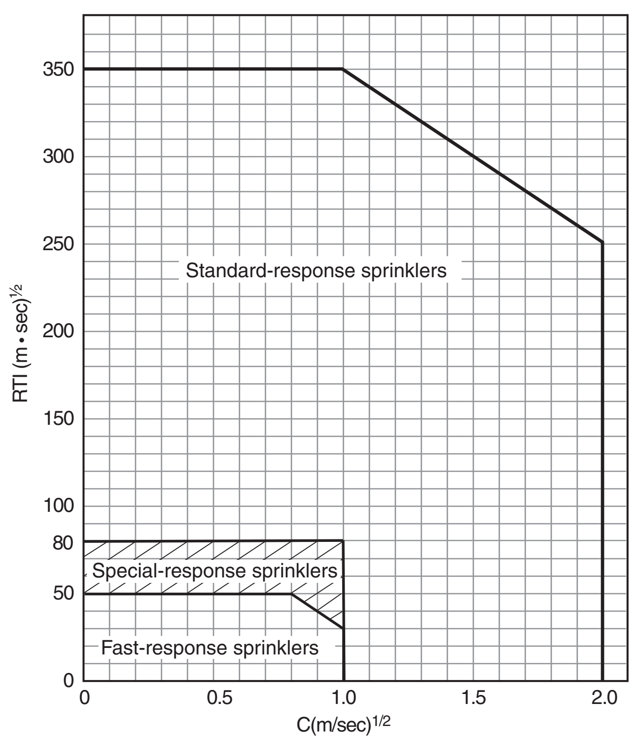


**FIGURE 16.6.3** International Sprinkler Sensitivity Ranges, Response Time Index (RTI) versus Conductivity (C). For SI units: 1 ft = 0.305 m.

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, FM Global Research researchers first applied the concept of the "tau" ($\tau$) factor and later developed the RTI.

## Sensitivity Testing

Both the $\tau$ factor and RTI refer to the performance of a sprinkler or its operating element in a standardized air oven tunnel or thermal sensitivity test. The test is known as a "plunge" test because a sprinkler at room temperature is plunged into a heated airstream of known constant temperature and velocity.[17,18] In the plunge test, the $\tau$ factor is the time at which the temperature of the sensing element of the sprinkler is approximately 63 percent of the difference between the hot gas temperature and the original temperature of the sensing element. 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. Figure 16.6.4 shows a time-temperature graph for several $\tau$ values ranging from 25 to 200.[24]

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 seconds was considered to indicate the needed level of sensitivity, but this was associated with the specific velocity of 5 ft/sec (1.52 m/sec) used in the FM Global Research 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.

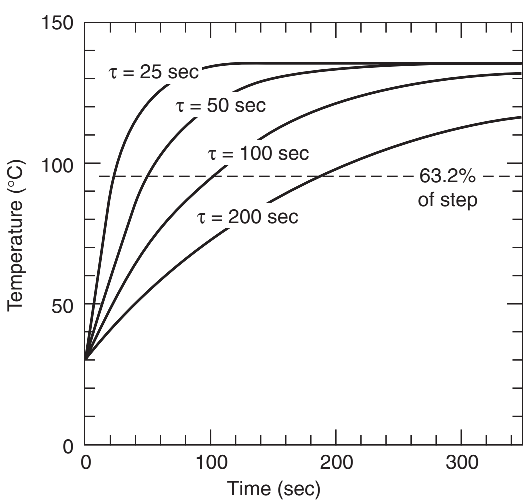


**FIGURE 16.6.4** Calculated Sprinkler $\tau$ Values Responding to a Step Change Temperature Increase of 105°C with a Gas Velocity of 8.33 ft/sec (2.54 m/sec)

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

The need to add a conductivity term to the model of sprinkler response was recognized in 1986.[23,25] The conductivity 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.

## Fast-Response Sprinkler

Full-scale tests conducted by FM Global Research 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.[12] Survivable conditions were established as follows:

- Maximum gas temperature at eye level of 200°F (93°C)
- Maximum ceiling surface temperature of 500°F (260°C)
- Maximum carbon monoxide concentration of 1500 ppm

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.[13–16] 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.

# RESIDENTIAL SPRINKLER STANDARDS

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 must be more uniform than that of standard spray sprinklers, which in large areas can rely on the overlapping patterns of several sprinklers to make up for voids. Additionally, residential sprinklers must protect sofas, drapes, and similar furnishings at the periphery of the room. In their discharge patterns, therefore, sprinklers must not only be capable of delivering water to the walls of their assigned areas but also be 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.

## Residential Sprinkler Testing

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, *Standard for Safety for Residential Sprinklers for Fire-Protection Service,* for residential sprinklers, and FM Global Research has published Approval Standard FM 2030, *Research Approval Standard for Residential Automatic Sprinklers,* 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. 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.

**UL 1626 Test Procedures.** The UL 1626 fuel package and test procedure was recently revised to (1) enhance the reproducibility of the tests and (2) increase the similarity between the fire performance of the fuel package used in the standard tests and that of the fuel packages used as part of the principal residential sprinkler research effort.[13,15,16] Details of the UL 1626 simulated furniture are shown in Figure 16.6.5. The arrangement of the fuel package within the test room is shown at the upper left of the figure.

The three fire test configurations are shown in Figures 16.6.6, 16.6.7, and 16.6.8. Figure 16.6.6 shows the configuration used to test pendent, upright, flush, recessed pendent, and concealed sprinklers. Figures 16.6.7 and 16.6.8 present the configurations used to test sidewall sprinklers; in the first case the sprinklers are located opposite the fuel package, and in the second case the sprinklers are located on the same wall as the fuel package.

The floor plan dimensions of the test room depend on the rated sprinkler coverage. As shown in Figure 16.6.5, the width of the test room, *w*, equals the rated sprinkler coverage width, and the length of the test room equals twice the rated coverage length, *L*. For the sidewall sprinkler configurations, the dimensions of the test room should be the rated sprinkler coverage length, *L*, by 1½ times the sprinkler coverage width, *w*, plus 9 ft (2.7 m). The ceiling height in all cases is a nominal 8 ft (2.4 m). The fuel package is composed of several different components: a wood crib, two simulated sofa ends covered with foam, two sheets of ¼ in. (6.3 mm) Douglas fir plywood, a pan with heptane, and two heptane-soaked cotton wicks. The wood crib is composed of 16 pieces of nominal 1½ in. by 1½ in. (38 mm by 38 mm) kiln-dried spruce or fir lumber 12 in. (300 mm) in length and 5.5 to 7.0 lb (2.5 to 3.2 kg) in weight. The pieces of lumber are to be arranged in four layers, with four pieces of wood per layer. The pieces of lumber should be evenly spaced along the length of the previous layer of wood members and stapled in place. The layers of lumber are to be placed at right angles to the layer below. The finished size of the wood crib is approximately 12 in. (305 mm) on a side and 6 in. (152 mm) high.

The simulated sofa ends are composed of a wood frame support and a ½-in. (12.7-mm) thick piece of plywood, 33 in. by 31 in. (840 mm by 790 mm) high in a vertical position. The plywood has 3-in. (76-mm) thick uncovered urethane foam cushions 30 in. (760 mm) high by 32 in. (810 mm) wide attached to the side facing the crib. The foam has a density of 1.70 to 1.90 lb/ft$^3$ (27.2 to 30.4 kg/m$^3$). The walls of the test room are covered with 4 ft by 8 ft by ¼ in. (1.2 m by 2.4 m by 6.4 mm) Douglas fir plywood paneling (flame spread rating 130 ± 30) attached to wood furring strips. The ceiling of the test room is 8 ft (2.4 m) high and covered with 2-ft by 4-ft by ½-in. (0.61-m by 1.20-m by 12.7-mm) thick acoustical panels (flame spread rating 25 or less) with a density of 13.5 ± 1.5 lb/ft$^3$ (216 ± 24 kg/m$^3$) attached to wood furring strips.

A 12-in. by 12-in. by 4-in. (305-mm by 305-mm by 104-mm) high steel pan containing 16 oz. (0.5 L) of water and 8 oz. (0.24 L) of heptane is positioned under the wood crib and ignited to start the test.

**Fire Control Requirements.** To meet the UL 1626 test criteria, residential sprinklers, installed in a fire test enclosure with an 8-ft (2.4-m) ceiling, are required to control a fire for 10 minutes with the following limits:

1. The maximum gas or air temperature adjacent to the sprinkler—3 in. (76.2 mm) below the ceiling and 8 in. (203 mm) horizontally away 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 half the room length away from each wall—must be less than 200°F (93°C) during the entire test. This temperature must not exceed 130°F (54°C) for more than a 2 minute period.
3. The maximum temperature—¼ 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 enclosure is kept at an initial ambient temperature of 80°F (27°C) ± 5°F (3°C) and it is ventilated through two door openings on opposite walls. The fire test is conducted for 10 minutes after the ignition of the wood crib. The waterflow to the first sprinkler that operates and the total waterflow when the second sprinkler operates are specified as part of the listing limitations for the sprinklers in the test. The total waterflow for two sprinklers must be a minimum of 1.2 times the minimum flow for a single sprinkler.

**Water Distribution Requirements.** The water distribution test requirements are based on the distribution pattern of the prototype residential sprinkler used in the Los Angeles test fires.[16] 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 minute 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.

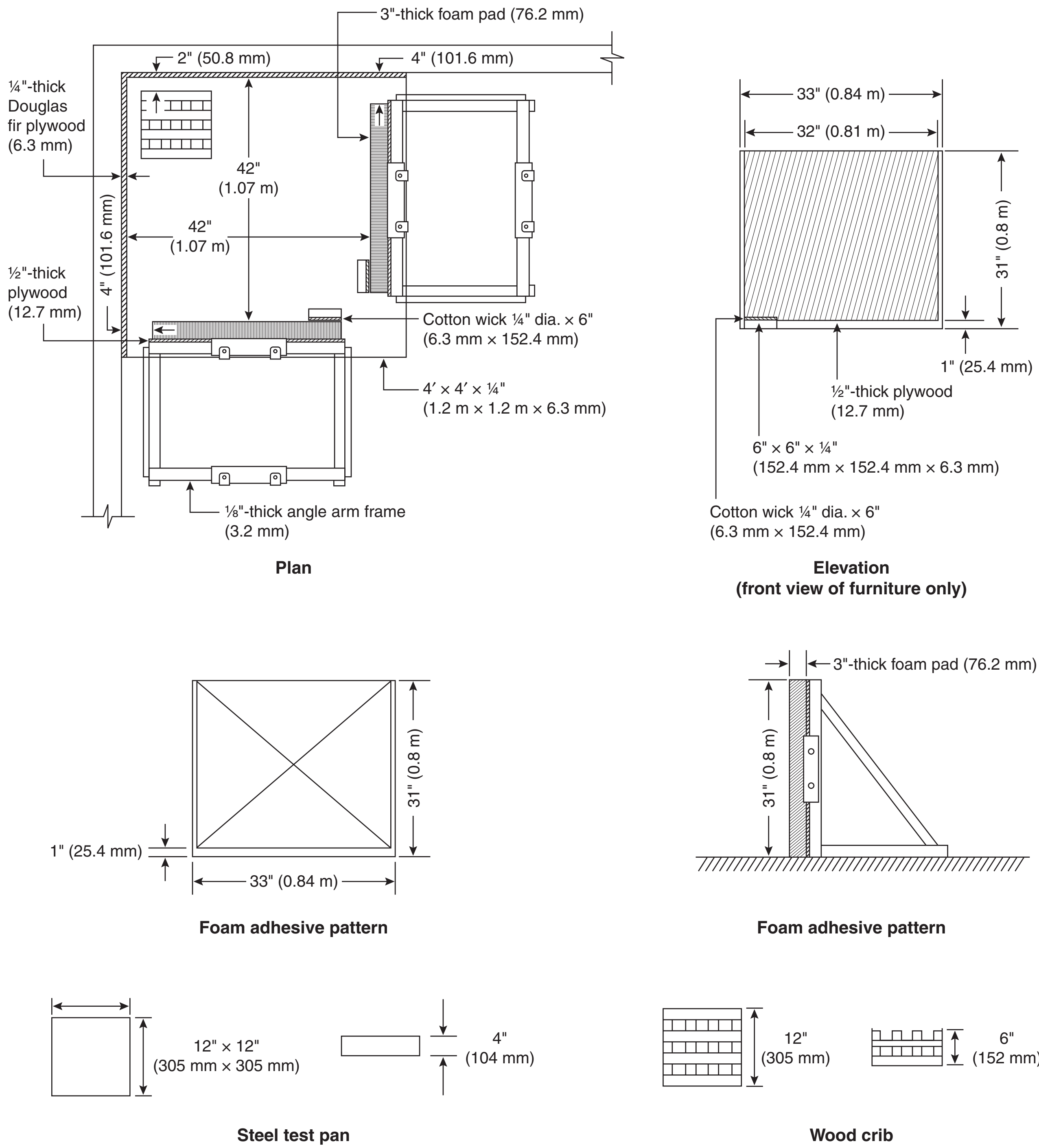


**FIGURE 16.6.5** Simulated Fuel Package from UL 1626

Sprinklers being tested are required to discharge a minimum of 0.02 gpm/ft$^2$ [(0.8[L/min]/m$^2$) over the entire horizontal design area, with the exception that no more than four 1-ft$^2$ (0.09-m$^2$) areas shall be allowed to be at least 0.015 gpm/ft$^2$ (0.6[L/min]/m$^2$). 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. Each wall surrounding the coverage area is required to be wetted with a minimum of 5 percent of the sprinkler flow.

Changes to the 2002 editions of NFPA 13D and NFPA 13R were coordinated with revised listings for residential sprinklers, calling for a minimum water spray density of 0.05 gpm/ft$^2$ (2.05 mm/min). Although the number of sprinklers to be included in the design area did not change for the 13D and 13R standards, the concept of the reduced multiple-sprinkler flow rate was abandoned. Residential sprinklers are now listed with a single minimum flow rate for a given area of coverage.

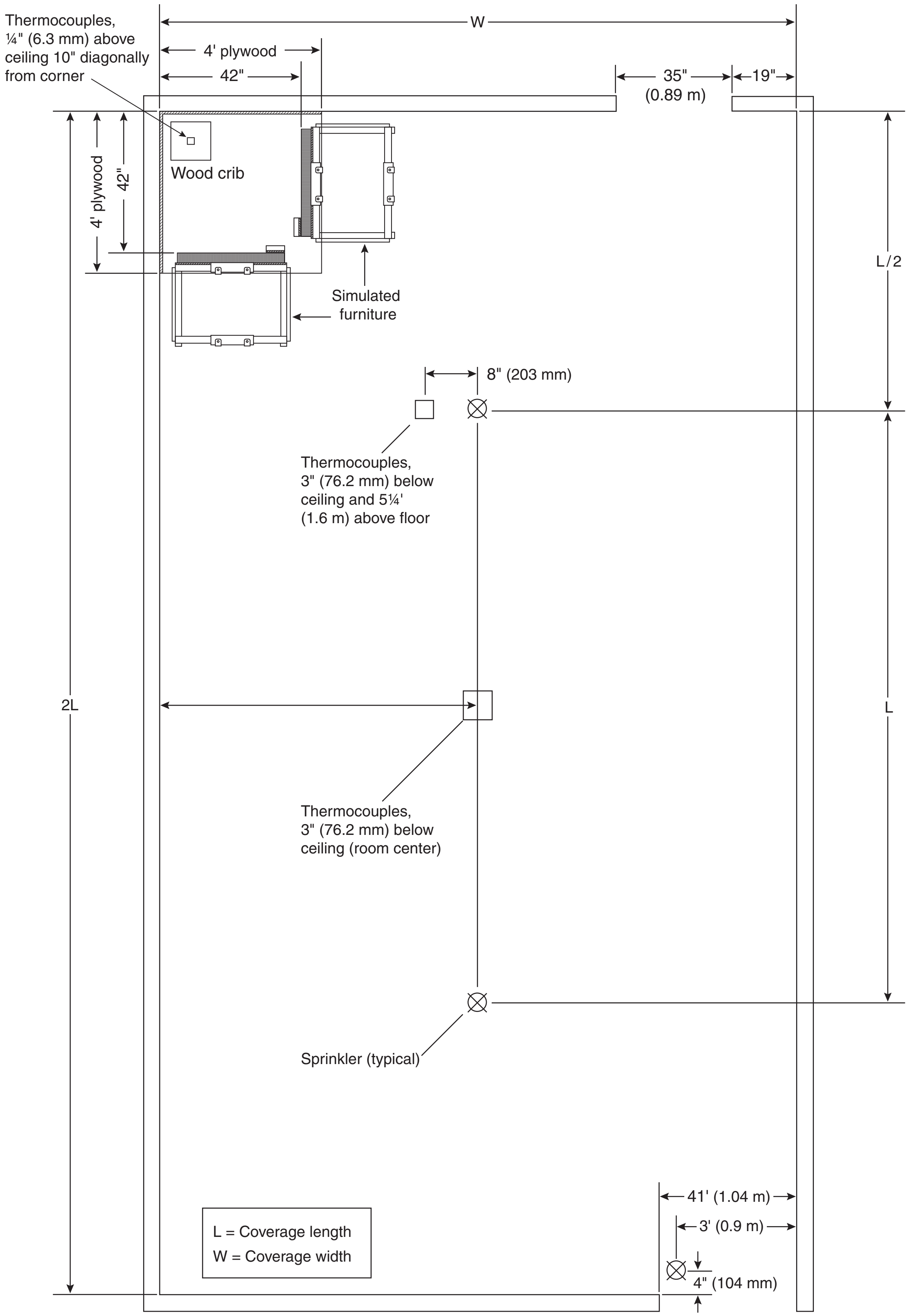


**FIGURE 16.6.6** Fire Test Arrangement from UL 1626 for Pendent, Upright, Flush, Recessed Pendent, and Concealed Sprinklers

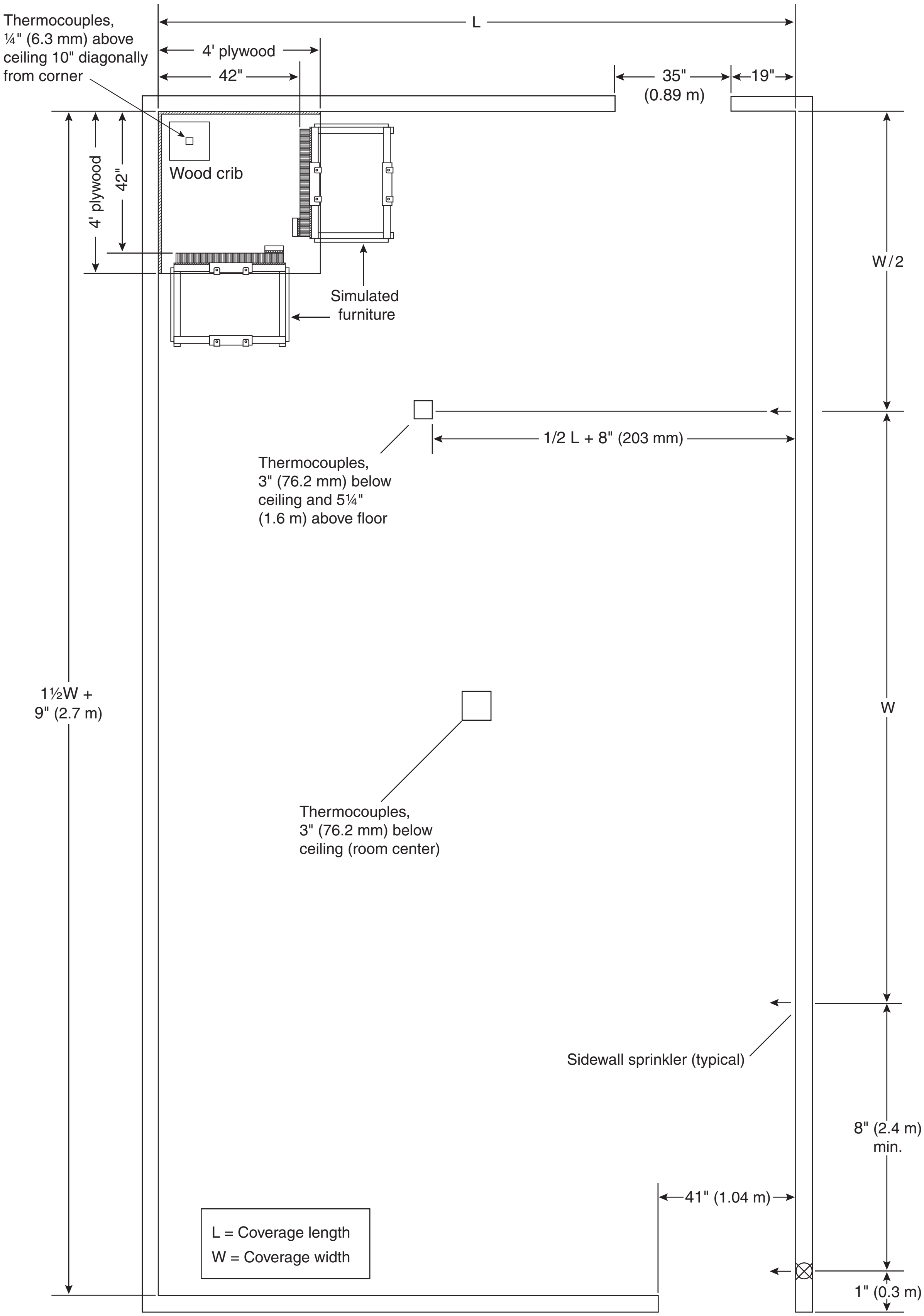


**FIGURE 16.6.7** Fire Test Arrangement from UL 1626 for Sidewall Sprinklers, Test Arrangement 1

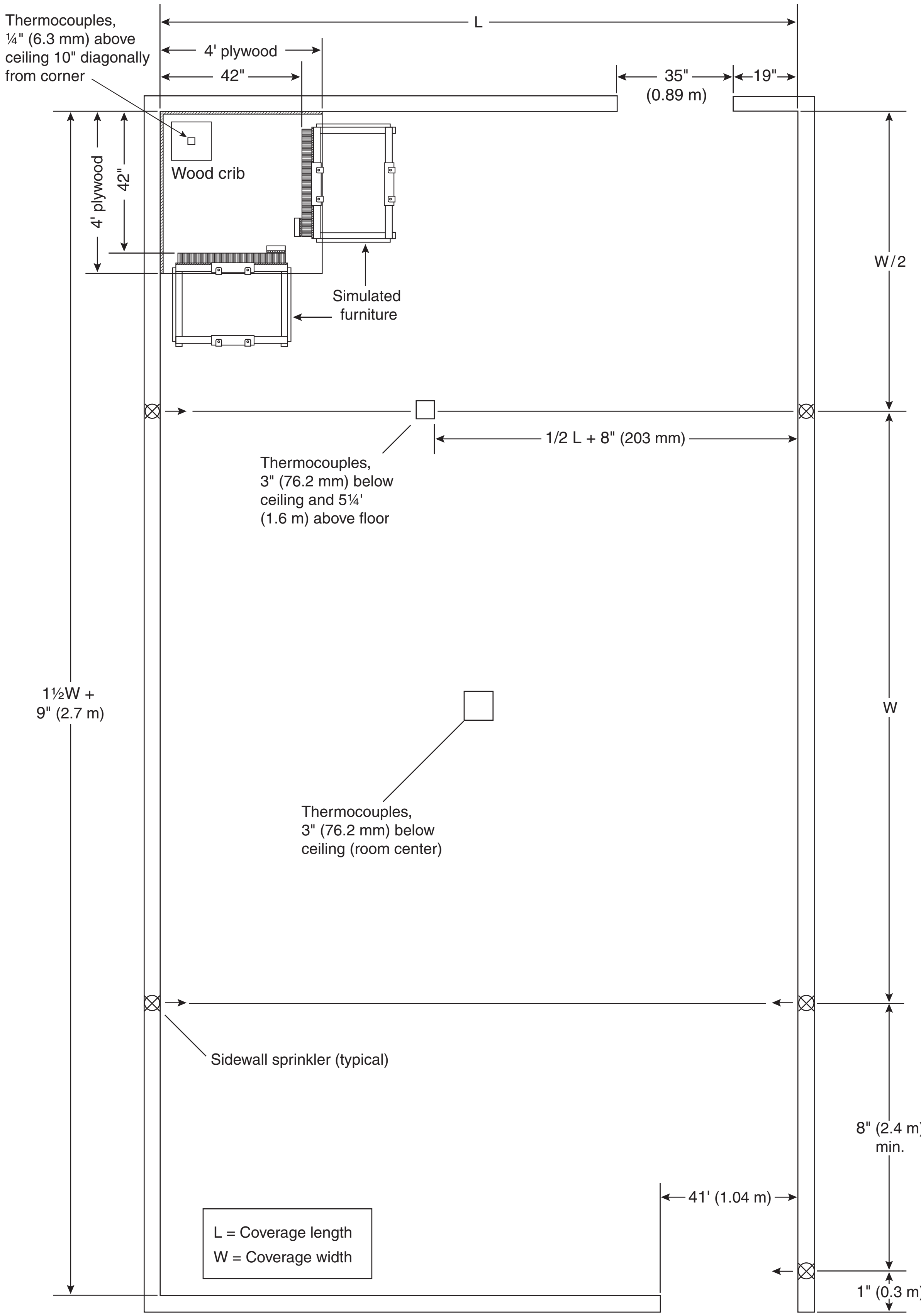


**FIGURE 16.6.8** Fire Test Arrangement from UL 1626 for Sidewall Sprinklers, Test Arrangement 2

Research on residential and domestic sprinklers outside the United States supports the trend toward a single minimum flow rate for residential sprinklers. Swedish research published in 2001 indicated that the minimum water application rate of 0.05 gpm/$ft^2$ (2.05 mm/min) was sufficient to achieve reasonably good protection when the fire test scenario involved upholstered furniture.[26]

## 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 16.6.9). 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.** Design criteria include the following:

- Only listed residential sprinklers to be used
- 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
- Maximum area protected by a single sprinkler of 144 $ft^2$ (13.4 $m^2$)
- Maximum distance between sprinklers of 12 ft (3.7 m)
- Minimum distance between sprinklers of 8 ft (2.4 m)
- 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:

- Sprinklers allowed to be omitted from bathrooms no larger than 55 $ft^2$ (5.1 $m^2$)

**FIGURE 16.6.9** Listed Residential Sprinkler

- 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 $ft^2$ (2.2 $m^2$), and the walls and ceiling are surfaced with noncombustible materials
- Sprinklers allowed to be omitted from open-attached porches, garages, carports, and similar structures
- Sprinklers allowed to be omitted from attics and crawl spaces that are not used or intended for living purposes or storage
- Sprinklers allowed to be omitted from entrance foyers that are not the only means of egress

In the 30 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 $ft^2$ (37.2 $m^2$) per sprinkler.

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 must consist of the four most hydraulically demanding sprinklers (Figure 16.6.10).

Other areas, such as attics, basements, or other types of occupancies outside of dwelling units but within the same structure, must 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 protection means, for example, that combustible concealed spaces generally require sprinklers. For NFPA 13 applications, 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.

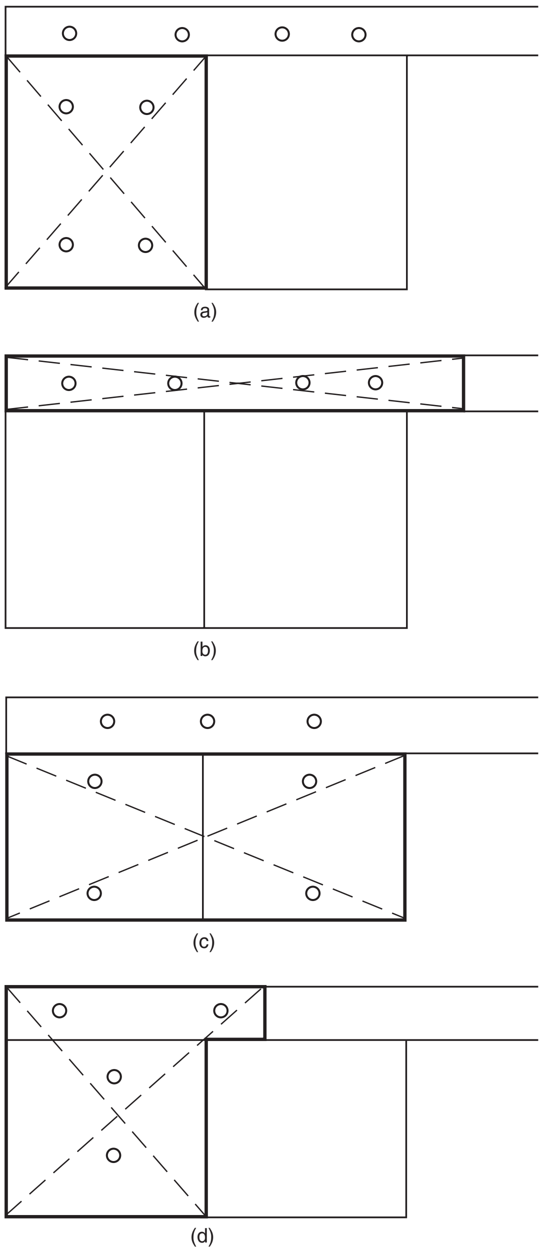


**FIGURE 16.6.10** Design Areas for Dwelling Units

**Ceiling Fan Criteria.** Technical improvements to NFPA 13D are made with each new edition. One of the major areas of improvement to the 2007 edition was the development of criteria for the obstructions created by ceiling fans. Figure 16.6.11 shows a sprinkler obstructed by a ceiling fan. Research conducted in 2005 by the National Fire Sprinkler Association at the facilities of the Viking Corporation involved distribution and fire testing using three different styles of ceiling fans, one with the housing tight against the ceiling, one with a suspended housing, and one with large blades obstructing half of the plan view of the area swept by the blades.[27] Based on the results of the tests, the Committee on Residential Sprinkler Systems agreed that the minimum distance from a sprinkler to the center of a ceiling fan should be 3 ft (0.9 m) for pendent sprinklers and 5 ft (1.5 m) for sidewall sprinklers.

**FIGURE 16.6.11** Residential Sprinkler Obstructed by Ceiling Fan

## Development of NFPA 13R

Like NFPA 13D, NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height,* is oriented toward economical life safety protection from fire. Sprinklers can be omitted from building areas that have been found to have a low incidence of fatal fires, 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, 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.

# NEW TECHNOLOGY IN RESIDENTIAL SPRINKLER SYSTEMS

## Multipurpose Piping Systems

Although NFPA 13D has had the option for a combined or multipurpose piping system for many years, in 1999 the committee further encouraged the use of this option by allowing nonlisted pipe to be connected to the sprinkler system for the purpose of supplying plumbing fixtures and by specifying a working pressure requirement of not less than 130 psi (8.9 bar) at not less than 120°F (49°C). The combined system may be a means to integrate the sprinkler system into new homes as a standard feature instead of as an option.

The multipurpose system uses the cold water piping to serve as a supply for both the domestic fixtures, such as sinks and showers, and the fire sprinklers. Given the potential for a reduced amount of pipe and fittings, there is a potential for reduced system cost. Supplying the sprinklers from the domestic water system can provide increased system reliability because any impairment to the water supply would be more quickly recognized. In addition, a combined system eliminates the need for backflow prevention devices. This setup also helps to reduce the cost of the system and eliminates any water pressure losses that would be incurred by a backflow prevention device.

New piping materials composed of cross-linked polyethylene have recently been listed by UL for use in residential sprinkler systems.[28] This piping is similar to piping already used in domestic plumbing systems and is therefore easily used in combined systems.

### Residential Water Mist System

Residential fire suppression/control systems are also being developed under NFPA 750, *Standard on Water Mist Fire Protection Systems.* A water mist system uses very fine water sprays to control or extinguish fires by cooling of the flame and fire plume, oxygen displacement by water vapor, and radiant heat attenuation.[29]

Water mist systems typically use smaller amounts of water at significantly higher pressures when compared to a NFPA 13D residential sprinkler system. The spacing of water mist nozzles tends to be smaller than the spacing of residential sprinklers; hence more nozzles are needed to provide fire protection for a given area. Studies sponsored by the U.S. Fire Administration showed that in some cases water mist systems could provide equivalent levels of fire safety relative to a residential sprinkler system, however, at a significantly higher cost.[30,31] (For further information, see Section 16, Chapter 8, "Water Mist Fire Suppression Systems.")

## RESIDENTIAL SPRINKLER EXPERIENCE

### Scottsdale, Arizona

Due to the proven effectiveness of residential fire sprinklers, communities in 25 states require sprinklers in one- and two-family homes.[32] One of these communities, Scottsdale, Arizona, has conducted a detailed 10 year study on the impact of residential fire sprinklers on its community. In June 1985, the city of Scottsdale passed a comprehensive fire sprinkler ordinance that required all new multifamily and commercial structures to be protected by sprinklers, beginning in July 1985, and all new single-family homes, beginning in January 1986.[33]

The results of the study held some surprises. The average installation cost of a residential sprinkler system decreased significantly over the 10 year period. In 1986, the average installation cost was $\$1.14/ft^2$. By January 1996, the average cost was $\$0.59/ft^2$, a decrease of approximately 45 percent.[33]

Surveys of the home insurance companies in the Scottsdale area yielded an average discount of 10 percent for homes with residential sprinkler systems installed.[33] The Scottsdale study also examined the issue of water usage during a fire incident. The first 38 sprinklered fire incidents, a combination of fires in commercial, multifamily, and single-family units, were investigated. Based on the incident time lines, the waterflow times for the sprinkler systems were determined and the total waterflow was calculated. The average amount of water used per fire was 357 gal. Assuming that manual suppression could be accomplished in the same amount of time as the sprinkler flow time, the average amount of water used per fire incident by the fire department would amount to more than 4800 gal.[33]

In 1996, a review of the 109 fires that had occurred in sprinklered buildings in Scottsdale included 44 residential fires. In over 90 percent of the incidents, the fire was controlled with one or two sprinklers activated. The average amount of water flowed by the sprinklers was 299 gal per fire versus an estimated manual suppression usage of approximately 6000 gal per fire.

In 2001, the Scottsdale data were updated to include 15 years of experience with the Scottsdale sprinkler ordinance.[34] The updated data show the trends continuing, with the average fire loss in a sprinklered home to be \$2166, as compared to \$45,019 in a home without sprinklers. Efforts are under way to update the study to include 20 years of experience.

### Prince Georges County. Maryland

Prince Georges County, Maryland, enacted an ordinance in 1990 by which all new residential structures were required to be sprinklered beginning in January 1, 1992. A report of the first 8 years' experience was compiled in January 2001.[35] The total fire loss in 117 fire incidents in which sprinklers were involved was reported as \$401,220, as compared to an estimated \$38,230,000 had sprinklers not been present. Although 7 minor injuries were reported in these fires, 154 lives were reported as having been saved by the sprinkler systems.

Among the 121 reported fire incidents, more than one residential sprinkler operated in only 11. In 7 of those, more than two sprinklers operated. An investigation revealed that those 7 involved some extenuating circumstance, such as the use of an accelerant or human intervention, which contributed to the operation of the additional sprinklers. During this same time period, there were only 4 incidents of sprinkler discharge for reasons other than a fire.

### Residential Fire Sprinkler Activation Project

Starting in July 2003, the National Association of State Fire Marshals established a residential fire sprinkler activation reporting system on its website (http://www.firemarshals.org). The objective of the project is to collect current and detailed data pertaining to residential sprinkler activations.[36] There are 18 data fields, which include the type of occupancy, number of stories, story of origin, room of origin, area of the room of fire origin, number of sprinklers installed in room of origin, number of sprinklers activated, type of sprinkler activated, and reason for activation. Other inputs regard smoke detectors, and estimates for lives saved, dollar loss due to fire, and dollars saved by sprinkler activation.

During the first two years of the project, 448 incidents were submitted by 167 different fire departments. Over 60 percent of the sprinkler activations documented occurred in apartment buildings. The sprinkler activations in kitchens accounted for 40 percent of the recorded incidents. Of the incidents where the number of sprinklers was reported, approximately 83 percent of the activations involved only a single sprinkler. This project is supported by a grant from the U.S. Fire Administration.

## INCENTIVES FOR MORE WIDESPREAD USE OF RESIDENTIAL SPRINKLERS

Certain incentives 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 because financial restrictions hamper a fire department's ability to grow with the community. As a result, alternatives to traditional firefighting techniques must be found. One of them is the use of residential sprinklers. San Clemente, California, 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 test fires in Los Angeles during the early 1980s and concluded that residential sprinklers have the potential for reducing homeowners' claim payment expenses.[37] 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. Although this would not pay for the system over a short period of time, as is the case in many commercial installations, the continuing increases in the cost of insuring a single-family home make this a significant incentive nonetheless. NFPA analysis indicates that home sprinklers, like other sprinkler installations, reduce average fire loss per home fire by a much larger one-half to two-thirds.[38]

### 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, because 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.

It actually may be considered an incentive simply to add the value of a fire sprinkler system to the assessed value of a property. In a national poll commissioned by the Home Fire Sprinkler Coalition in December 2000, it was found that 69 percent of homeowners believe having a fire sprinkler system increases the value of a home, and 38 percent said they would be more likely to purchase a new home with sprinklers than one without.[39]

### 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. The more complex analysis required to assess the net effects of full sprinklering of a neighborhood with smaller lot sizes has yet to be conducted.

### 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. In 1993, more than 4 million Californians lived in communities in which residential sprinklers were mandated in all new homes.[40] Since 1982, Greenburgh, New York, and several surrounding communities have enacted sprinkler ordinances that require the installation of automatic sprinklers in virtually all new construction, including all new multiple-, one-, and two-family dwellings. A similar law went into effect in Prince George's County, Maryland, in 1992.

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

In 1983, the city of Honolulu, Hawaii, adopted legislation that required all new and existing high-rise hotels, which are those more than 75 ft (23 m) above grade, to be sprinklered.

In the late 1980s, additional jurisdictions, including Atlanta, Georgia, the state of Connecticut, and the commonwealth of Massachusetts, acted to require retroactively 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 sprinkler protection of hotels, because only hotels with satisfactory levels of fire protection are eligible for federal employee travel.

The Federal Fire Safety Act of 1992 requires automatic sprinkler systems or an equivalent level of safety in all federally assisted housing four or more stories in height, as well as in office buildings owned or 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.

Adoption of fire sprinkler ordinances continues in various areas. One of the most active areas in the early twenty-first century are the suburbs of Chicago. Between 2000 and 2005 the number of communities that had adopted an NFPA 13D ordinance grew from 3 to 35, with 14 of those adopted in 2005.[41] Lessons learned from the experience of communities that have adopted ordinances is being used to provide guidance to others that might wish to pursue their own ordinances.[42]

## Construction

Many authorities having jurisdiction have used building code modifications as an incentive to install sprinklers. Cobb County, Georgia, was one of the first communities to amend its Buildings and Construction Code to include such an approach for multifamily structures equipped with residential sprinkler systems. Although 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 possibility of disaster is especially true if the system is designed with the minimal water supplies required by NFPA 13D.

The city of Dallas, Texas, adopted a building code that requires all new buildings or those undergoing major renovation, having an area greater than 7500 $ft^2$ (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.

## Code Requirements

Beginning with the 1991 edition, NFPA *101*®, *Life Safety Code*®, required the use of quick-response or residential sprinklers in new health care occupancies in smoke compartments that contain 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. Beginning in 1996, NFPA 13 requires quick-response or residential sprinklers in all new light hazard construction.

Because of these and other incentives, the use of new technology, such as residential and quick-response sprinklers, increased by a factor of 15 in the United States between 1990 and 2000, while the total number of sprinklers installed nearly doubled.[43] There is growing recognition of the enhanced ability of residential and other types of fast-response sprinklers to protect life and property from fires.

A major milestone for residential sprinkler came in August 2005 with the issuance of the 2006 editions of NFPA *101*® and *NFPA 5000*®, *Building Construction and Safety Code*®, both of which require fire sprinkler systems in all new one- and two-family dwellings.

## SUMMARY

Residential sprinkler systems are an effective means of controlling fire in the home, allowing occupants the time to escape or be rescued. Several different systems exist, and research is ongoing to develop systems that are more efficient and cost-effective. The design and installation must take into account where sprinklers in a home are most effective in reducing the risk to life and property. The sprinkler system needs to activate automatically while a fire is small and the smoke and heat conditions in the home are survivable. Once the system is activated, it needs to control the fire with a smaller amount of water relative to a commercial sprinkler system.

Although most fire-related deaths in the United States occur in the home, it is estimated that less than 3 percent of one- and two-family dwellings have sprinkler systems installed. This percentage will rise as more legislation is passed requiring new homes to have sprinkler systems and as technology and costs continue to improve.

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### NFPA Codes, Standards, and Recommended Practices

*Reference to the following NFPA codes, standards, and recommended practices will provide further information on residential 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 750, *Standard on Water Mist Fire Protection Systems*
*NFPA 5000*®, *Building Construction and Safety Code*®