Fire Protection

By Richard C. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part 1

In the debate between engineers and sprinkler contractors over who should design sprinkler systems, the contractors maintain that many engineering firms involved in the design of sprinkler systems are simply not qualified to do the work. If you are a long-time reader of this column, you know it is my opinion that the contractors have a valid point.

The column which appeared in the March 1999 issue of *Plumbing Engineer* addressed the review of a sprinkler and standpipe system specification for a high rise hotel issued by an engineering firm. If you recall the column, the specification was filled with numerous basic design errors, yet another illustration of the sprinkler contractors' point. Clearly, the specification writer was not qualified to write the spec for the sprinkler and standpipe installation.

For many, it's time to go back to the basics. This month, let's take a look one of the most basic elements of sprinkler design — steel sprinkler pipe.

From a fire protection standpoint, there really isn't much to sprinkler system design. The engineering aspects of the design are, for the most part, all laid out in NFPA 13, *Installation of Sprinkler Systems*. Once the hazard classification and water supply are determined, the sprinkler designer simply applies the rules contained in NFPA 13. Of course, it's a little more complicated than that, but not a whole lot more.

What the design of a sprinkler system is really all about is pipe. The sprinklers themselves are relatively inexpensive, so the largest material cost in the installation is the pipe. What that means is that any competent designer needs to know a whole lot about pipe. Not only does a designer need to know about material costs, but also about the most efficient methods of joining and routing the pipe. What a sprinkler design is really all about is how to route the pipe most efficiently to minimize both labor and material costs.

In the old days, you didn't need to know too much about pipe. Every sprinkler system was constructed using schedule 40 steel pipe and screwed fittings. Those days are long gone. Today, sprinkler designers have all sorts of choices regarding the types of pipe to be used and how that pipe will be joined. Schedule 40 steel pipe and screwed fittings are still used, of course, but most experienced sprinkler designers will only use threaded pipe for pipe which is 2 inch and smaller. Larger pipe will typically be schedule 10 pipe or specially listed (thinner wall) steel pipe.

The requirements for pipe used in a sprinkler system installation are addressed in section 2-3 in the 1996 edition of NFPA 13. This section in NFPA 13 makes reference to various ASTM and ANSI standards on steel pipe. Any steel pipe that meets the standards listed is permitted to be used in a sprinkler system installation.

Sections 2-3.2 and 2-3.3 in NFPA 13 address how steel pipe is joined. Section 2-3.3 indicates that schedule 40 pipe must be used (for 6 inch and smaller pipe) if the pipe will be threaded or if grooves will be cut into the pipe. If the pipe will be roll grooved or plain end fittings will be used, section 2-3.2 indicates that schedule 10 pipe is permitted to be used (for pipe which is 5 inch and smaller).

What the design of a sprinkler system is really all about is pipe.

The difference between schedule 10 and schedule 40 pipe is explained in Table A-2-3.2 in Appendix A of NFPA 13. The outside diameters of schedule 10 and schedule 40 pipe are the same. The difference between these two types of steel pipe is the pipe wall thickness. The wall thickness of schedule 40 pipe is greater than the wall thickness of schedule 10 pipe. This means that there is more steel in schedule 40 pipe than in schedule 10 pipe.

From a material and installation cost standpoint, the implications of the difference between schedule 10 and schedule 40 pipe should be obvious. Because there is more steel in schedule 40 pipe than schedule 10 pipe, schedule 40 pipe costs more than schedule 10 pipe. Because schedule 40 pipe is heavier than schedule 10 pipe, schedule 40 also costs more to transport and install than schedule 10 pipe (because of the weight differential).

Of course, because the outside diameters of these two types of steel pipe are the same, this means the inside diameter of schedule 10 is larger than the inside diameter of schedule 40 pipe. This means there is also a hydraulic advantage to using schedule 10 pipe over schedule 40 pipe.

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In other words, the only advantage to using schedule 40 pipe, over schedule 10 pipe, is that schedule 40 pipe can be threaded, while schedule 10 pipe must be joined by some other method. Schedule 10 and schedule 40 steel pipe are not the only options available as far as steel pipe goes, however. Section 2-3.5 in NFPA 13 also permits other types of steel pipe to be used, provided that the pipe has been "investigated for suitability in automatic sprinkler installations and listed for this service." There are a number of specially listed steel piping products with thinner pipe walls than schedule 40 and schedule 10 which have been specially listed by Underwriters Laboratories for use in sprinkler installations. Every sprinkler designer needs to know about these specially listed piping products. For more information about these products, see pages 329 through 332 in the 1998 edition of the Underwriters Laboratories' *Fire Protection Equipment Directory.*

The issue of pressure ratings of the components of a sprinkler system is addressed in section 2-1.2 in NFPA 13. This section in NFPA 13 indicates that all components of a sprinkler system are required to have a minimum working pressure rating of 175 psi. The issue of the working pressure ratings of steel pipe is addressed in sections 2-3.2 and 2-3.3 in NFPA 13. These two sections indicate that threaded schedule 40 pipe and (roll) grooved schedule 10 pipe should be assumed to have a working pressure of 300 psi. The working pressures assigned to specially listed steel pipe are included in the listings for the pipe.

All of the above is basic information for anyone involved in the design of sprinkler or standpipe systems. Most of the information presented comes directly out of NFPA 13 and the UL *Fire Protection Equipment Directory*. If you're involved in sprinkler system design, and you learned something from this column, this ought to be cause for some concern. While sprinkler design isn't rocket science, there's a whole lot to it. □

Fire Protection

By Richard G. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part II

If you examine the typical (standard spray) sprinkler, you'll see that sprinklers are actually pretty simple devices. The typical sprinkler consists of a frame, a deflector, an orifice cap and an operating element. That's pretty much it.

But if you examine the typical sprinkler a little closer, you should also notice a few other things. The name of the manufacturer, the model number (or designation) and the year the sprinkler was manufactured are stamped on the sprinkler. If the sprinkler operates using a fusible element (rather than a glass bulb), you should also see the temperature rating of the sprinkler stamped on the sprinkler. In addition, you should see the (testing laboratory) listing or the approval markings stamped on the sprinkler.

Depending on the type and temperature rating of the sprinkler, you may also see that a portion of the sprinkler frame is painted (typically either white or blue). If the sprinkler is a glass bulb sprinkler, note the color of the liquid in the glass bulb.

Actually, there's quite a lot to be learned just from looking at a sprinkler. Now, let's take a look at some of the requirements regarding sprinklers contained in *NFPA 13: Installation of Sprinkler Systems.*

Requirements in the standard

NFPA 13, the standard for the installation of sprinkler systems, requires that all devices required for the successful operation of the sprinkler system be listed for fire protection service. Hence, the laboratory listing (or approval) markings are stamped on the sprinkler.

NFPA13 specifies the discharge characteristics of sprinklers, as well as other features of sprinklers. The standard orifice sprinkler has a nominal 1/2-inch orifice and 1/2-inch pipe threads. In addition to the standard sprinkler, small and large orifice sprinklers are also manufactured. The nominal orifice sizes of small orifice sprinklers include 1/4-inch, 5/16-inch, 3/8-inch and 7/16-inch nominal orifice sizes. NFPA 13 indicates that small orifice sprinklers are also required to have 1-inch pipe threads. Because standard orifice and small orifice sprinklers have the same pipe thread size, NFPA 13 requires that small orifice sprinklers be provided with a pintle so small orifice sprinklers can be readily identified. (In this context, a pintle is a projection from the sprinkler deflector.)

Large orifice sprinklers have a nominal 17/32-inch orifice and are permitted to be manufactured with either 1/2-inch or 3/4-inch pipe threads. (Large orifice sprinklers manufactured with 1/2-inch pipe threads are only permitted to be used to replace 1/2-inch sprinklers in existing systems.) NFPA 13 also requires that large orifice sprinklers manufactured with 1/2-inch threads be provided with a pintle so that the installation of these types of sprinklers can be differentiated from installations with standard orifice sprinklers.

In addition to large orifice sprinklers, there are other larger orifice sprinklers manufactured with nominal 5/8-inch and nominal 3/4-inch orifices. Again, NFPA 13 requires that these sprinklers be identified with pintles.

Why so many orifice sizes? Well, because the flow from an orifice varies with the size of the orifice and the pressure at the orifice, sprinklers with orifice sizes larger than half-inch orifice sprinklers are used when larger flows are required at lower pressures. Similarly, small orifice sprinklers are used when lower flows are required at a pressure of 7 psi. (NFPA13 requires that the pressure at any operating sprinkler be a minimum of 7 psi.)

Standard spray sprinklers are actually pretty simple devices.

NFPA 13 places a number of restrictions on the use of small orifice sprinklers. One of these restrictions is that small orifice sprinklers are only permitted to be used in rooms and spaces which are classified as a light hazard occupancies. Another restriction is that small orifice sprinklers are only permitted to be used in wet-type sprinkler systems. (Given the limitations on space and time, I'll simply refer you to NFPA13 if you're unfamiliar with the hazard classification system used by NFPA13 or if you're unfamiliar with the term "wet-type system.")

Temperature ratings

In addition to various orifice sizes, sprinklers are manufactured with a variety of temperature ratings. The temperature rating of a sprinkler is the temperature which the "operating element" of the sprinkler must reach in order to activate the sprinkler. The temperature at the ceiling of a room or space will typically be much higher than the temperature rating of the sprinklers prior to activation of sprinklers in a fire.

NFPA 13 sets up seven separate classifications of sprinklers based on the temperature rating of the sprinklers. The "ordinary" temperature classification is defined as sprinklers with a temperature rating between 135 degrees Fahrenheit and 170 F. The “intermediate” temperature classification is defined as sprinklers with a temperature rating between 175 F and 225 F (typically 212 F), while the “high” temperature classification is defined as sprinklers with a temperature rating between 250 F and 300 F (typically 286 F). Because the use of sprinklers with higher temperature ratings than “high” temperature sprinklers is not very common, there is little need to commit the temperature ranges of the other four temperature classifications to memory. See NFPA13 if you’re interested.

A third reason higher temperature rated sprinklers are manufactured is because using higher temperature sprinklers in storage occupancies reduces the number of sprinklers which operate in a fire (under certain conditions), thereby allowing more water to flow from the sprinklers located directly over the fire. Rather than discuss this issue in detail, it is recommended that you review *NFPA 231C: Standard for Rack Storage of Materials*.

NFPA 13 requires that sprinklers be color-coded so the temperature rating of the sprinklers can easily be identified in the field. Sprinklers with a plain brass finish are ordinary temperature rated sprinklers. Sprinklers with an “intermediate” temperature rating are provided with white paint on the sprinkler frame, while sprinklers with a “high” temperature rating are provided with blue paint on the sprinkler frame. It should be noted that NFPA 13 permits a different color coding system to be used for glass bulb sprinklers and that ornamental-type sprinklers are exempted from color coding.

The temperature rating of a sprinkler is the temperature which the “operating element” of the sprinkler must reach in order to activate the sprinkler.

Why are sprinklers manufactured with different temperature ratings? Well, because sprinklers are required to be installed throughout the building, sprinklers often have to be located near heat sources, such as unit heaters, steam and hot water pipes, etc. Obviously, sprinklers with higher temperature ratings are required in these instances.

Another reason sprinklers are manufactured with different temperature ratings is that the metals used to cause sprinklers with fusible elements to operate lose part of their structural capabilities when repeatedly exposed to temperatures close to their melting point over a period of years. Given this, NFPA 13 requires that higher temperature sprinklers be installed in locations where lower temperature sprinklers would be exposed to ambient temperatures which are close to the temperature rating of the sprinklers. As an example, NFPA 13 only permits ordinary temperature rated sprinklers to be installed in locations where the ambient temperatures will be 100 F or less.

The above just scratches the surface of the basics on sprinklers. To learn more, you only need to consult two of the basic references used in sprinkler design, NFPA13 and the *Fire Protection Equipment Directory*, published by Underwriters Laboratories. □

The first part of this series appeared in the April 1999 issue of Plumbing Engineer.

Additional reference material cited in this article is available by calling the National Fire Protection Association (800/344-3555) or Underwriters Laboratories (847/272-8800, ext. 42899), or via the Internet at www.nfpa.org and www.ul.com.

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Nuts and Bolts of Sprinkler Installations — Part III

Last month's column discussed some of the basics of sprinklers, including orifice sizes and temperature ratings of sprinklers. (Part I, in the April 1999 issue, discussed pipe.) Although NFPA 13, *Installation of Sprinkler Systems*, makes reference to nominal orifice sizes, the definition of the orifice size of a sprinkler is actually based on the "k" factor of the sprinkler. The k factor of a sprinkler refers to the nozzle discharge coefficient of the sprinkler.

The equation used to determine the flow from an operating sprinkler is:

$$Q = k P^{1/2}$$

Where Q = Flow from the nozzle, in gpm (gallons per minute)

P = Pressure at the nozzle, in psi (pounds per square inch)

k = Nozzle discharge coefficient

Note: $P^{1/2}$ is equal to the square root of P.

By definition, a nominal one-half inch sprinkler has a k factor of between 5.3 and 5.8. Similarly, a nominal 17/32 inch sprinkler has a k factor of between 7.4 and 8.2. (See NFPA 13 for the k factor requirements for extra large orifice sprinklers and small orifice sprinklers.)

During the course of testing the sprinkler for listing purposes, the testing laboratory determines the (average) k factor for the sprinkler. The k factors of each manufacturer's sprinklers vary and are reported in the manufacturer's product literature. The k factor is used to calculate the flows from operating sprinklers in hydraulic calculations.

Static head

Water in a container exerts a force on the sides and bottom of the container. If you completely fill a container of water with inside dimensions of 1 foot by 1 foot by 1 foot, the pressure exerted on the bottom of this container will be equal to the weight of the water in the container divided by the area of the bottom of the container. Fresh water weighs 62.4 pounds per cubic foot, so the pressure on the bottom of the container referred to above will be 62.4 pounds per square foot or, expressed in pounds per square inch, 0.433 psi.

If you fill different containers with water and do the math, you'll find that the pressure on the bottom of the container is always proportional to the height of the water in the container and that this pressure can be calculated by multiplying the depth of the water (in feet) by 0.433. In other words, the pressure exerted by fresh water is equal to 0.433 psi per foot of depth (or elevation change). Because pipe and tube used in a sprinkler or a standpipe system is just another form of a container, the 0.433 psi/foot factor is also used in hydraulic calculations for sprinkler and standpipe systems.

Friction loss

The equation used to determine friction loss in pipe and tube is far more complex. NFPA 13 requires that the Hazen-Williams formula for computing friction loss be used in hydraulic calculations for sprinkler systems. This formula is used to calculate the friction loss in straight lengths of pipe and is as follows:

$$P = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}}$$

Where P = Friction loss, in psi per foot length of pipe or tube

Q = Flow in the pipe or tube, in gpm (gallons per minute)

C = Pipe or tube roughness coefficient

d = Inside diameter of the pipe or tube, in inches

NFPA 13 indicates that the pipe (or tube) roughness coefficient ("C factor") varies with the type of pipe (or tube) being used. If steel pipe is used, NFPA 13 indicates that the pipe roughness coefficient used is to be either 100 or 120, depending on whether the system is a wet system or a dry system. If plastic or copper tubing is used in the system, NFPA 13 indicates that a C factor of 150 is used.

The inside diameter of the pipe used in the Hazen-

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Williams formula varies with the type of pipe or tube being used in the system. Tables in the appendix in NFPA 13 provide the inside diameters for schedule 10 and schedule 40 steel pipe and for copper tubing. Information on the inside diameters other types of steel pipe or on plastic tubing can be obtained from the manufacturer of the pipe or tube.

With the fractional exponents in the Hazen-Williams formula, this equation is difficult to use in a hand calculation and, when hydraulic calculations are done by hand, friction loss tables are typically used. Obviously, the Hazen-Williams formula was made for a computer and today hydraulic calculations for sprinkler systems are almost always done by computer.

Of course, the sprinkler hydraulics concepts are only part of actually doing a calculation for a system.

Equivalent length

The pressure loss due to turbulence caused by fittings in a piping system is determined using the concept of “equivalent length.” The equivalent length concept expresses the pressure loss in a fitting due to turbulence in terms of equivalent friction loss in straight pipe. For example, NFPA 13 indicates the equivalent length of a 2-inch tee is 10 feet of schedule 40 steel pipe with a C factor equal to 120. This means the pressure drop in the 2-inch tee (where the water turns 90 degrees) is the same as the friction loss in 10 feet of straight schedule 40 steel pipe.

Obviously, if the equivalent length of a 2-inch tee is 10 feet of schedule 40 steel pipe with a C factor of 120, the equivalent length will be different if the system is a dry system and steel schedule 40 pipe is used or if pipe or tube with different inside diameters or C factors is used. NFPA 13 contains adjustment factors for different C factors and contains a formula for computing the adjustment factor if pipe or tube other than schedule 40 steel pipe is used.

While the concept of equivalent lengths may seem complicated if this is the first time you’ve seen it, the concept is actually rather simple. And believe it or not, that’s about all there is to the hydraulics used in calculations for sprinkler systems. With a little effort, just about anyone with a high school mathematics background should be able to grasp the hydraulic concepts outlined above. Of course, the sprinkler hydraulics concepts are only part of actually doing a calculation for a system. The other part is the hydraulic design criteria. The next installment in this series will discuss the design criteria for sprinkler systems. □

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By Richard G. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part IV

Part III (July 1999 *Plumbing Engineer*, p. 10) of this series discussed the basic equations and concepts used in hydraulic calculations. Actually, the basics of hydraulic calculations are rather simple. Now let's take a look at the hydraulic design criteria used for spray sprinklers.

Fire control vs. fire suppression systems

To begin with, it is helpful to understand some basic terminology. There are two basic types of sprinkler systems–systems designed for "fire control" and systems designed for "fire suppression."

NFPA13, *Installation of Sprinkler Systems*, defines a **fire control** sprinkler system as a system which is designed to limit the size of the fire by discharging water spray directly over the fire and on unignited combustibles located in close proximity to the fire in order to decrease the rate of heat release from the fire and to pre-wet (unignited) combustibles adjacent to the fire. NFPA 13 further indicates that a fire control sprinkler system will also limit the temperature at the ceiling over a fire to prevent damage to the building structural systems.

NFPA13 defines a **fire suppression** sprinkler system as a system which is designed to discharge sufficient quantities of water over the fire so that water penetrates the thermal column (fire plume) generated by the fire so that water is applied directly to the surfaces of the combustibles which are burning.

The use of fire suppression concept for the design of sprinkler systems is typically limited to storage occupancies. Storage occupancies may either be protected by fire control or fire suppression type systems. Which type of system will be used is dependent upon the type of storage, the height/configuration of the storage and, of course, economics. Other types of buildings will normally be protected by sprinkler systems which utilize the fire control concept. Because sprinkler systems designed using the fire control concept are the most commonly used type of sprinkler system, the discussion in this column will be limited to this type of system.

Design criteria — fire control system

There are three parts to the design criteria for fire control sprinkler systems: the sprinkler discharge density, the assumed area of sprinkler operation and the hose stream demand. The required density is used to determine the minimum flow required at each sprinkler which is assumed to operate, while the area of operation is used to determine how many sprinklers must be assumed to operate. The hose stream demand is the amount of water which the fire department will need to use to complete extinguishment of the fire.

Discharge Density. The sprinkler discharge density (D), which is developed at an operating sprinkler, is determined by dividing the flow from the sprinkler (Q) by the area (A) protected by that sprinkler. In other words, the formula used to compute density is as follows:

$$D = Q / A$$

In English units, Q is expressed in gallons per minute (gpm) and Ais expressed in square feet. Hence, density is expressed in units of gallons per minute per square foot (gpm/sf).

The density achieved at a sprinkler is dependent upon the pressure available at the sprinkler, as well as the "k" factor for the sprinkler. Recall from Part III of this series, the formula for determining flow from a sprinkler nozzle is as follows:

$$Q = k\,P^{1/2}$$

Using these two formulas, the sprinkler designer can determine the minimum pressure required at a sprinkler to achieve a specific density. For example, if the hydraulic design criteria requires that a minimum density of 0.20 gpm/sf be achieved at each operating sprinkler and each sprinkler protects 100 square feet, the minimum flow required at each sprinkler to achieve the minimum density can be computed by multiplying the density times the area protected by the sprinkler. In this example, the required minimum flow at the sprinkler would 20 gpm. If the k factor of the sprinklers used in the system is 5.6, the pressure required to achieve the density can be computed by dividing the sprinkler flow (Q) by the sprinkler k factor and squaring this quantity. In this example, the pressure required at the sprinkler to achieve the minimum density would be approximately 12.8 psi.

Area of (Sprinkler) Operation. Another part of the hydraulic design criteria used for sprinkler systems designed using the fire control concept is the assumed area of operation. In a fire control system, it is expected that sprinklers will not only activate directly over the fire, but also in the immediate area surrounding the fire. Again, the activation of sprinklers which are not located directly over the fire serves to pre-wet the unignited combustibles adjacent to the fire. Pre-wetting the unignited combustibles

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around the fire means that the fire will be surrounded by wet fuel. Surrounding the fire with wet fuel checks the further growth of the fire and allows the sprinkler system to gain control of the fire.

There are two methods of determining the area of sprinkler operation: the area/density method and the room design method. In the **room design method** of determining the area of sprinkler operation, all the sprinklers in a single room enclosure are assumed to operate. In order for the room design method to be used, NFPA 13 requires that the room enclosure walls develop a fire resistance rating (equal to the required duration for which the water supply must be sized). NFPA 13 further requires that any door or window openings in the room enclosure be protected by fire door or fire window assemblies (with ratings as required by NFPA80). An exception to this requirement permits unprotected openings in the room enclosure in light hazard occupancies when it is assumed that two sprinklers operate outside the enclosure at each unprotected opening in the room enclosure.

The other means of determining the required area of operation to be used in the design of a sprinkler system is referred to as the **area/density method**. In this method, design curves which relate density and the area of assumed sprinkler operation are used to determine the area of sprinkler operation. NFPA 13 contains a design curve for each of the five hazard classifications. The design curves are based upon the assumption that, as the quantity of water spray per square foot (density) delivered by the sprinklers increases, the floor area over which sprinklers will operate will decrease, or, put in another way, as the density decreases, the floor area over which sprinklers will operate will increase. The design curves provided in NFPA13 indicate the minimum area of operation which must be assumed (when standard response sprinklers are used) is 1,500 square feet for light and ordinary hazards and 2,500 square feet for extra hazards.

The assumed area of operation determines the number of sprinklers which must be assumed to operate. For instance, if the assumed area of operation is 1,500 and each of the sprinklers in the system protect an area of 120 square feet, the assumed area of operation tells the designer that the hydraulic calculation must assume that a minimum of 13 sprinklers operate.

One of the most misunderstood concepts about the design of sprinkler systems is that a sprinkler system is not designed for all of the sprinklers in the system to operate simultaneously. In the example cited above, the system would only be designed for 13 sprinklers to operate. The number of sprinklers which are required to be assumed to operate remains the same regardless of the size of the building. Since a fire control sprinkler system is designed to control the fire, the same size fire would be expected in a sprinklered building which is 100,000 square feet in area as a sprinklered building which is only 10,000 square feet in area (assuming all other building features and contents are the same).

Hose stream demand

In addition to the density and area of operation, NFPA 13 also requires the hydraulic calculations for a sprinkler system include an allowance for the fire department to use water at the fire scene. Given the discussion above, the reason for this should be obvious. Since a sprinkler system designed using the fire control concept is only designed to control the fire, it will be necessary for the fire department to use water to complete the extinguishment of the fire.

NFPA 13 indicates that a hose stream demand of 100 gpm must be included in the calculations for a light hazard occupancy and that a hose stream demand of 250 gpm be included for an ordinary hazard occupancy. For an extra hazard occupancy, NFPA 13 requires that a hose stream demand of 500 gpm be included in the calculations. A100 gpm hose stream demand corresponds to the use of a single 1-1/2 inch hose line, while a 250 gpm hose stream demand corresponds to the use of a single 2-1/2 inch hose line. The 500 gpm hose stream demand required for an extra hazard occupancy corresponds to the use of two 2-1/2 inch lines.

In essence, what the above means is that the fire department can safely use a single 1-1/2 inch hose line in a light hazard occupancy and a single 2-1/2 inch hose line in an ordinary hazard occupancy. Because the water spray discharging from operating sprinklers is far more efficient in fighting a fire than fire department personnel using hose lines, proper firefighting tactics in sprinklered buildings dictate that the fire department allow the sprinkler system to control the fire and then effect final extinguishment using minimal amounts of water.

Of course, the above are just some of the basics. There's certainly more to it than what has been outlined above. For more information on the subject, just pick up a copy of NFPA13 and start reading. □

Fire Protection

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Nuts and Bolts of Sprinkler Installations — Part V

The purpose of running hydraulic calculations on a sprinkler system is to determine the hydraulic demand of the system. Of course, the other side of the equation is the available water supply at the site where the sprinkler system is going to be installed. In Parts III and IV of this series (page 10 of July and September 1999 *Plumbing Engineer*), we discussed the equations used in hydraulic calculations for sprinkler systems and the basic hydraulic design criteria contained in NFPA 13. Now, let's take a look at the water supply.

The water supply for most sprinkler systems is typically the municipal distribution system. The available water supply from a municipal distribution is determined by conducting a water supply test, more commonly referred to as a "flow test."

In the typical flow test, two fire hydrants are normally used to conduct the test. One hydrant is designated as the "test" hydrant, while the other hydrant is referred to as the "flow" hydrant. To begin the flow test, the cap covering one of the hydrant outlets is removed and a hydrant cap with a pressure gage is attached to the hydrant. The test hydrant is then turned on and a pressure reading is taken. This pressure reading is referred to as the "static pressure." The static pressure at the hydrant represents the available pressure in the water main (at the elevation of the hydrant outlet) with domestic consumption occurring.

After the static reading is taken, one (or more) outlets on the flow hydrant are opened and the inside diameter of each outlet is measured. The flow hydrant is turned on so that water flows from the hydrant and an instrument referred to as a "pitot tube" is used to measure the velocity pressure of the streams issuing from the hydrant. At the same time, the pitot pressure reading is being taken, a second pressure reading is taken at the test hydrant. The second pressure taken at the test hydrant is referred to as the "residual" pressure reading. The residual pressure reading is a reading with simultaneous domestic flows and a fire flow occurring. (The flow from the flow hydrant simulates the sprinkler system operating in a fire.)

Once the pitot pressure and the residual pressure readings are taken, the flow test is essentially complete. The only thing left to do is to shut down the flow hydrant and then take another static pressure reading. The purpose of taking this second static pressure reading is to verify that both static pressure readings are essentially the same.

If the second static pressure reading is much higher than the first reading, then it is likely that pumps at the water plant started due to the increased demand on the water system from the open hydrant. If this is the case, then the flow test should be repeated with the pump which started during the test manually shut down. The reason for this is simple. If only a few sprinklers in a fire operate, the flow demand may not be sufficient to start the additional pump, hence, the pressure available in the water system to operate the sprinkler system may be lower than indicated in the flow test.

If the second static pressure reading taken is far less than the first reading, then this is an indication that a water main broke during the test, probably because the hydrants were shut down too fast.

When the flow test is completed, there will be three pressure readings (assuming only one hydrant outlet was opened on the flow hydrant). To convert the test data to a usable form, the pitot pressure reading is converted to a flow, using the following equation:

$$Q = 29.83cd^2p^{0.5}$$

Where Q = Flow in gallons per minute (gpm)
c = Hydrant outlet flow coefficient
d = Inside diameter of the hydrant outlet (inches)
p = Pitot (velocity) pressure (psi)

The hydrant flow coefficient used in this equation is either 0.7, 0.8 or 0.9, depending upon the design of the hydrant outlet/hydrant barrel intersection. If the hydrant outlet is designed such that the outlet projects into the hydrant barrel, then a "c" factor of 0.7 is used. If the intersection of the outlet and barrel is "squared-off," then a "c" factor of 0.8 is used and if the intersection of the outlet and barrel is "rounded-off", a "c" factor of 0.9 is used. The appropriate "c" factor for the hydrant is determined simply by placing your hand in the open outlet and feeling the outlet/barrel intersection. Hydrants with "c" coefficients of 0.7 and 0.8 are older hydrants. Modern fire hydrants are all manufactured with a "rounded" intersection between the hydrant outlet and the hydrant barrel.

Rather than do the computation using the equation above, flow tables are normally used to convert pitot (velocity) pressures to flows. Because flow tables are normally based on outlets or nozzles with a "c" factor of 1.0, the flow indicated

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in the table must be adjusted by multiplying the flow in the table by the appropriate "c" factor.

Once the pitot pressure has been converted to a flow, the test data is in a form which can be used. An example of flow test data would be as follows:

Static Pressure:	90 psi
Residual Pressure:	60 psi /1,000 gpm flowing

In the "old days," before the extensive use of computers to do hydraulic calculations, flow test data was plotted on hydraulic graph paper to establish a water supply curve. (See the appendix of NFPA 13 for a sample of hydraulic graph paper and a plot of the flow test results indicated above.) Hydraulic graph paper is actually semi-log (logarithmic) paper with the horizontal axis representing Q (flow in gallons per minute) raised to the 1.85 power and the vertical axis representing P (pressure in psi).

To determine the water supply curve, the two points determined by the flow test are plotted on the hydraulic graph paper and are then connected by a straight line. (In the example above, one point is 0 gpm, 90 psi and the other point is 1,000 gpm, 60 psi.) This straight line represents the water supply curve.

The above are the basics of flow testing and using flow testing results, but, of course, there is far more to determining the water supply at a site than what is described above. If you review the provisions contained in NFPA 13, you'll see that shop drawings submitted for review and approval are required to indicate the location of the test and flow hydrants used in the water supply test, the date and time the test was conducted, the elevation of the test hydrant with respect to the base of the sprinkler riser (or some other reference point) and who actually conducted the test.

Why does NFPA 13 require that all of this information be provided on the shop drawings? The answer to this question is found in the chapter which addresses water supplies. NFPA 13 states the following:

> "The authority having jurisdiction shall be permitted to require an adjustment to the water flow test data to account for daily and seasonal fluctuations, possible interruption by flood or ice conditions, large simultaneous industrial use, future demand on the water supply system, or any other condition that could affect the water supply."

Because the pressures in the typical municipal water supply system are constantly fluctuating, taking a single flow test is simply like taking a "snapshot" of the water supply system at one point in time. When a structural engineer designs a building, the engineer analyzes the loads which are expected to be applied to the building over the life of the building. Structural engineers do not simply use the records of last year's snowfalls to predict the snow loads which will be applied to a building over the next 50 years, and neither should engineers or contractors involved in the design of sprinkler system use a single flow test as an indication of what the water supply at a site will be over the next 50 years.

Determining the water supply which should be used to design a sprinkler system involves researching the history of the water system to determine the fluctuations in the system pressures which typically occur in the system. For instance, in the Village of Maywood, Ill., the static pressure in the water distribution system serving this community is typically around 49 psi, but the water company's records indicate that in hot and dry summers, the static pressures in the village may drop to as low as 33 psi. If historical records indicate that the static pressure in the village will be as low as 33 psi, is it appropriate to design the sprinkler system assuming that a static pressure of 49 psi is available?

In another community in the Chicago area, the low pressures in the water distribution system occur not in the summer, as is typical, but in the winter. The reason for this is that the heating system for the water supply tanks used in this system is not sized to keep the water from freezing in the winter if the tanks are kept full. Because water demands are lower in the winter, the water company reduces the amount of water stored in the tanks to keep the water from freezing. Of course, a fire protection designer wouldn't know this unless the designer looked into the operation of the water system and looked at the history of pressures in the system.

In the "old days," before the extensive use of computers to do hydraulic calculations, flow test data was plotted on hydraulic graph paper to establish a water supply curve.

It is all too common today for engineers and contractors involved in designing sprinkler systems to base their designs on a single water supply test. Obviously, in a competitive bidding situation it is difficult for a fire protection or plumbing contractor to take into account fluctuations in the water supply (if the competition isn't going consider the fluctuations.) What this means is that the engineer for the project should be doing the water supply research for the project and include the water supply to which the system should be designed in the contract drawings so that each contractor bidding the job uses the same water supply data. □

Fire Protection

By Richard C. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part VI

I've been reviewing shop drawings for sprinkler installations for almost 20 years now, and one of the things I've noticed is that sprinkler installation contractors rarely ever submit complete shop drawings to enforcing authorities for approval. I'm sure you're probably scratching head right about now and wondering what I'm talking about. If the drawings aren't complete, how can a code enforcement authority approve the drawings? That's an excellent question. Quite frankly, I don't have an answer for that one.

Section 8-1.1.1 in the 1999 edition of NFPA 13, *Installation of Sprinkler Systems*, is quite specific as to exactly what information is required to be provided on shop drawings (working plans) submitted for approval to the enforcing authorities. Let's take a look at some of the information NFPA 13 requires on the shop drawings.

Building Cross-Section. Section 8-1.1.1(4) in NFPA 13 requires that the sprinkler system designer provide a cross-section of the building so the plan reviewer will have some idea as to the construction of the building. The cross-section is intended to convey whether the building is constructed using combustible or noncombustible construction, as well as give the reviewer an idea as to the elevations of the various floors, ceilings and roof in the building. Because the sprinkler installation requirements vary based upon whether or not the building is constructed with combustible or noncombustible materials, providing this information is essential for an adequate review of the drawings and hydraulic calculations.

Concealed Spaces. Section 8-1.1.1(8) in NFPA 13 requires that the drawings indicate the size and location of concealed spaces (which will not be provided with sprinkler protection). In general, it can be stated that NFPA 13 requires that sprinklers be installed in combustible concealed spaces. Section 5-13.1.1 in NFPA 13 contains a total of 12 different exceptions to this general rule. The shop drawings are required to show the location of concealed spaces so the reviewer can determine whether or not sprinkler protection is required in the concealed spaces and whether the hydraulic design criteria used to design the system must take into consideration that there are unsprinklered combustible concealed spaces in the building.

Water Supply Test Results. Section 8-1.1.1(10) in NFPA 13 requires that the results of the water supply test be shown on the drawings, as well as the elevation of the outlet of the "test" hydrant used in the water supply test. Section 8-2.1 in NFPA 13 requires that even more information be provided on the water supply test. This section in NFPA 13 requires that the location and elevation of the hydrants (with respect to the riser reference point) used in the water supply test be shown on the drawings. This section also requires that information on the date and time of the test, as well as who performed the water supply test be provided.

Because the hydraulic calculations for a sprinkler system are based upon the water supply test results, information regarding the water supply test is critical to determining whether or not the hydraulic calculations submitted are correct. As discussed in Part V of this series (November 1999 *Plumbing Engineer*, page 10), the pressures available in a municipal distribution system are constantly varying. Hence, the time and date the water supply test was conducted is important to know to determine whether or not the results of the water supply test should be adjusted by the enforcing authority. (See section 9-2.1 and section A-9-2.1 in NFPA 13 for a brief discussion on adjusting the results of water supply tests.)

NFPA 13 is quite specific as to exactly what information is required to be provided on shop drawings submitted for approval to the enforcing authorities.

Manufacturer/Model of the Sprinklers. Section 8-1.1.1(12) in NFPA 13 requires that information on the manufacturer and model of the sprinklers to be used in the installation be shown on the drawings. The reasons for this requirement should be obvious — the "k" factors (nozzle flow coefficient) of sprinklers vary from manufacturer to manufacturer, and in some cases from sprinkler model to sprinkler model within a manufacturer's line of sprinklers.

In addition, when specially listed sprinklers are used in

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the installation, the requirements for installation of these sprinklers often vary from that of standard sprinklers. Hence, the reviewer needs to verify that the special sprinklers being used will be installed in accordance with the criteria used to list the special sprinklers. The only way the reviewer can do this is to look up the listing. To do that, the reviewer, of course, needs to know both the manufacturer and the specific model of sprinklers being used.

Pipe Type. Section 8-1.1.1(18) in NFPA 13 indicates that the type of pipe (piping material), as well as the specific pipe materials which will be used in the installation be indicated on the shop drawings. NFPA 13 specifically allows the use of schedule 10 and schedule 40 steel pipe, as well as Type K, Type L and Type M copper tubing. In addition to these specific piping materials, NFPA 13 allows the use of any other specially listed pipe or tubing material. The listings for piping materials contained in the UL *Fire Protection Directory* indicate there are a number of specially listed types of steel piping materials which can be used in sprinkler installations, as well as CPVC plastic pipe.

The various types of piping/tubing materials have different pipe wall thicknesses and inside diameters. The varying types of wall thicknesses and inside diameters not only affect the hydraulics of the piping system, but also affect how the piping materials are joined together. Hence, indicating the specific type of pipe being used in the installation allows the reviewer to determine whether or not the correct inside diameters have been used in the hydraulic calculations, as well as determine whether the method of joining the pipe complies with either the requirements contained in NFPA 13 or the special listing for the piping/tubing material.

Pipe Sizes and Lengths. Section 8-1.1.1(19) in NFPA 13 requires that the shop drawings indicate the pipe sizes and lengths to be used in the installation. While it seems obvious that shop drawings should show this information, more often than not, the drawings I review for enforcing authorities only partially show this information.

To do a proper review of drawings and hydraulic calculations, it is necessary to compare the pipe sizes and lengths shown on the drawings to those used in the calculations. If all of the pipe sizes and/or lengths are not shown on the drawings, there is simply no way for the reviewer to verify that the drawings and calculations actually match.

To do a proper review of drawings and hydraulic calculations, it is necessary to compare the pipe sizes and lengths shown on the drawings to those used in the calculations.

Underground Piping. Section 8-1.1.1(28) in NFPA 13 indicates that the size, length and type of pipe materials to be used in the installation of the underground supply piping are required to be shown on the shop drawings. This section also indicates that the type and location of valves and meters in the underground supply piping are required to be shown on the shop drawings.

Because the size, length and type of piping materials used in the underground installation, as well as the type and size of valves and meters, affect the hydraulics of the sprinkler system, it seems obvious that this information should be shown on the drawings. All too often, though, many sprinkler designers seem uninterested in the underground supply piping and the valves and meters in this portion of the system. The reason for this is rather simple — the underground supply piping is being installed by another sub-contractor.

Although the underground piping might be installed by another contractor, it still is part of the fire protection system and this information needs to be shown on the sprinkler shop drawings (or perhaps be submitted on a separate shop drawing for the underground installation).

I was talking with a designer working for a sprinkler contractor about the information required to be shown on the shop drawings to be submitted for approval just a few weeks ago. The designer indicated that he could show all the information required on the drawings by NFPA 13, but that would increase the cost of designing the system and thus increase the cost of the installation.

Whether sprinkler system installation contractors like it or not, in order to comply with the requirements contained in NFPA 13, compliance with sections 8-1 and 8-2 is required. Of course, it's not really the sprinkler contractor's fault if they don't comply with these two sections in NFPA 13 if no one enforces these provisions. Any contractors who comply with all of the provisions of NFPA 13, when the competition simply disregards NFPA 13, will likely soon find themselves out of business. So enforcing authorities and engineers who approve incomplete shop drawings should also shoulder the blame for non-compliance by sprinkler contractors. If sprinkler contractors are not going to comply with NFPA 13 and enforcing authorities are not actually going to enforce the provisions of NFPA 13, let's quit playing games and simply stop requiring that sprinkler installations comply with NFPA 13. Makes sense to me. □

Fire Protection

By Richard C. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part VII

Combustible Concealed Spaces

Section 5-1.1 in the 1999 edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*, spells out the basic requirements for installing sprinklers in a building. This section in NFPA 13 indicates that sprinklers are required to be installed throughout a building (if the building is to be considered to be a sprinklered building). In other words, the provisions contained in NFPA 13 are intended to apply to buildings that are protected throughout by sprinklers. As with all general requirements, there are exceptions. Exception No. 1 to section 5-1.1 specifically references the provisions contained in sections 5-13.1, 5-13.2 and 5-13.9 in NFPA 13.

Section 5-13.1 addresses concealed spaces and states that concealed spaces which have exposed combustible construction are required to be protected by sprinklers. Although not specifically stated, this provision infers that concealed spaces that do not contain exposed combustible construction are not required to be protected by sprinklers.

Again, the provisions contained in Section 5-13.1.1 are the general requirements pertaining to the installation of sprinklers in concealed spaces. There are 12 separate exceptions to this general requirement. Let's take a look at those exceptions.

Double-Stud/Double-Joist Construction. Exception 1 to section 5-13.1.1 applies to concealed spaces that can be referred to as "double-stud" or "double-joist" construction. In other words, a wall space (or chase) formed by two sets of studs, or a ceiling space formed by two sets of joists — floor (or roof) joists and ceiling joists. This exception indicates that sprinkler protection is not required within double-stud walls or double-joist horizontal spaces where the distance between the inside faces of the studs or joists is 6 inches or less.

Bar Joist Construction. Exception 2 to section 5-13.1.1 applies to concealed spaces which contain bar joists. This exception indicates that sprinkler protection is not required within a concealed space formed by a floor and ceiling (or roof and ceiling) where the distance between the floor and ceiling is 6 inches or less. One example of this type of construction is plywood decking supported by small bar joists with a ceiling attached directly to the underside of the bar joists. Regardless of the construction of the ceiling, the exposed plywood within the construction creates a combustible concealed space.

Ceilings Attached Directly to the Underside of Wood Joists. Exception 3 to section 15-13.1.1 indicates that sprinkler protection is not required in concealed spaces formed by ceilings attached directly to the underside of wood joists. This exception further indicates that sprinkler protection is also not required where the distance from the top of the ceiling to the bottom of wood joists is 6 inches or less.

Ceilings Attached to Composite Wood Joists. The provisions contained in Exception 4 to section 15-13.1.1 are similar to those contained in Exception 3. Sprinkler protection is not required in concealed spaces which contain composite wood joists where the ceiling construction is attached directly to the underside of the composite wood joists. There is one additional requirement though — the joist channels formed by the composite wood joists are required to be firestopped so that the volume formed by the webs of the joists and the firestopping does not exceed 160 cubic feet.

Provisions contained in Section 5-13.1.1 of NFPA 13 are the general requirements pertaining to the installation of sprinklers in concealed spaces, with 12 separate exceptions.

(A composite wood joist is a "built-up" wood structural member typically constructed with a plywood web and 2 X 4 flanges to create a wood "I-beam." If you're not familiar with what a composite wood joist looks like, see Figure A-1-4.6(a) in the 1999 edition of NFPA 13 for an illustration of a composite wood joist.)

Concealed Spaces Filled With Noncombustible Insulation. Exception 5 to section 5-13.1.1 provides an

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alternative to providing sprinkler protection within a concealed space which would otherwise be required to be protected by sprinklers. In lieu of providing sprinkler protection within the concealed space, this exception permits a combustible concealed space to be filled with noncombustible insulation. Noncombustible insulation

Sprinkler protection can be omitted in combustible concealed spaces which occur over rooms which are 55 square feet or less in area

pressed up against a combustible surface will limit the amount of oxygen available for a fire to spread across the combustible surface, as well as act as a heat seat which will act to slow the spread of fire across a combustible surface.

Concealed Spaces Partially Filled With Noncombustible Insulation. Exception 6 to section 5-13.1.1 combines the provisions of Exceptions 3 and 4 with the provisions contained in Exception 5. This exception permits sprinkler protection to be omitted from concealed spaces where noncombustible insulation is installed from the ceiling to the underside of wood joists or to the underside of composite wood joists.

Small Concealed Spaces. Exception 7 to section 5-13.1.1 permits sprinkler protection to be omitted in combustible concealed spaces which occur over rooms which are 55 square feet or less in area. An example of where this exception could be applied is a combustible concealed space which occurs over the toilet room in a hotel guest room in a building constructed with wood framing.

Exposed Low Flame Spread Materials. Exception 8 to section 5-13.1.1 permits sprinkler protection to be omitted in combustible concealed spaces where the exposed combustibles are covered with rigid materials which have a flame spread rating of 25 or less. An example of this exception would be wood framing covered with gypsum wallboard.

Fire Retardant Treated Wood. Based upon the definition of the term "noncombustible" contained in NFPA 13 and other building codes, fire retardant treated wood (FRTW) does not comply with the requirements for classification as a "noncombustible" material. Exception 9 to section 5-13.1.1 addresses the use of fire retardant treated wood and permits sprinkler protection to be omitted in combustible concealed spaces which are constructed using fire retardant treated wood.

Exposed Combustible Insulation. Exception 10 to section 5-13.1.1 addresses the issue of combustible insulation used in otherwise noncombustible concealed spaces. This exception indicates that sprinkler protection is not required in noncombustible concealed spaces which contain exposed combustible insulation provided that the heat content of the insulation is 1,000 Btu per square foot or less.

Concealed Spaces Below Insulation Installed in Joist Spaces or Over Joists. Exception 11 to section 5-13.1.1 addresses concealed spaces formed by batt insulation which is installed over the top of or within ceiling joists. This exception states that sprinkler protection is not required to be provided in these concealed spaces provided that the space (typically an attic) in which the unsprinklered concealed spaces are located is protected by sprinklers.

Small Pipe Chases. Exception 12 to section 5-13.1.1 addresses pipe chases formed by combustible materials. This exception indicates that sprinkler protection is not required within a pipe chase provided that the floor area of the chase does not exceed 10 square feet in area and that the chase does not contain any source of ignition. This exception also indicates that any pipe within the chase is required to be metallic (or other noncombustible material) and that the penetrations of the floor construction above and below the chase are required to be firestopped.

In addition to provisions relating to whether or not sprinkler protection is required in combustible concealed spaces, NFPA 13 also contains modifications to the hydraulic design provisions which apply when sprinkler protection is omitted from combustible concealed spaces. Section 7-2.3.1.2(b) in the 1999 edition of NFPA 13 requires that the minimum assumed area of operation be increased to 3,000 square feet when sprinkler protection is not provided in combustible concealed spaces. Again, this is a general rule and there are three exceptions to this general rule. Each of these three exceptions indicates that the requirement to increase the assumed area of sprinkler operation to 3,000 square feet is not applicable under certain specific conditions. Rather than try to discuss these three exceptions here, I'll simply refer you to NFPA 13.

Unfortunately, I have found that it's all too common for sprinkler installation contractors to simply ignore the requirements for sprinkler protection in combustible concealed spaces, particularly in cases of sprinkler retrofit installations. Obviously, it's less costly (and more profitable) for contractors to ignore the requirements concerning sprinkler protection in combustible concealed spaces. That's why engineers and building inspection personnel need to be familiar with the requirements for sprinkler protection in combustible concealed spaces (and to spend time looking above ceilings). □

Fire Protection

By Richard G. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part VIII

Hazard Classification

The design of most building sprinkler systems really involves only two basic engineering decisions — the available water supply at the site and the hazard classifications of the building. (In most designs, the rest of the design is just "layout" and, in my opinion, can adequately be performed by sprinkler designers employed by the sprinkler contractor using the design requirements contained in NFPA 13, *Installation of Sprinkler Systems.* Obviously, there are exceptions.) Determining the available water supply at the building site has already been discussed in Part V of this series (November 1999 *Plumbing Engineer*, page 10). Now let's discuss hazard classification.

Hazard classification hierarchy

The requirements contained in NFPA 13 are keyed to the hazard classification. Section 2-1 in the 1999 edition of NFPA 13 indicates there are three basic hazard classifications used in the design of sprinkler systems. These three hazard classifications are as follows:

- Light Hazard
- Ordinary Hazard
- Extra Hazard

This same section in NFPA 13 also indicates that the ordinary hazard classification is divided into two sub-classifications — an ordinary group 1 hazard and an ordinary group 2 hazard. Similarly, the extra hazard classification is also divided into two sub-classifications — an extra group 1 hazard and an extra group 2 hazard.

The definitions of each of the hazard classifications are also included in section 2-1 in NFPA 13, which defines hazard classification based upon a number of occupancy characteristics. These characteristics are as follows:

- The combustibility of contents.
- The quantity of combustibles.
- Rate of heat release.
- Storage height.
- Quantity of flammable and/or combustible liquids.

NFPA 13 defines a light hazard occupancy using the following description:

- Combustibility of the contents is low, and
- Quantity of the combustible is low, and
- Low rates of heat release.

The NFPA 13 definition an ordinary group 1 hazard is as follows:

- Combustibility of the contents is low, and
- Quantity of the combustibles is moderate, and
- Moderate heat release rates, and
- Height of storage is 8 feet or less.

NFPA 13 defines an ordinary group 2 hazard as follows:

- Combustibility of the contents is moderate to high, and
- Quantity of the combustibles is moderate to high, and
- Moderate to high rates of heat release, and
- Storage height is 12 feet or less.

The NFPA 13 definition of an extra group 1 hazard is as follows:

- Combustibility of the contents is very high, and
- Quantity of the combustibles is very high, and
- High rates of heat release, and
- Quantity of flammable and/or combustible liquids small.

Finally, the NFPA 13 definition of an extra group 2 hazard is as follows:

- Quantity of flammable or combustible liquids is moderate to high, or
- Extensive shielding of the combustibles is present.

Interpretation by example

If this is the first time you've seen these definitions, I'm sure you're shaking your head right about now. The obvious question is, "What are the definitions of the adjectives used to describe the combustibility and quantities of the contents and the rates of heat release?" Well, NFPA 13 doesn't contain engineering definitions of the term "low rate of heat

NFPA 13 defines hazard classification based upon a number of occupancy characteristics.

release" or "moderate rate of heat release," or of what the difference is between "high" and "very high" as it relates to the combustibility of the contents. This makes it extremely difficult for someone unfamiliar with NFPA 13 to be able to determine hazard classifications.

Although NFPA 13 doesn't define the hazard classifications in precise terms, information provided in Appendix A in NFPA 13 does provide "clues" as to what the adjectives used in the definitions of the hazard classifications actually mean. For instance, section A-2-1.1 in NFPA 13 indicates that the following occupancies are typically classified as light hazards:

- Offices.
- Dwelling units.
- Restaurant seating areas.
- Unused attics.

Occupancies which are typically classified as an ordinary group 1 hazard include the following:

- Kitchens.
- Mechanical rooms.
- Electrical rooms.
- Elevator equipment rooms.
- Parking garages.

Occupancies which are typically classified as an ordinary group 2 hazard include the following:

- Retail stores.
- Storage rooms.

It should be noted that the list of typical hazard classifications for various rooms and spaces are just that — typical hazard classifications. For instance, the sales area of a retail stores is typically classified as an ordinary group 2 hazard, but this hazard classification isn't correct for all retail stores. For example, contrast the typical supermarket with low shelving used to display goods (and a separate storage area) with the supermarket which displays goods in racks and uses the upper portions of the racks to store goods. Both supermarkets are retail stores, however, the supermarket which uses the sales area to also store goods above the goods which are offered for sale would not be classified as an ordinary group 2 hazard.

Another key to understanding the hazard classification system used by NFPA 13 is that each room or space in a building is classified separately. In other words, few buildings are a single hazard classification. For instance, the hazard classifications that would normally apply to a "full service" hotel are as follows:

Guest Rooms	Light
Corridors	Light
Meeting Rooms	Light
Toilet Room	Light
Restaurant Seating	Light
Kitchen	Ordinary Group 1
Parking Garage	Ordinary Group 1
Mechanical Rooms	Ordinary Group 1
Electrical Rooms	Ordinary Group 1
Storage Rooms	Ordinary Group 2
Ballroom	Ordinary Group 2

In the example above, the ballroom in the hotel is classified as an ordinary group 2 hazard, rather than a light hazard, because occasionally the ballroom will be used as an exhibition space. If the sprinkler system protecting the ballroom were designed for a light hazard occupancy, then the hotel would not legally be permitted to use the ballroom as an exhibition space.

While grasping the concept of sprinkler system hazard classification is difficult because of the imprecise manner in which the various hazard classifications are defined, once you become comfortable with the concept, determining hazard classification is normally an easy task. □

Fire Protection

By Richard C. Schulte, Schulte & Associates, Evanston, IL

Nuts and Bolts of Sprinkler Installations — Part IX

Details, Details, Details

A good sprinkler system installation is all about details. This column will take a look at some of the detailed requirements for sprinkler system installations. The sections referenced in NFPA 13 refer to the 1999 edition of NFPA 13, *Installation of Sprinkler Systems*.

Minimum Working Pressure Ratings. NFPA 13 indicates that the rated working pressure of the components of a sprinkler system is required to be a minimum of 175 psi. This requirement means that the rated working pressure of a listed sprinkler is typically 175 psi. Where the working pressures in a sprinkler system will exceed 175 psi, either pressure reducing devices must be installed in the system or sprinklers with a rated working pressure higher than 175 psi must be used. As standard operating procedure, fire departments typically supply sprinkler system fire department connections with 150 psi to avoid exceeding the working pressure ratings of the sprinkler system components. (Section 3-1.2, NFPA 13)

New Sprinklers. NFPA 13 indicates that only new sprinklers are permitted to be installed. The reason for this requirement is just common sense — sprinklers that have been previously installed in another system may be damaged during removal and storage, hence the use of "used" sprinklers is prohibited to avoid water leakage from sprinklers. (Section 3-2.1, NFPA 13)

Small Orifice Sprinklers. NFPA 13 indicates that small orifice sprinklers are only permitted to be used to protect light hazard occupancies. This section also states that small orifice sprinklers are only permitted to be installed in wet systems. (Section 3-2.4.2, NFPA 13)

Escutcheons for Recessed Sprinklers. NFPA 13 indicates that the escutcheons used as part of an installation of recessed or flush-type sprinklers are required to part of a listed sprinkler assembly. In other words, one manufacturer's recessed escutcheons are not permitted to be used with another manufacturer's sprinklers. (Section 3-2.7.2, NFPA 13)

Pipe Identification. NFPA 13 requires that all piping used in a sprinkler system be continuously marked with the manufacturer's name and model designation or schedule. How can a sprinkler system inspector differentiate between schedule 40 steel pipe, schedule 10 steel pipe or a specially listed "thin wall" steel pipe in the field? That's easy — if the pipe is schedule 40, "S40" will be stenciled on the side of the pipe. If the pipe is schedule 10 pipe, "S10" will be stenciled on the side of the pipe and if the piping is a specially listed type of steel pipe, the manufacturer and model will be stenciled on the pipe. Obviously, it doesn't take a rocket scientist to figure out what type of pipe has been installed in a sprinkler system. (The type of steel pipe installed in a system impacts the hydraulics of the piping system, hence, verifying that the proper type of pipe has been installed is extremely important.) (Section 3-3.7, NFPA 13)

Bushings. NFPA 13 prohibits the use of bushings, except where fittings with the outlet sizes required are not available. Although the use of bushing is, in general, prohibited, it is common to see sprinkler installers using bushings. Why? Because sprinkler installers know that most sprinkler inspectors don't know what a bushing is and don't know that the use of bushings is not permitted. (Section 3-5.5, NFPA 13) Note: An exception to the general requirement which prohibits the use of bushings is contained in section 5-13.20.1 in NFPA 13.

Pressure Relief Valves in Gridded Piping Systems. NFPA 13 indicates that a pressure relief valve is required to be installed in gridded piping systems. The relief valve is required to be a minimum of 1/4 inch in size and is required to be set to operate at a pressure of 175 psi or less. (Section 4-1.2, NFPA 13)

Gridded Dry Systems. NFPA 13 indicates that gridded piping systems are not permitted to be used in dry systems. (Sections 4-2.3.2, NFPA 13)

Upright Sprinkler Installation. NFPA 13 indicates that upright sprinklers are required to be installed with the sprinkler frame parallel to the piping on which the sprinkler is installed. Again, this is another common sense requirement — the sprinkler frame and piping below an upright sprinkler both create "shadows" in the sprinkler spray. The sprinkler frame is required to be aligned with the pipe supplying the sprinkler to reduce the width of the "shadows" created in the sprinkler spray. (Section 5-3.1.2, NFPA 13)

Sidewall Spray Sprinklers. NFPA 13 indicates that side-

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wall sprinklers are only permitted to be used to protect light hazard occupancies, unless the sidewall sprinkler is specifically listed to be used to protect ordinary hazard occupancies. Reviewers of shop drawings for sprinkler system installations should always verify that the sidewall sprinklers specified in the shop drawings are specifically listed to protect ordinary hazard occupancies where sidewall sprinklers are used in this application. (Section 5-4.2, NFPA 13)

Location of Sprinklers With Respect to Walls. NFPA 13 indicates that standard pendent and upright sprinklers are required to be installed a minimum of 4 inches from a wall.

Sprinklers are required to be installed so that the sprinkler deflector is parallel to the ceiling above.

(Section 5-6.3.3, NFPA 13)

Sprinkler Deflector Orientation. NFPA 13 indicates that sprinklers are required to be installed so that the sprinkler deflector is parallel to the ceiling above. This requirement applies not only to upright and pendent sprinklers, but also to sidewall sprinklers. (Sections 5-6.4.2 and 5-7.4.2.1, NFPA 13)

Sprinkler Installations in Electrical Equipment Rooms. NFPA 13 specifically indicates that sprinkler protection is required in electrical equipment rooms. An exception to this general requirement permits sprinklers to be omitted from electrical rooms if the electrical room is enclosed in 2-hour construction. See NFPA 13 for additional conditions which must be fulfilled prior to omitting sprinkler protection from electrical rooms. (Section 5-13.11, NFPA 13)

Pipe Drainage. NFPA 13 indicates that sprinkler system installations are required to be installed so that the system can be drained through the main drain. NFPA 13 gets more specific. NFPA 13 states that wet systems are permitted to be installed level, while dry systems are required to be pitched. Branch lines in dry systems are required to be pitched a minimum of 1/2 inch for each 10 feet of pipe length, while mains are required to be pitched 1/4 inch for each 10 feet of pipe length.

NFPA 13 requires that auxiliary drains be provided where offsets in the piping system create “trapped” piping. Where the volume of the trapped piping is less than 5 gallons, an auxiliary drain is permitted to consist of a 1/2-inch plug or nipple and cap. Where the volume of the trapped piping exceeds 5 gallons, a drain valve is required to be provided for the auxiliary drain in a wet system. See NFPA 13 for the requirements for auxiliary drains in dry systems.

An exception to the requirement for auxiliary drains in wet systems indicates that auxiliary drains are not required to be provided in trapped piping which can be drained by removing a single pendent sprinkler. Another exception to the auxiliary drain requirements in wet systems indicates that auxiliary drains are not required in trapped piping which can be drained by disassembling flexible couplings installed in the piping. (Section 5-14.2, NFPA 13) □

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Fire Protection

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Nuts and Bolts of Sprinkler Installations — Part X

Making rational adjustments to flow test data.

The basics of conducting a water supply (flow) test to determine the available water supply from a municipal distribution were discussed in Part V of this series (November 1999 *Plumbing Engineer*, p. 10). Now let's take that discussion one step further.

Most municipal water supply systems consist of pumps and some form of elevated water storage. During the day and early evening, when the demand for water is "high," the pumps at the water treatment plant are unable to keep up with the demand and water flows out of the elevated storage to meet the excess demand for water. At night, when the demand for water is lower than during the day, the capacity of the pumps at the water treatment plant exceeds the demand for water and the excess water being pumped flows into the elevated storage until the storage is full. This cycle of filling and emptying of the water storage is repeated on a daily basis.

The pressures available in a municipal distribution system are directly related to the elevation of the water in the elevated storage. Because water flows out of storage during the day and early evening, the elevation of the water storage is reduced during the day. Conversely, since water flows into storage during the evening, the elevation of the water storage increases during the night. Based upon this, the pressures available in a municipal distribution system typically fluctuate in a range determined by the fluctuation in the elevation of the water storage in the system.

The operation of a municipal water system described above has a direct impact on the design of sprinkler systems. Explanatory information contained in Appendix A in NFPA 13 reads as follows:

> *"The authority having jurisdiction shall be permitted to require an adjustment to the water flow test data to account for daily and seasonal fluctuations, possible interruption by flood or ice conditions, large simultaneous industrial use, future demand on the water supply system, or any other condition that could affect the water supply."*

A water supply (flow) test is simply a measure of the flows and pressures available from a municipal distribution system at the time the test is conducted. In other words, a flow test is just a snapshot of the water supply system. In order for the results of the flow test to be meaningful, they must be adjusted to account for the daily and seasonal fluctuations in the pressures in the distribution system, but how does an engineer (or an enforcing authority) make these adjustments? The answer to this question is based upon how a municipal water supply system operates.

Obviously, the greatest operating pressure in the system is available when the elevated storage is at full capacity — typically in the early morning. As people use water, the elevated storage drains to keep up with demand and the operating pressures in the system drop. Water utilities keep tabs on the elevation of the water in storage, so determining the typical range of pressure fluctuations on a daily basis is as simple as contacting the water utility and asking.

NFPA 13 also suggests that the results of water supply tests be adjusted for seasonal fluctuations. Again, because water utilities maintain records of the operating pressure in their system, the low water pressures due to seasonal fluctuations can be determined by simply contacting the water utility and researching the water utility's records. In the East and Midwest, the seasonal low pressures normally occur in July or August in the early evening when people are watering their lawns.

In many areas in the country, such as the Midwest, droughts occur with some regularity. Given that, the results of water supply tests should also be adjusted for drought conditions. Again, the fluctuation in the operating pressures due to droughts can be determining by contacting the water utility and researching the water company's records.

Let's look at an example to illustrate how to make an adjustment to water supply data. Assume that the results of a flow test conducted on April 4, 2000, at 7:30 a.m. are as follows:

Static pressure: 52 psi
Residual pressure: 45 psi with 720 gpm flowing

Given that the flow test was conducted in the early morning, it is likely that the static pressure in the distribution system will be lower later in the day. Also, given that the test was conducted in early April, it is probable that the static pressure in the system will be lower during the summer months. Given this, basing the design of a sprinkler system on the water supply test data indicated above without adjustment could produce a system which is inadequately designed based on NFPA 13 requirements. (It should be noted that indicating that the system may be inadequately designed based on NFPA 13 requirements is different from saying that the system may be inadequate to control a fire.

NFPA 13 contains a number of factors of safety which could compensate for a system design which is hydraulically deficient due to fluctuations in the water supply.)

To adjust the "raw" water supply test data for the fluctuations in pressures within the system, we first need to know the elevation differences between the elevated storage and the test hydrant. For purposes of this example, let's assume that the elevated storage is a tank (rather than a reservoir) and that the elevation of the base of the tank riser is 100 feet. Let's also assume that the elevation of the outlet of the test hydrant used in the water supply test is located at elevation 82 feet. In other words, the elevation of the test hydrant outlet is 18 feet lower than the elevation of the base of the elevation tank riser. Given that, the elevation pressure difference between the base of the tank riser and the test hydrant is approximately 7.8 psi. (The factor used to convert elevation change in feet to elevation change measured in pressure is 0.433 psi per foot of elevation change.)

If the top of the elevated tank is 106 feet above the base of the tank riser and the low water level in the tank during the summer months is 80 feet above the base of the tank riser, the pressure produced by the water in the elevated tank varies from approximately 45.9 psi (when the tank is full) to 34.6 psi (at the low water level in the tank) measured at the base of the tank riser. Based on this, the static pressure at the hydrant will vary between 53.7 psi and 42.4 psi (assuming no friction loss between the tank riser and the test hydrant).

After checking with the water utility, let's assume that it was determined that the pressure at the water plant at the time the water supply test was conducted was 45 psi (measured at the base of the elevated tank riser). Based on that, it can be determined that the difference in pressure at the water plant at the time of the test and the pressure at the low water level in the tank is 10.4 psi (45 psi minus 34.6 psi). Hence, in order to adjust the flow test data indicated above for the pressures available during the summer, at least 10.4 psi should be subtracted from both the static and residual pressure readings in the flow test.

Water supply data to be used in a sprinkler installation should be determined by either the enforcing authority or specified by an engineer (or preferably both), rather than a contractor.

The adjusted flow test results would then be as follows:

Static pressure: 41.6 psi
Residual pressure: 34.6 psi with 720 gpm flowing

When the results of both tests are graphed on hydraulic (semi-log) graph paper, this set of flow test data produces a line parallel to the unadjusted flow test data. Actually, given the increased flows in the distribution system during the summer, it is likely that the pressures and the flow indicated above will be slightly less than indicated above, however, the adjustment to the flow test results will produce a far better approximation of the water supply available during the summer months than simply using the unadjusted flow test results.

Obviously, it is unrealistic to expect contractors to make adjustments to water supply data when bidding on a sprinkler installation. After all, if not every contractor bidding on a sprinkler installation is going to adjust the flow test results, then it is difficult for any contractor to make adjustment to the flow test results. That's why the water supply data to be used in a sprinkler installation should be determined by either the enforcing authority or specified by an engineer (or preferably both), rather than a contractor.

Please note the calculations above have been rounded to the tenth of a psi to enhance the understanding of the methodology used to make adjustment to the flow test results. Under real world conditions, it is not possible to read pressure gauges accurately to the tenth of a psi. □

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