Fire sprinkler system design guidelines

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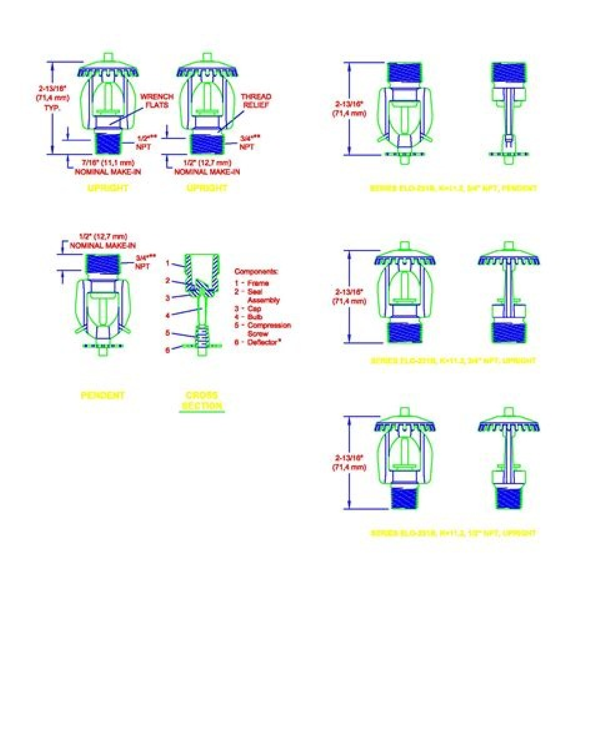

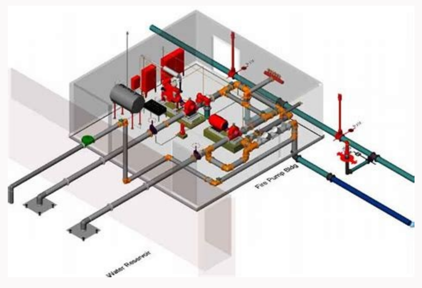

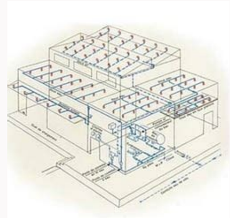

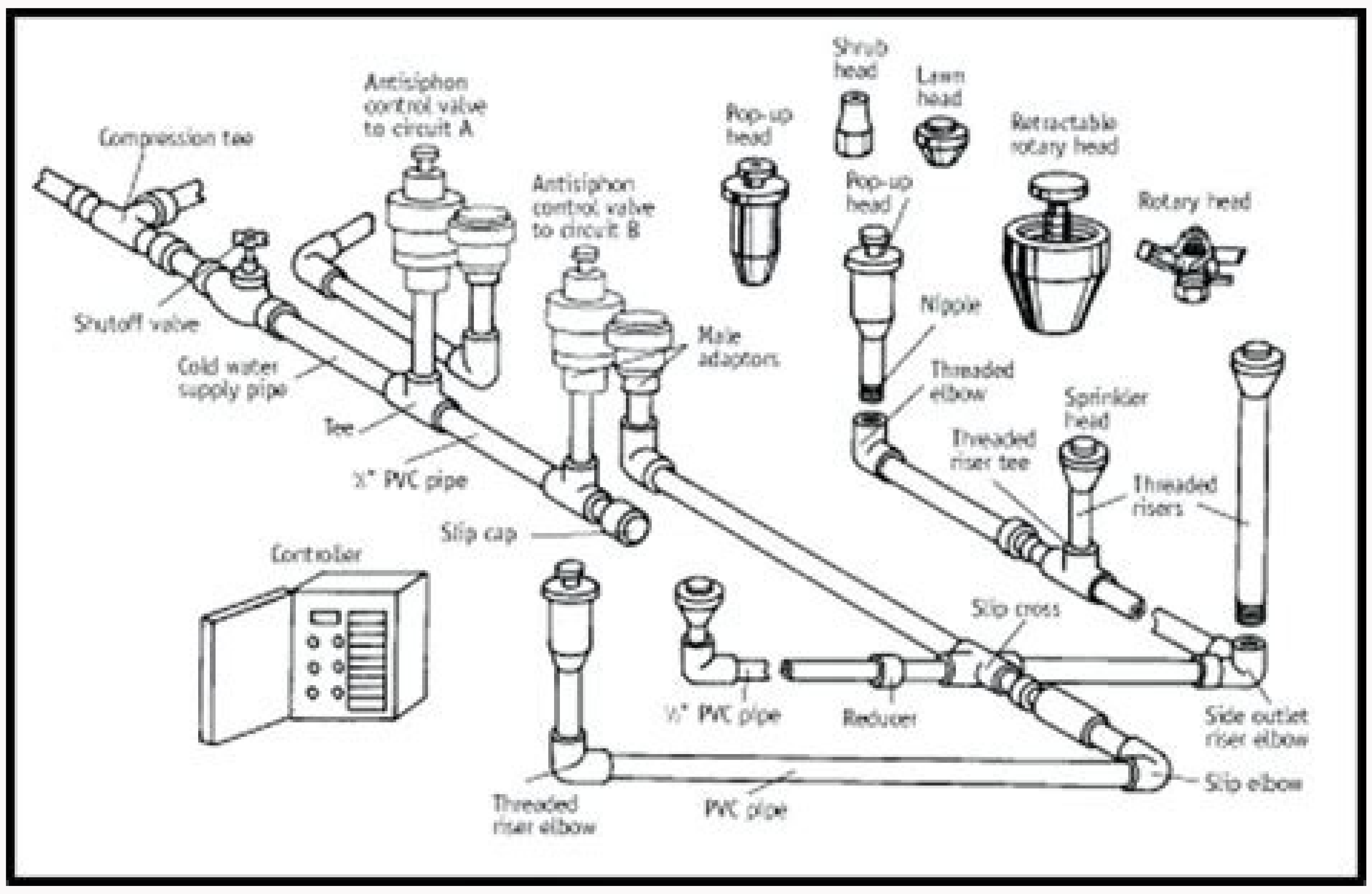

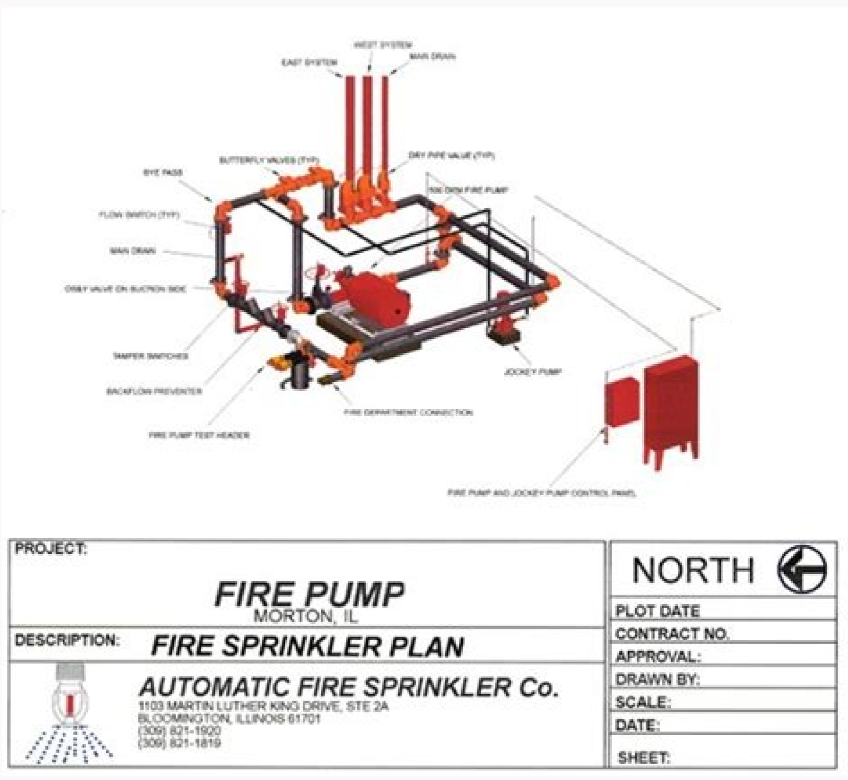

Fire sprinkler system design standards. Fire sprinkler system testing requirements. Fire sprinkler system design examples.

Open navigation This article was originally published as part of The impact of automatic sprinklers on building design, an independent report produced by WSP, sponsored by the Business Sprinkler Alliance (BSA), published in September 2017. General Automatic sprinkler systems extinguish or control fires by discharging water locally. Detection is handled mechanically by heat sensitive elements which can be constructed from soldered links or glass bulbs containing oil based liquids. The thermal element holds in place a plug which prevents water from flowing from the sprinkler head. The thermal elements respond to localised heating which acts to release the plug and allow water to flow. Key facts about their operation are: An automatic sprinkler system consists of water supply (tank, pump and valves) and sprinkler installation (pipes and heads). The specifications of the design depend primarily on the hazard classification of the occupancy of the building. The specifications include head spacing dimensions, assumed area of maximum operation (number of heads in-operation), design density (water discharge), water supply period, and tank volume. Automatic sprinkler system design The automatic sprinkler standards applicable at the time of writing this document are: Alternative systems Automatic sprinkler system designs can be adopted to suit a specific fire safety objective. Sprinklers are typically installed throughout a building, whereas drenchers are placed to address a specific risk such as on glazing as an alternative to fire rated glass, or on a structure as an alternative to passive fire protection. The principle was applied at a Hong Kong Air Cargo Handling Facility [2] where hollow structural members were water-cooled internally to reduce maintenance requirements and cost associated with passive fire protection. The design was justified using fire engineering methodologies. A performance-based approach to fire engineering design allowed fire safety to be addressed to meet clear performance requirements rather than the traditional prescriptive approach. References [1] PD 7974-7: 2003 Application of fire safety engineering principles to the design of buildings — Part 7: Probabilistic risk assessment [2] Water-Cooled Roof Incorporating Sprinklers into the Structure: Hong Kong Air Cargo Handling Facility, Lovell, T. and Bressington, P. (2001) 282001%2987 --Business Sprinkler Alliance Related articles on Designing Buildings NFPA 13 is the American standard for the design and installation of automatic fire sprinkler systems. A constantly evolving standard Sprinkler systems first appeared in the middle of the 19th century in the United States of America. In 1895, a working party of system installation engineers and insurers published a document aimed at harmonising practices and the equipment used along the US east coast with a view to improving system reliability. This document, now known as NFPA 13, marked the beginning of the National Fire Protection Association whose purpose and operation have remained close to their original goals: to provide reliable fire protection regulations that are recognised by insurers and installers alike. NFPA 13 is revised every three to five years based on feedback and research conducted by the NFPA. Completely rewritten in 1991, the latest edition totals almost 500 pages. Definitions and general requirements The first part of NFPA 13 defines all the components and hardware used in an automatic sprinkler-type fire extinguishing system: sprinkler, valves, piping, etc. The standard lays down: – The required characteristics: materials, certification, acceptable pressure, etc. – Installation regulations: sprinkler head layout and spacing, consideration of obstructions, etc. – Pipe hanging and bracing regulations – Piping system design regulations: hydraulic calculations Activity and commodity classification NFPA 13 classifies the premises to be protected according to the level of risk they represent: – Low risk: little combustible material present – Ordinary risk: moderate amount of combustible material present and a limited storage height – High risk: high amount of combustible material or combustible or flammable liquids present The risks linked to commodity storage are subsequently ranked by NFPA 13 into four classes, from least to most vulnerable to fire. These classes are determined both by the contents and the container (cardboard boxes, pallets, plastic film, etc.). Finally, some activities are considered as special risks such as chemical storeage, aircraft hangars, etc. Protection principles NFPA 13 gives protection recommendations appropriate to the established risk classification: – Density of water to be applied and surface area covered by ceiling-mounted protection – Sprinkler installation in racks for commodity storage – Zone to be protected specifically for special risks – System autonomy. Conclusion NFPA 13 is recognised today as an industry benchmark by insurance companies all over the world. It is an extremely comprehensive standard in terms of the technical aspects and fire risks covered and demanding in its application. Its practical implementation therefore calls for solid experience in design. Fire sprinkler systems save lives. When a fire breaks out, standard spray sprinklers control the blaze by cooling and wetting surfaces to deprive it of fuel sources and prevent flashover, the sudden ignition of everything in a room when it reaches autoignition temperature. Some sprinkler types in specific systems take this further—they're designed to completely suppress a fire in more challenging environments like storage facilities. But how are fire sprinkler systems designed, from head types to pipe to pressure? It's a pretty complicated process, so we obviously can't explain everything. But this article gives an overview of the basic steps of fire sprinkler system design, including: At each step, we explain broadly what a designer has to do, including the calculations (financial and technical) involved. We'll frequently refer to NFPA 13: Standard for the Installation of Sprinkler Systems (2019 edition), the document adopted by jurisdictions that govern commercial fire sprinkler system design. Fire sprinkler design is a detailed process, and designers are highly skilled and qualified professionals. They frequently hold a Professional Engineer (PE) certification and meet local and state licensing standards. Jurisdictions often defer testing and licensing for sprinkler system layout to the National Institute for Certification in Engineering Technologies (NICET). Usually, at least a NICET Level III Water-Based System Layout certification is required to work without supervision as a sprinkler system designer. Fire sprinkler systems are complicated, as is fire protection. If you have questions, we have answers. Our Ask a Fire Pro service lets you submit inquiries to fire protection professionals. In three business days or less, they'll respond with an easy-to-understand answer based on technical expertise and relevant laws and model codes and standards. Submit your questions today! Start with the basics—determining the water supply Sprinkler system design begins with water— everything else depends on having enough of it ready to control a fire. NFPA 13 requires an automatic water supply for sprinkler systems (5.1.2), meaning that the water will flow through sprinkler heads without any human intervention. Many possible sources can be used, including city water, ponds, rivers, reservoirs, water tanks, pressure tanks, and gravity tanks or water towers. But in most cases, a municipal waterworks is the go-to supply. Whatever the source, it must have sufficient capacity for fire control (5.1.3). The factors that determine capacity include flow rate (in gallons per minute, GPM), pressure (in pounds per square inch, PSI), and duration (how long it can maintain the required pressure and flow). For a municipal water supply, capacity is determined with a flow test performed at nearby fire hydrants. A flow test requires at least two hydrants, A and B. First, a static pressure reading is taken at hydrant A while neither hydrant is flowing water. Then, hydrant B is opened wide and another pressure reading is taken at hydrant A. This residual pressure reading is the amount of pressure that can push water through sprinkler heads (minus some losses). A pitot tool is used to measure the pressure of the water flowing from hydrant B. In this video, Grapevine, TX's fire department shows how to conduct a flow test: This value is used to calculated flow as follows: Q=29.83 x C x d2 x With: Q = flow rate (GPM) C = C-factor, the roughness coefficient of the hydrant outlet d = inside diameter of the outlet P = pressure observed at hydrant B The water supply capacity is the foundation of sprinkler system design. Many of the steps following this one are all about ensuring hydraulic demands won't exceed this capacity. Designers choose pipes and sprinklers to make the hydraulic calculations work out. If they can't do it with the available flow and pressure, they have to resort to using a fire pump (which may cost tens of thousands of dollars) to boost the water supply. Check out our blog for more information about tools and kits used for flow tests. If you are conducting flow tests, shop for test kits, pitot gauges, and hydrant wrenches. Know the building—what kind of sprinkler system does it need? If the first step of sprinkler system design is knowing the water supply, the second is understanding the building. Sprinkler system designers sit down with the architectural and engineering plans to sort out just what the building needs from a sprinkler system. Is it a residential structure? Industrial? How significant is the fuel load? Will it have climate control? Questions like these. determine the requirements the system should meet and what kind of sprinkler system is appropriate. NFPA 13, NFPA 13R, or NFPA 13D—which standard to use? As mentioned, NFPA 13 is the go-to standard for commercial sprinkler system design. NFPA 13-compliant systems are defined by full sprinkler coverage. The standard is typically used in commercial facilities—offices, mercantile spaces, warehouses, industrial buildings, etc. Two alternatives to NFPA 13 exist: NFPA 13R: Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies NFPA 13D: Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes. NFPA 13R and NFPA 13D both focus on affordable and convenient life safety protection, so they don't require sprinklers in unoccupied spaces like closets and attics. But in some larger residential settings, a full-coverage NFPA 13 system is still used. Does the building need a wet, dry, or preaction system? In addition to determining the standard, designers also have to figure out whether a building needs a wet pipe system, dry pipe system, or preaction sprinkler system. Most buildings simply use a wet sprinkler system in which water fills the pipes at all times. As soon as a sprinkler head operates, water flows. Structures like parking garages where freezing is a concern need dry pipe systems, so named for the absence of water in the pipes. A dry valve, held shut by a pressurized gas, stops the water in an insulated section of the pipe until its needed. When a sprinkler head activates, the gas depressurizes, the dry valve opens, and water flows. Parking garages and other structures without climate control often use dry sprinkler systems to prevent water in pipes from freezing. Image source: ArmourCo Where the cost of an accidental discharge would be severe (such as in an art gallery), a preaction system may be used. Water is held back by a preaction valve, which may also function as a dry valve. Activation also relies on a separate trigger, such as electric input from a smoke or heat detector, providing another layer of control over whether the water flows from sprinklers. Know the building—how much water is needed for fire sprinkler design, including the hazard level? How much water does it take to control a fire? This depends on many factors, including the size of the fire and the type of fuel. Three conceptual tools help designers plan systems that can produce sufficient water flow and pressure: occupancy hazard, design area, and density/area curves. Occupancy hazard NFPA 13 groups (4.3) buildings or portions of buildings into occupancy hazards, helping designers estimate the fuel load and thus the water demands. The assignment of an occupancy hazard depends on several factors explained in NFPA 13: 19.3.1.2.3 Occupancies or portions of occupancies shall be classified according to the quantity and combustibility of contents, the expected rates of heat release, the total potential for the energy release, the heights of stockpiles, and the presence of flammable and combustible liquids, using the definitions contained in 4.3.2 through 4.3.7. Warehouses—like the Redlands warehouse near Los Angeles that burned June 5, 2020—have special hydraulic needs. The occupancy hazard concept helps designers plan systems that can meet a facility's hydraulic needs. Image source: KTLA via Redlands Community News NFPA 13's hazard classifications are (19.3.1.2.4): Light Hazard Ordinary Hazard (Group 1) Ordinary Hazard (Group 2) Extra Hazard (Group 1) Extra Hazard (Group 2) Special occupancy hazard (including storage) It's important to note that NFPA 13's occupancy hazard categories apply only to the design of sprinkler systems and "shall not be intended to be a general classification of occupancy hazards" (4.3.1.2). NFPA 101: Life Safety Code also groups buildings into occupancy hazards, but these classifications are different; they're related to threats to life, not fuel load. Design area The design area concept lets designers select a worst-case scenario part of their building to base the whole system around. As with hazard level, "worst-case scenario" refers to hydraulics. The design area is a "hydraulically challenging" location, usually because of high elevation and/or its distance from the fire sprinkler riser. The design area concept is used because it would be impractical to supply every fire sprinkler with water at once. Identifying a design area isn't always straightforward, so layout professionals often perform calculations for multiple areas to find the one with the highest demand. NFPA 13 has various rules for the selection of the design area. Density/area curves Designers use the hazard level and design area to determine how much water they need with density/area curves. "How much water" means water density—gallons per minute per square foot (GPM/ft2). When designers know the hazard level of their building and the size of the design area, they can use the density-area curves (19.3.3.1.1) provided by NFPA 13 to determine the exact required water density. Once the design area density is determined from the curve, calculating the total required flow is simple. Flow (GPM) is density times area. NFPA 13's density/area curves let designers determine the required water density based on design area size and hazard level. In this case, a 2500-ft.2 design area in extra hazard group 1 requires 0.30 GPM/ft.2. Graph source: NFPA 13 Laying out sprinkler system components—sprinkler heads Sprinkler system design is an iterative process. Designers have to tentatively plan a set-up and then check the math to see if the hydraulic calculations work out. One part of this process involves laying out and sizing the sprinkler heads. Laying out sprinkler heads and determining their coverage area in fire sprinkler design To know how much density a sprinkler can deliver, a designer must first determine the area it covers. They follow guidelines from NFPA 13 to ensure that sprinklers cover an appropriate amount of space. Tables 10.2.4.2.1(a-d) tell how far apart, on center, standard-spray upright and pendent sprinklers can be. The max distance is 15 ft., but this is reduced in many situations. Whatever distance between sprinklers is allowed, the heads can be no more than half that distance (10.2.5.2.1) from the walls. So, the max length from a sprinkler to a wall is 7.5 ft. Designers mark the location of sprinklers and pipes on the plans based on these rules and then determine how much space each head protects according to NFPA 13's rules. There is a limit to how much floor space one sprinkler can reasonably cover. These maximum protection areas for standard spray sprinklers are also laid out in Tables 10.2.4.2.1(a-d); the biggest possible value is 225 ft.2, but this is only applicable in noncombustible unobstructed spaces. (And note that different types of sprinklers, such as extended coverage, have different rules and values.) Protection area, As is calculated with the formula As=S x L (9.5.2.1). Along the branch line, S is the larger of either: The distance to the closest sprinkler Twice the distance to the closest obstruction or wall The value of L is determined in the same way but perpendicular to the branch line (e.g., in the direction of the next branch line). Sprinkler K-factor determines the flow a sprinkler can produce Sprinkler system designers have a lot of sprinklers to choose from when designing a system. There is an incredible array of temperature ratings, finishes, and performance characteristics available. But when it comes to the hydraulics of sprinkler system design, perhaps the most critical sprinkler spec is K-factor, which is essentially its orifice size. Every sprinkler has a defined K-factor, which describes how much flow (GPM) it can produce at a given pressure (psi). Common K-factor values include 2.8, 5.6, and 8.0. The relationship between K-factor, flow (q), and pressure (p) is: $K=q/\sqrt{p}$ Designers often select a common K-factor and check to see if they can achieve the required flow with the available pressure. If they can't, they may choose another K-factor. Or, they may change something about the pipes to boost the available pressure. For more information on fire sprinklers, check out our articles on maximum and minimum sprinkler distances and different sprinkler head specifications. Also, feel free to browse our selection of commercial fire sprinklers, fire sprinkler escutcheons, and installation tools. Laying out system components—pipes, fittings, and hydraulic calculations in fire sprinkler design When designers lay out a sprinkler system on paper (or digitally, nowadays), they mark where the pipes will go and decide their size and material. Pipe selection affects hydraulic calculations, cost, corrosion resistance, and more. The flow test only tells designers how much pressure is available from the source and at the base of the system riser. They have less to work with at the sprinkler heads because of head loss. Head loss is the loss of pressure due to resistance as fluid flows in pipes from its source to its destination. Three kinds of resistance create head loss—gravity, friction, and turbulence. Designers can't fight the effects of gravity unless they use pumps; no matter the pipes' diameter, 0.433 psi is lost for every vertical foot. But they can and do select pipes, fittings, and devices to reduce the head loss from friction and turbulence. Pipe selection and friction loss The friction of water against the walls of the pipe fights against the pressure from the water supply. The size of the friction force depends on three factors: The rate of flow (q) The empirical roughness of the pipes (C; small C means rough pipe) The diameter of the pipes (d) Designers use the Hazen-Williams formula (27.2.2.1.1) to calculate pressure loss per foot of pipe (p): p = (4.52Q1.85) ÷ (C1.85d4.87) Selecting appropriate pipe materials and sizes helps minimize friction losses. If hydraulic calculations reveal that a sprinkler head in the design area won't get enough pressure to produce the design density, the pipes' size can be increased to reduce pressure loss. Pipe material also affects the pressure losses. C-value describes the roughness of the pipe, and pipe made of copper (C=150) or CPVC (C=150), for example, is smoother than one made of unlined cast iron (C=100). With pipe size and material, there are considerations other than the hydraulic calculations. Up-front and long-term costs are also important things to think about. Bigger pipe costs more, and copper pipe costs more than thermoplastics, for example. Nonmetallic pipes like CPVC also have unique concerns regarding exposure and melting and can only be used in specific settings. Balancing cost and function is a major part of a fire sprinkler system designer's job. Devices and fittings and turbulence loss Turbulence also creates pressure loss. Devices (such as valves) and fittings (like elbows and tees) create turbulence that, in turn, decreases the amount of pressure available downstream. Turbulence occurs when water is forced to change direction or pass through small orifices. The math behind turbulence loss is complicated, but NFPA 13 allows designers to estimate head loss from devices and fittings in terms of equivalent feet of pipe (27.2.3.1.1). Tables from either NFPA 13 or manufacturer data indicate what length of pipe will create the same head loss that a particular device or fitting makes. Backflow preventers are frequently unavoidable sources of pressure loss from turbulence. There are pressure-eating devices that can't be left out of the equation. For instance, backflow preventers are frequently required to prevent the contamination of municipal water supplies. If the city supply loses pressure for whatever reason, stagnant water in a fire sprinkler system could flow backward, contaminating potable water. Backflow preventers tend to create large head losses, but this is unavoidable where they are required. Fire sprinkler system design takes a pro Designing fire sprinkler systems involves many elements. Designers check the water supply, identify building needs, lay out pipes and sprinklers, and perform hydraulic calculations. It's a complicated process, and we've barely scratched the surface in this article. Sprinkler systems definitively save lives and property, but they only work as intended when they're well-engineered and up to code. Always rely on a licensed professional to design a fire sprinkler system. And note that different states and municipalities may have additional requirements from what's specified in NFPA 13. A widely accepted credential is the NICET Level III certification in Water-Based System Layout, which qualifies a designer to work without supervision. If you're interested in becoming a sprinkler system designer, an excellent place to start is on-the-job-training in a design, pipe-fitting, or sprinkler installation firm, along with an engineering degree and eventual certification. Due to the complexities of these systems, as well as the codes and standards that govern them, fire protection often requires expert advice. If you have tough technical problems with a sprinkler system, detection and alarm set-up, or other fire protection system, you need to Ask a Fire Pro. This QRFS service lets you submit questions to experts who will respond with a researched, actionable, and understandable answer in three business days or less. Try it out today! This blog was originally posted at blog.qrfs.com. If this article helped you, check us out at Facebook.com/QuickResponseFireSupply or on Twitter @QuickResponseFS.

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