*A SunCam online continuing education course*

# What Every Engineer Should Know About Fire Protection

By

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## 1.0 Introduction

This course is intended to provide a thorough background of information about all types of fire protection systems for buildings. The intent is to educate design engineers and facilities engineering personnel who design, work or interact around systems that are intended to protect buildings from fi,re primarily under the guidelines of NFPA 13, 13D, and 13R. In most cases, this includes the different types of building sprinkler systems, but will also include chemical systems and other specialized fire protection systems. In this course, we will briefly touch on the history of sprinklers, discuss the various types of modern sprinklers, understand the code classification of the occupancies, design concepts, system layouts, components, and special systems. A separate section is provided to discuss the complexities of storage classifications.

This course is not intended to teach students how to specify, design and install fire protection, but rather, it is to provide an understanding as to how fire systems work to protect a structure and how they safeguard the people who occupy that structure in the event of a fire occurrence.

Although there is material on chemical systems for fire protection, this course is primarily focused on the use of "water" when fighting a fire. NFPA 13 determines how much water is needed to fight a fire, as well as how it is to be distributed over a fire area.

Why water? From a thermodynamic and chemical standpoint, a fire is a self-sustaining reaction. However, for it to be self-sustaining, the fuel must be maintained at a minimum temperature, with an adequate supply of oxygen.

Water has a high heat capacity. Water consumes heat in the process of changing from a liquid to a gas. Therefore, water will effectively absorb a great amount of heat produced by the fire reaction, decreasing the temperature of the materials involved in the reaction. If the temperature falls below the minimum required to sustain that fire, it will extinguish.

The second effect is that there will be a thin layer of water between the burning materials and the surrounding air. The fire needs oxygen as well as a fuel. The water vapor consists of hydrogen and oxygen with a strong bond that cannot be broken by a fire. Therefore, the thin layer of water acts as a blanket, separating the fire from the oxygen.

  

## 2.0 Overview

NFPA 13 is the worldwide standard for the design and installation of automatic fire sprinkler systems. It reflects the input of many industry stakeholders whose interest is in creating the highest standards possible to help ensure the proper functioning of water-based sprinkler systems. NFPA 13D is the code used for one and two family dwellings, and NFPA 13R is the code utilized for multifamily residential occupancies up to and including four stories in height.

It differs from most other codes, which are the product of a singular point of view – a building code official, for example. NFPA 13 is continually updated and new technologies, testing results and actual fire experiences are used to make those updates.

Although various types of fire protection systems have been used dating back to the 1600's, the first fully automatic sprinkler head was patented in 1872. Successive improvements came along over the next few years until 1881 when Frederick Grinnell invented the earliest generation of the modern sprinkler head that is used in the majority of today's buildings. In 1890, he invented the glass disc sprinkler, which is essentially the same as the modern frangible bulb sprinkler in service today.

Over the next few years, insurers such as the parent companies of Factory Mutual, drove the requirement for installation of sprinklers in buildings. Competing standards immediately caused problems with building owners until 1896, when the National Fire Protection Association was formed and NFPA 13, *Standard for the Installation of Sprinkler Systems* was adopted. Today it is considered the worldwide standard for the installation of sprinklers and other types of fire protection systems.

NFPA 13 incorporates the highest possible standards to help ensure the proper functioning of water-based sprinkler systems. It is written with the assumption that the sprinkler system is designed to protect against a single fire originating within a structure, and is primarily focused toward those who specify, design and install the systems, such as architects, engineers, and contractors.

Among other things, the goal of NFPA 13 is to avoid the under-design of a fire alarm system, which would create unwanted risk, and to avoid the over-design of the system which is costly, with little technical support for that design..

  

NFPA 13 is organized into 27 chapters, each relating to a different topic, and several Annexes that contain supplemental information. Chapters 1-4 are foundation chapters that include administrative information such as the scope and purpose of NFPA 13; other publications that are referenced in the standard such as government-issued and other NFPA documents, definitions of terms used in the standard and general sprinkler system requirements.

Chapter 1 lays out the scope and purpose of NFPA 13:

1. The rules and requirements are intended to protect against a single fire in the building.
2. Requirements are considered "reasonable" from an economics standpoint that takes into account cost vs. risk.
3. With some exceptions, new requirements are not considered retroactive in existing systems that were installed in a previous version of the code.
4. The Authority Having Jurisdiction has the ultimate authority to approve alternatives in design and installation.

## 2.1 Authority Having Jurisdiction

The phrase "authority having jurisdiction" or its acronym, AHJ, is found frequently throughout the standard. It is defined as an organization, office, or individual responsible for enforcing the requirements of a code or standard, in this case, NFPA 13. The AHJ can be a governmental enforcer, such as a fire marshal or building inspector. Insurers also play the role of AHJ when specifying requirements that must be met by the building owner to obtain insurance. In some cases, the AHJ can be the owner or the owner's representative, such as an architect or general contractor. It is common for multiple authorities having jurisdiction to be involved with the same project.

## 2.2 Important Definitions

Although NFPA Chapter 3 lists the definitions of terminology in the code, of particular note, in addition to the definition of the AHJ, are the terms "approved" and "listed".

"Approved" means that equipment, materials, or services are acceptable to the Authority Having Jurisdiction.

  

“Listed” means that equipment, materials, or services are included in a list that is published by an organization that is acceptable to the AHJ, is concerned with the evaluation of products and services, maintains periodic inspection, and whose listing meets designated standards or has been tested and determined suitable.

Listing is a very important concept. Many products are marketed as being equal to each other, but if a product is not listed as being a suitable component in a fire protection installation, it is a code violation if installed.

## 3.0 Types of Sprinkler Systems

### 3.1 Wet Pipe Systems

A wet pipe system is defined as a system that employs automatic sprinklers that are attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire. This type of system is by far the most common system in use and is utilized in offices, hotels, warehouses, most factories, and anywhere that is not normally below freezing temperatures.

### 3.2 Dry Pipe Systems

Similar to wet pipe systems, this is a system of automatic sprinklers that are attached to a piping system that is normally filled with air or nitrogen that is under pressure. When the sprinkler frangible bulb breaks in a fire, the gaseous volume is released, and the subsequent drop in pressure permits water to trip a “dry-pipe”valve open, and water then flows through the piping system and out the opened sprinkler(s). Dry pipe systems are used most commonly in areas that are subject to freezing.

Dry pipe systems utilize a small air compressor to maintain enough pressure in the pipe to prevent the dry-pipe water valve from tripping, and this compressor is small enough that if a sprinkler head opens it would be unable to maintain air pressue that would prevent the release of the water valve.

### 3.3 Pre-Action Systems

A pre-action system also utilizes a dry piping network and automatic sprinklers, but the piping may or may not be under pressure. In this type of system there is a supplemental automatic fire detection system (heat detectors, smoke detectors, flame detectors, etc) in the space where the pre-action system is located. If the detector senses heat, smoke, or flame, it releases the dry-pipe water valve and sends an alarm to the fire-alarm control panel. Water will not be released unless a sprinkler head opens.

This type of system is also referred to as a "double-locked" system.

Conversely, if a head is open for any reason, water will not flow past the dry-pipe valve unless a fire detection device has sensed that there is a problem.

This type of system is mostly used in computer data centers, or telecommunications facilities, or any other commercial/industrial space where the risk of accidental water discharge would have enormous financial implications.

Even in a pre-action system, some facilities utilize "cross-zoned" detectors where it would require two detectors in the space to be in alarm before the dry-pipe water valve is tripped.

### 3.4 Deluge Systems

A deluge system utilizes a dry piping network but the sprinklers have open orifices. When a smoke, heat, or flame condition is presented, the automatic fire detection device or devices opens the dry-type water valve and water flows to and through all sprinklers on the deluge system. There are certain building occupancies where this type of system is required, notably, multi level atriums, aircraft hangars, certain places of assembly, flammable liquid storage areas, and any area where there is the potential for a fast fire.

**Figure 1 - Sprinkler Head for a Deluge System**

  

### 3.5 Combined Dry Pipe Pre-Action Systems

As mentioned earlier, a pre-action system may have piping that is normally under pressure. In this case it is sometimes referred to as a "combined system". When this system allows its water to be released, it also opens an exhaust valve to release the air pressure in the system, thus allowing the piping network to be completely flooded.

### 3.6 Antifreeze Systems

As its name implies, this is an alternate system to a dry pipe system where the piping contains an antifreeze solution that is discharged first and then followed by the water. These systems are much simpler than dry pipes, and are typically used in loading docks, porch canopies and small unheated spaces.

In 2012, antifreeze solutions used in sprinkler piping are required to be listed for non-flammability characteristics. Testing is required for solutions installed prior to 2012 and in accordance with NFPA 25.

### 3.7 Waterless Systems

In the event of a fire, sprinkler systems are undoubtedly the most effective tool for extinguishing the fire and limiting the loss of life and structural damage to the building. However, most businesses and structures have at least one key area containing valuable and sensitive equipment such as computers, telecommunication systems, and other vulnerable physical assets. These areas need a different kind of protection since they are just as likely to be irreparably damaged by the water used to extinguish the threatening fire as by the fire itself, thereby causing the business catastrophic losses of time, technology, and equipment needed during clean-up, repair, and restoration.

Waterless systems consist of either an inert gas such as FM-200 (DuPont's tradename for HFC-227), which displaces a percentage of the oxygen in the air, or they utilize a chemical agent, such as carbon dioxide. Fires are quickly and safely detected and extinguished, eliminating the typical water, smoke, and fire damage common after conflagrations are extinguished by the use of sprinkler systems. When smoke or heat detectors are activated, controls are enabled, and the area is flooded with the agent. There may be some cleanup involved based on the type of chemicals used, but the loss of valuable equipment and paper is minimized.

  

Dry waterless systems are significantly more expensive than either wet or dry sprinklers, but the decision to use these methods is offset by the potential loss of valuables.

Nearly all jurisdictions in the United States will require wet protection systems in addition to the chemical systems if there is water available to the site. This water will be a back-up system in the protected space in case the chemical agents did not fully extinguish the fire.

### 3.8 Water Mist Systems

A water mist system is a fire protection system that uses a very fine droplet water spray. The small water droplets act as a mist, suppressing or extinguishing a fire by rapidly cooling the flame through evaporation, and eventually displacing the oxygen away from the source of combustion.

The effectiveness of a water mist system in fire suppression depends on its spray characteristics, which include the droplet size, distribution, flux density, and spray dynamics, with respect to the fire scenario, such as the shielding of the fuel, fire size, and ventilation conditions.

The use of water mist fire suppression, when compared to the use of gaseous agents and traditional sprinkler systems, has revealed advantages such as:

- Immediate activation
- High efficiency in the suppression of a wide variety of fires
- Minimized water damage
- Environmentally sound characteristics
- No toxic problems

The NFPA 750 regulates the use of mist systems. They are not common due to the high initial cost as well as high maintenance costs. These systems are typically located in historically important architectural buildings, or facilities that house priceless treasures such as museums.

## 4.0 Sprinkler Head Types

Automatic Sprinkler Definition:

As defined by the *NFPA Fire Protection Handbook*, an automatic sprinkler is a thermo-sensitive device designed to react at a predetermined temperature by automatically releasing a stream of water and distributing it in specified patterns and quantities over designated areas.

  

Modern sprinklers have deflectors that deliver a wide even pattern of spray. “Old style” sprinklers have a more narrow pattern and are, with few exceptions, not allowed in new installations.

All sprinklers are marked with their temperature rating and year of manufacture.

### 4.1 Upright Sprinklers

Upright sprinklers are the most common types found in buildings where there is not a dropped or lay-in ceiling. These sprinklers direct their spray upward, hitting their deflector which provides the downward spray pattern.

**Figure 2 – Typical Brass Upright Sprinkler Head**

### 4.2 Pendant Sprinkler

In buildings where there are dropped ceilings, or the sprinklers are mounted nearly flush with the ceiling, pendant type sprinklers are provided where the spray is pointed downward, hitting the deflector and creating the spray pattern.

  

**Figure 3 – Typical Brass Pendant Style Sprinkler Head**

Office building sprinklers are typically semi-concealed or fully concealed and do not detract from the aesthetics of the space. Semi-concealed sprinklers are mounted with only the deflector below the level of the ceiling, while fully recessed sprinklers are covered with a thin metal disc. When the temperature of the space reaches a certain point, the metal cover drops away and the spray deflector drops, so the sprinkler functions exactly as the semi-recessed variety.

**Figure 4 – Semi-Recessed Factory Painted Pendant Head**

  

**Figure 5 - Fully Recessed Sprinkler Head – Before and After Deployment**

### 4.3 Sidewall Sprinkler

As its name suggests, these sprinklers are mounted along walls and discharge most of the water away from the nearby wall in a pattern resembling one-quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

**Figure 6 – Chrome Plated Sidewall Sprinkler Head**

  

### 4.4 Dry Sprinkler

A dry type sprinkler is a type of sprinkler that is used to provide sprinkler protection in unheated areas or areas that are exposed to low temperatures such as docks, unheated areas of buildings, or freezers. The sprinkler has a "weep hole" (or annular clearance) at the seat as a means of identifying water leakage past an inlet seal. The pipe nipple is sealed at the inlet to prevent water from entering the nipple until the sprinkler operates. The inlet end of the dry type sprinkler is installed into a threaded tee fitting, typically above a ceiling or enclosure.

**Figure 7 – Examples of Dry Sprinkler Heads**

### 4.5 Corrosion Resistant Sprinklers

Corrosion-resistant sprinklers are used in locations where chemicals, moisture, or other corrosive vapors exist. Corrosion-resistant sprinklers are found in locations such as metallurgical smelters, power plants, semiconductor fabrication facilities and chemical processing plants. Corrosion resistant coatings can only be applied by the sprinkler manufacturer. The installer or the owner of a building cannot apply any special coating or modify the sprinkler in any way.

### 4.6 Decorative Sprinklers

Similar to corrosion resistant sprinklers, decorative sprinkler are painted or polished to provide a pleasing aesthetic appearance. Also similar is that the installer or the owner of a building cannot apply any special coating or modify the sprinkler in any way.

### 4.7 Early Suppression Fast Response (ESFR) Sprinklers

ESFR sprinklers are predominately used for the protection of high piled storage. Storage arrangements may include palletized, solid pile, shelf, bin box, or rack storage of materials. The primary advantage associated with ESFR Sprinkler Systems is a protection scheme that may be able to avoid the use of in-rack sprinklers in a rack storage configuration. Using ESFR sprinklers may eliminate the risk of accidental discharge of water caused by rupture of a sprinkler or pipe struck by a piece of material handling equipment or pallet load. Another advantage with an ESFR system is that a facility manager can alter rearrangement of storage racks without the costly reconfiguration of the in-rack sprinkler piping when such systems are installed in racks.

ESFR sprinkler systems can provide protection from a variety of commodities ranging from non-combustible to normal combustible products, up to high hazard commodities such as plastics without the use of additional in-rack sprinkler protection in rack storage structures.

ESFR sprinklers are intended to operate differently than other types of sprinklers. While most other sprinklers are intended to control the growth of a fire, an ESFR sprinkler system is designed to suppress a fire, that is, to “knock" the fire back down to its original point of origin. ESFR sprinklers accomplish this design objective by using large volumes of water, and may approach 100 gallons per minute of water per sprinkler. Accordingly these systems require large water supplies and often require the installation of fire pumps.

### 4.8 Control Mode Specific Application (CMSA) Sprinklers

CMSA sprinklers are used for protecting class I-IV commodities and cartoned unexpanded plastics, without the use of in-rack sprinklers. CMSA sprinklers provide greater design and installation flexibility than ESFR sprinklers while requiring less water demand. CMSA sprinklers are also approved for use in pre-action systems with the same water delivery as wet systems.

### 4.9 Variations

Both upright and pendant sprinklers can be manufactured with a high level of thermal sensitivity, enabling the device to respond at an early stage of fire development. This includes residential sprinklers, different types of quick-response (QR) sprinklers, and ESFR sprinklers. The purpose of the fast response sprinkler concept was to reduce the thermal lag associated with a sprinkler, as measured by its “response time index” (RTI).

  

### 4.10 Sprinkler Temperature Ratings

Most automatic sprinklers have color-coded temperature ratings that make it easy to determine if the sprinkler is applied in the correct environment. All automatic sprinklers are stamped with this rating as well. The temperature rating is the temperature at which they are expected to operate and release water. A source of confusion exists with color coding. Fusible link sprinklers may have their frames painted with a certain color. Frangible glass bulb sprinklers have colored glass, with colors that are different from the required frame color.

In general, a sprinkler with a too low temperature rating that is applied in a too high ambient temperature environment will be subject to the risk of a nuisance operation. There are many rules in NFPA 13 regarding sprinkler placement and temperature rating that go far beyond the scope of this lesson, but these rules are all listed in various places of the code and its appendices.

The following table summarizes the high points of Table 6.2 in NFPA 13 regarding temperature ratings:

**Table 1 – Color Coding Chart for Listed Temperature Sprinkler Heads**

| Max Ceiling Temp, °F | Sprinkler Temp. Rating, °F | Temperature Classification | Color Code | Glass Bulb Color |
|---|---|---|---|---|
| 100 | 135-170 | Ordinary | Uncolored* | Orange or Red |
| 150 | 175-225 | Intermediate | White | Yellow or Green |
| 225 | 250-300 | High | Blue | Blue |
| 300 | 325-375 | Extra High | Red | Purple |
| 375 | 400-475 | Very Extra High | Green | Black |
| 475 | 500-575 | Ultra High | Orange | Black |
| 625 | 600 | Ultra High | Orange | Black |

*or Black

## 5.0 Classification of Occupancies

The basis for the design of any sprinkler system is to first determine the occupancy classification for the space. Chapter 5 of NFPA 13 lists the different occupancies and there are tables in the appendix that assign certain occupancy examples to certain hazard classifications. The appendices are not part of the code; therefore, final determination rests with the AHJ.

The occupancy classification dictates the significant design parameters for the space. These parameters include water density, sprinkler spacing, both of which on a secondary level determine the need for a fire pump, especially if the municipal water supply is marginal. All these factors will have great impacts on the cost of the installation, so it is imperative that the occupancy is correctly determined before there is any engineering.

NFPA bases the occupancy class on the "fuel load" as opposed to other building codes, which classify the occupancy based on use. Under this philosophy, there can be two identical spaces in two different buildings, but if one is utilized with a dense concentration of combustible materials, it will certainly have a different occupancy than the other.

A basic breakdown and representative examples of uses for a given occupancy are listed below:

**Table 2 – Classification of Occupancies**

| | |
|---|---|
| Light Hazard (LH) | Offices, churches, schools, museums, auditoriums, library seating areas, restaurant seating areas, and unused attics. |
| Ordinary Hazard Group 1 (OH1) | Laundries, restaurant service areas, automobile parking garages. |
| Ordinary Hazard Group 2 (OH2) | Dry cleaning establishments, automobile repair and services areas, auditorium stages, woodworking plants, post offices, and stack room areas of libraries. |
| Extra Hazard Group 1 (EH1) | These occupancies are defined as having a high probability of rapidly developing fires with high rates of heat release, but with little or no combustible or flammable liquids. Examples include places such as sawmills and die-casting facilities. |
| Extra Hazard Group 2 (EH2) | These are occupancies with moderate to substantial amounts of flammable or combustible liquids present, or where shielding of combustibles is extensive. Examples include printing plants and plastics manufacturing. |

Extra Hazard Occupancies represent the most severe fire conditions addressed under the occupancy hazard classifications in NFPA 13 and present the highest challenge to sprinkler protection.

  

Storage is a severe hazard faced when designing fire sprinkler systems. Storage is allowed within any occupancy classification but the requirements for protection are substantially different than the underlying occupancy. Storage is significant topic and is treated separately in Section 8 of this course.

In 1999, NFPA incorporated a Special Occupancy Hazard classification. Special occupancies are listed in different chapters outside of NFPA 13. Those requirements were extracted and consolidated into Chapter 22 in order to give NFPA 13 users ready access to relevant requirements. Included in this section are special occupancies such as aerosol products manufacturing and light water nuclear power plants.

## 6.0 Design Approaches

### 6.1 General Considerations

Once the occupancy has been established, the designer would then determine the "water demand". From there, the fire protection engineer moves through the text and tables of NFPA13, Chapter 5 to determine water requirements and layouts of heads.

The rules for laying out sprinklers along with the exceptions for special conditions (obstructions, openings, etc.) are quite specific. The design engineer uses the code rules for laying out the sprinkler heads, and then makes calculations based on the Hazen-Williams formula for waterflow in pipes. The calculations will reveal any points in the system that need to be adjusted, such as pipe diameters, water velocity and sprinkler flow. Everything is recalculated, adjusted, etc. until the designer is satisfied that the layout meets code, as well as reflects the most economical layout as far as installation cost is concerned.

There are many software programs on the market that provide sprinkler calculations, and the use of software has made it possible to refine the economic benefits of layouts. Although the most common configurations can still be hand calculated, commercially available software has rendered hand calculations mostly obsolete.

### 6.2 Piping Configurations

When the concern for building a new sprinkler system is primarily one of lowest first cost, a "tree" system is used. A tree system consists of a grid of sprinkler piping with one point of supply, and all the branch runs radiate out to the areas in the space with single taps off the header. Tree systems are able to be calculated manually with an exponential function calculator.

  

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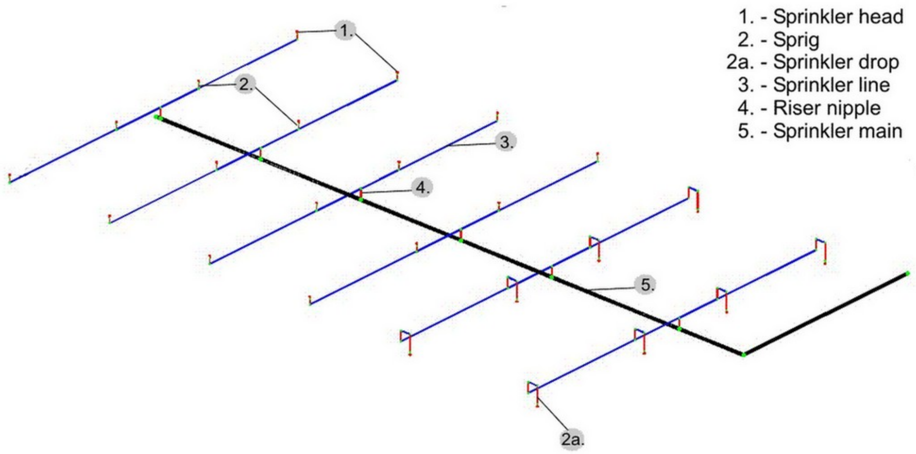


**Figure 8 – Typical Tree System Sprinkler Layout**

Looped systems have a single supply, consist of two or more tree systems, and the ends of the system are tied together, creating a loop. With this type of system, pressure drops are reduced in the piping.  Although uncommon, when large area layouts are required, this type of system may be a benefit.

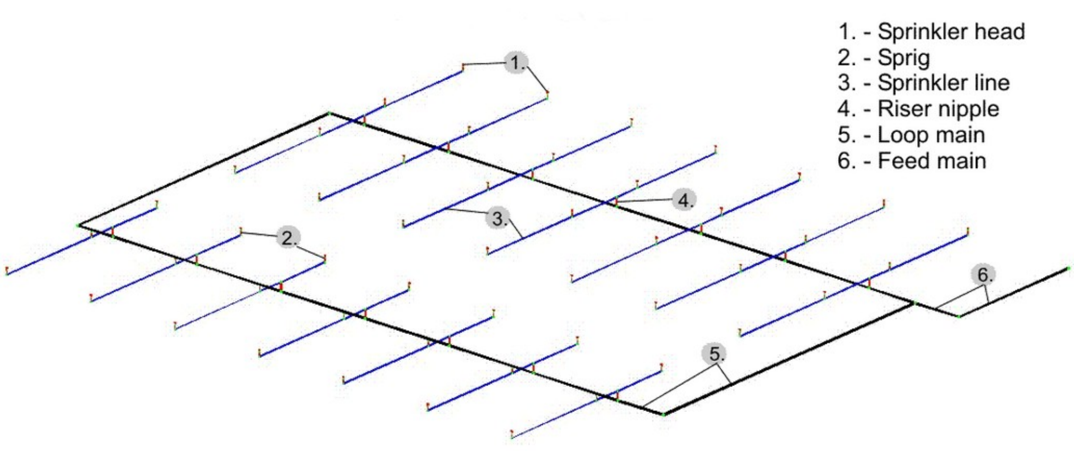


**Figure 9 – Typical Loop System Layout**

To further improve the flow characteristics of large systems, and if the physical layout presents the ability to allow this, a gridded system may be utilized. In a gridded system, all the branch lines are interconnected thus providing many paths of travel for the flow. Gridded systems are mathematically complex, and especially so if piping paths are not symmetrical to the grid. Computer software must be used for gridded systems.

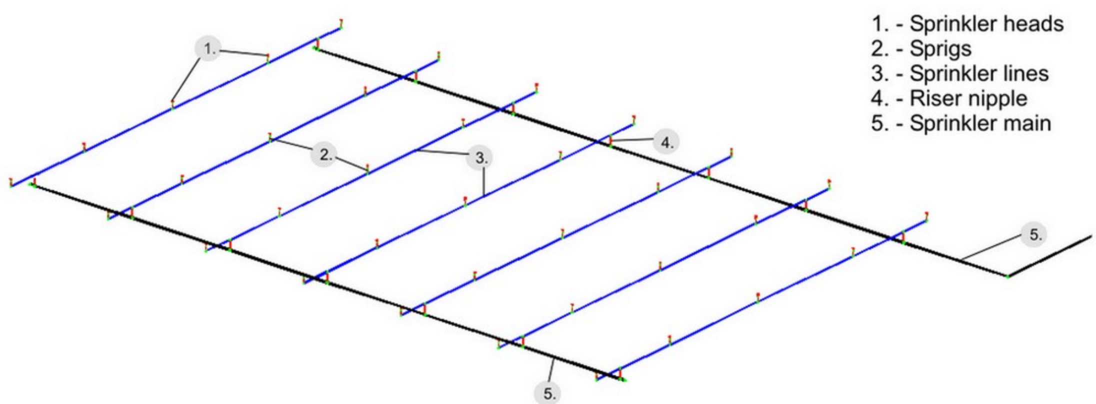


**Figure 10 – Typical Gridded System Layout**

### 7.0 Fire Protection System Components and Accessories

### 7.1 Piping

Piping used for sprinkler systems must meet ASTM or AWS standards found in Chapter 2 of NFPA 13. In general, most piping is steel, either Schedule 10 or Schedule 40. Copper piping is allowed, and in some cases, CPVC piping is also allowed. Commercial buildings rarely have installations with CPVC piping. Copper, because of its high first cost as compared with steel, is also rarely used.

Piping may be joined using welds. Steel piping is often threaded or cut-grooved, as the two methods have approximately the same installed cost. Grooved piping is almost always used on the larger sizes. Piping must have identification continuously along its length that identifies the manufacturer's name and technical specifications.

Fittings are considered acceptable as long as they are installed in accordance with their listing limitations.

  

Return bends are required when pendant sprinklers are used and the water source may have sediment, such as a pond or open-top reservoirs. They are also used typically to allow the installer a certain amount of adjustment in order to position the sprinkler head in the center of a ceiling tile, for example.

Piping must be protected from damage and failure that includes, impact, freezing, corrosion, and earthquake.  Seismic bracing is required by most building codes to prevent or limit the amount of movement in sprinkler systems.

Hangars must be listed and provided in accordance with the standard and must be capable of supporting five times the weight of the water-filled pipe plus 250 lbs. There are many other requirements for the support of piping including the distance between hangars, the length of unsupported ends, rules for risers, etc., all of which are of interest to the design engineer.

### 7.2  Valves and Trim

Valves are used to shut off entire systems or to isolate portions of the sprinkler system. The minimum working pressure for valves used in sprinkler systems is 175 psi. Valves controlling water flow must be listed. Valves, with very few exceptions, must indicate whether they are open or closed, for example, post indicator valves as shown in the photos below.


**Figure 11 – New and Old Post Indicator Valves**
**(note the supervisory alarm switch on the old valve.)**

Other types of valves such as outside screw and yoke (OS&Y) valves indicate their position by the visible length of their stem.  Furthermore, any valves that can stop the flow of water when the building needs to be protected, must have a supervisory contact installed on their mechanisms that is connected to a remote supervisory station.

**Figure 12 -  Examples of OS&Y Valves Open (right) and Closed (left)**

Control valves cannot be closed in less than 5 seconds. Stopping the flow of water too quickly can cause a condition called water hammer which may instantaneously raise the pressure of the system well beyond design limitations and cause damage or leakage.

A fully trimmed alarm check valve is a complicated assembly. It not only provides water to the fire.  It has an inspector's test connection point, a main drain, flow switch, retard chamber, a line for a water powered gong, bypass line, gauging, and so forth.


**Figure 13 - A Fully Trimmed Alarm Check Valve**

Drain valves and test valves are not required to be listed. Since they are not considered critical to the performance of the fire sprinkler system, they must simply be approved for use.

Fire department connections provide an auxiliary water supply to the sprinkler system which increases system reliability. The fire department connection is required to be approved by the AHJ and normally has two 2.5 inch inlets, unless other types are required. The purpose of the fire department connection is to supplement the water supply, but not necessarily to provide the entire sprinkler system demand.

  


**Figure 14 – Typical Fire Department Connection**
**(Note the missing cap)**

Waterflow alarm devices must be listed for use with fire sprinkler systems and installed so that a flow equal to that of a single operating sprinkler will produce an audible alarm within 5 minutes after the flow begins and must continue until the flow of water ceases.

Waterflow alarms can be mechanical, such as an alarm check valve and water motor gong, or electrical, consisting of a flow or pressure switch and electric bell or horn. A waterflow alarm is not required by NFPA 13 to be connected to the building alarm system (if one is present). However, if the sprinkler waterflow alarm is connected to the alarm system, it must be installed in accordance with NFPA 72, *National Alarm and Signaling Code*.

### 7.3 Fire Pumps

Fire pumps are needed when the local municipal water system cannot provide sufficient pressure to meet the hydraulic design requirements of the fire sprinkler system. This usually occurs if the building is very tall, such as in high-rise buildings, or in systems that require a relatively high terminal pressure at the fire sprinkler in order to flow a large volume of water, such as in storage warehouses. Fire pumps are also needed if fire protection water supply is provided from a ground level water storage tank.

Fire pumps may be powered by either an electric motor or a diesel engine, or, very occasionally a steam turbine. If the local building code requires power independent of the local electric power grid, a pump using an electric motor may utilize power from an emergency generator in conjunction with a listed automatic transfer switch.

The fire pump starts when the pressure in the fire sprinkler system drops below a threshold. The sprinkler system pressure drops significantly when one or more fire sprinklers open, releasing water, or alternatively when other firefighting connections are opened, causing a pressure drop.

Types of pumps used for fire service include horizontal split case, vertical split case, vertical inline, vertical turbine, and end suction.

A jockey pump is a small pump connected to a fire sprinkler system in parallel with the fire pump. It maintains pressure in a fire protection piping system to an artificially high level so that the operation of a single fire sprinkler will cause an appreciable pressure drop that will be easily sensed by the fire pump automatic controller, causing the fire pump to start. The jockey pump is essentially a portion of the fire pump's control system. The main code that governs fire pump installations in North America is the NFPA Chapter 20, *Standard for the Installation of Stationary Fire Pumps for Fire Protection*.

## 8.0 Storage Occupancies

### 8.1 General

Storage of combustible materials is taken very seriously in NFPA 13. There are no fewer than eight chapters of the code that address various types of storage and the measures needed for protection.

The main factors that affect the decision making process for storage include:

- The type of product that is stored
- The height of the storage
- The height of the storage building
- The method that the products are being stored

Once these parameters are established, the designer is able to find the appropriate chapter that addresses that particular storage plan, pick the appropriate fire protection system, and select the appropriate sprinkler type.

Storage methods and arrangements fall into one of the following categories:

  

Rack storage
Non-rack storage that includes
  Palletized
  Solid piled
  Bin-box
  Shelf Storage

Unfortunately, the methods for storing materials are usually in direct conflict with trying to provide proper protection in case of fire. Densely stored materials have a greater likelihood of more intense fires.

**8.2 Flue Spaces**

An important aspect of storage occupancies is the space between storage items, referred to in the code as “flue spaces.” These are the open spaces between storage rows from the floor up to the ceiling. Transverse flue spaces are parallel to the direction of loading, while longitudinal flue spaces are perpendicular to the direction of loading.

Flue spaces are necessary for rack storage spaces to allow heat from a fire to vent vertically. This enables the sprinklers to operate as quickly as possible, and slows down the spread of fire horizontally within the rack. Flue spaces also allow sprinkler water to reach the base of the fire down through the racks. If insufficient water reaches the base of a fire, the fire may not be controlled.

Unless in-rack sprinklers are provided at every storage level, transverse flue spaces are always needed in rack storage arrangements.

**8.3 Aisle Configurations**

Rack storage consists of rows of storage separated by aisles. Aisles have to be three and a half feet between rows of racks. The loads on the racks can be no more than six feet deep without a longitudinal flue space. This storage configuration is considered a single row rack.

When single row racks are placed back-to-back, having up to 12 feet of storage without a longitudinal flue, this is referred to as a double row rack. Again, the aisle used for retrieving and storing items on the racks can be no less than three and a half feet.

If aisles are less than three and half feet wide, or storage is greater than 12 feet deep, this is considered a multiple-row rack.

Movable and/or mobile aisles create a major increase in the efficiency of the storage space by allowing aisles to be reduced to almost nothing. Rack systems may be electrically or mechanically powered to achieve this flexibility.

Portable racks are essentially smaller versions of movable aisles that can be reconfigured very easily.

Shelving is generally fixed in place, and shelves may consist of wire mesh that allows ventilation and is a natural flue space. Solid shelving has very limited flue space openings.

### 8.4 Identification and Classification of Stored Materials

Stored materials must be properly identified or categorized in order to apply proper fire protection. The difficulty arises when a variety of materials are stored and may have different burning characteristics. NFPA addresses this situation by reviewing not only the product, but also the packaging and the shipping containers. The pallets are also part of the equation as there are flammable wood pallets or plastic pallets.

  

**Figure 15 – Typical Warehouse Facility with Combustible Storage**

Commodities are classified as follows:

> Class I commodities are non-combustible products in ordinary cardboard boxes with a single layer, on wood pallets. They may or may not be cardboard dividers in the boxes.
>
> Class II commodities are non-combustible products in multi-layered cardboard boxes, or wooden boxes or crates. They may also be placed on wooden pallets.
>
> Class III commodities include combustible products with less than 5% plastic by weight or volume. They may be placed on wooden pallets.
>
> Class IV commodities include combustible products with up to 15% by weight, or up to 25% by volume, of "Group A" plastics in the packaging, the product, or the shipping container. They may be placed on wooden pallets.

Plastics present a greater challenge because they can produce up to three times as much heat as paper or wood per unit of weight. They burn at a faster rate, compounding the need for protection.

Plastics are classified by their burn rate, and are categorized per Section 5.6 in NFPA 13.

Group A plastics have the most intense burning characteristics; Group B plastics are less intense, and Group C plastics are the least intense. In general, plastics consist of two types: expanded, such as Styrofoam, and unexpanded. Of the two, expanded plastics present the greater challenge.

Plastics that include rubber are separately classified, again by Group A, B, and C with Group A being the most difficult when fighting a fire.

To give an example of the relative intensity of plastics-based fires, Group C plastics, being the least combustible of the plastics, must be protected in the same manner as Class III commodities.

If Class I, II, or III commodities are stored on <u>unreinforced</u> plastic pallets, they must be classified <u>one</u> level higher than if they were stored on wooden pallets.

  

**Figure 16 – Examples of Plastic and Wooden Pallets**

If Class I, II, or III commodities are stored on reinforced plastic pallets, they must be classified two levels higher than if they were stored on wooden pallets.

It is extremely common to find storage applications where the product classifications are mixed. In these types of cases, and with some exceptions allowed for segregation, the protection must be applied for whatever product is being stored that has the highest or most hazardous classification.

Up to this point, we have taken a good look at the 'whats' and 'hows' of storage. Now, we will examine the question of storage height, building height and clearance. It is an absolute must that the information used to develop the design criteria is correct, and that all concerned parties agree on that information.

Once there is agreement, we can reference the appropriate storage chapter to determine what kind of system, sprinkler, and the associated design criteria to use.

Chapter 12 covers general requirements for all storage. The storage protection criteria are based on the assumption that roof vents and draft curtains are not used. If automatic roof vents are used, they must be set to operate at a higher temperature than the sprinklers. Draft curtains have been shown to have a negative impact on sprinkler effectiveness. If they are mandated, extreme care needs to be taken to minimize potential impacts.

  

### 8.4 Storage Height

If products are stored in areas with very high ceilings, the fire will grow before the sprinklers are exposed to the necessary temperatures to open. Therefore, there are rules stipulating both the minimum height of storage to a sprinkler, as well as the more common rules that require clearance from a sprinkler.

In most buildings, storage is incidental to the general use of the building. As long as the storage does not exceed 12 feet in height, and is less than 10 percent of the building area or 4000 square feet of the sprinklered area, whichever is greater. Such storage must not exceed 1000 square feet in one pile or area, and each pile or area must be separated from other storage areas by at least 25 feet.

## 9.0 When Are Sprinklers Required?

Up to this point, we have studied the details for implementing fire protection. Yet in some buildings, one one may notice there is not a sprinkler in sight. Some installations may be older, without ever having undergone renovations that would mandate an update to present codes, and others may simply be exempt from the requirement for fire sprinkler protection.

In small buildings, the latter is usually the case. The need for sprinklers is dictated by local state and municipal fire and building codes. Most states, however, adopt the standards published by the International Code Council. Many states then provide supplements to this code, and many larger cities have their own supplements as well.

As an example, the International Fire Code, Chapter 9, lists the requirements for buildings needing sprinkler installations. The following is an excerpt for Use Group A buildings:

> **903.2.1 Group A.**
> An automatic sprinkler system shall be provided throughout buildings and portions thereof used as Group A occupancies as provided in this section. For Group A-1, A-2, A-3 and A-4 occupancies, the automatic sprinkler system shall be provided throughout the floor area where the Group A-1, A-2, A-3 or A-4 occupancy is located, and in all floors from the Group A occupancy to, and including, the nearest level of exit discharge serving the Group A occupancy. For Group A-5 occupancies, the automatic sprinkler system shall be provided in the spaces indicated in Section 903.2.1.5

**903.2.1.1 Group A-1.**
An automatic sprinkler system shall be provided for Group A-1 occupancies where one of the following conditions exists:
1. The fire area exceeds 12,000 square feet (1115 $m^2$).
2. The fire area has an occupant load of 300 or more.
3. The fire area is located on a floor other than a level of exit discharge serving such occupancies.
4. The fire area contains a multi-theater complex.

**903.2.1.2 Group A-2.**
An automatic sprinkler system shall be provided for Group A-2 occupancies where one of the following conditions exists:
1. The fire area exceeds 5,000 square feet (464 $m^2$).
2. The fire area has an occupant load of 100 or more.
3. The fire area is located on a floor other than a level of exit discharge serving such occupancies.

**903.2.1.3 Group A-3.**
An automatic sprinkler system shall be provided for Group A-3 occupancies where one of the following conditions exists:
1. The fire area exceeds 12,000 square feet (1115 $m^2$).
2. The fire area has an occupant load of 300 or more.
3. The fire area is located on a floor other than a level of exit discharge serving such occupancies.

**903.2.1.4 Group A-4.**
An automatic sprinkler system shall be provided for Group A-4 occupancies where one of the following conditions exists:
1. The fire area exceeds 12,000 square feet (1115 $m^2$).
2. The fire area has an occupant load of 300 or more.
3. The fire area is located on a floor other than a level of exit discharge serving such occupancies.

**903.2.1.5 Group A-5.**
An automatic sprinkler system shall be provided for Group A-5 occupancies in the following areas: concession stands, retail areas, press boxes and other accessory use areas in excess of 1,000 square feet (93 $m^2$).

As can be seen, the requirements are very specific, but in general, small single story Group A buildings having non-hazardous uses are typically exempt from needing sprinkler systems.

The purpose of this section of the training is not to turn anyone into a code expert, but rather to introduce the student to the many intricacies concerning requirements for sprinklers. The student can, if they desire to learn more, can easily find sets of code handbooks at the local libraries or on the internet.

## 10.0 Single Family Residential Occupancies

**Figure 17 – Residential Fire**

States are slowly but surely mandating sprinkler systems for single-family homes. Other than larger apartment houses, residences generally are not required to have fire sprinklers installed. In 2013, FEMA published the following data regarding residential fires in the United States:

| | |
|---|---|
| Number of fires reported: | 380,300 |
| Number of deaths: | 2,755 |
| Number of injuries | 12,450 |
| Damage Estimates | $6,875,900,000 |

As one can see, the extraordinary cost of fires in lives and property is high, and sprinkler installations would greatly reduce these costs.

As of 2015, new residences in California, Maryland and the District of Columbia are required to have sprinkler systems. Aside from those three areas, the following states have legislated some sort of enhanced sprinkler provisions as noted:

Connecticut — No state law. Property owners must notify tenants if sprinkler systems are not installed.

  

| | |
|---|---|
| Delaware | No state law. Cost estimate required for new construction. |
| Massachusetts | One and two family dwellings greater than 14,000 square feet must be sprinklered. |
| Minnesota | Sprinklers are required in homes greater than 4,500 square feet. |
| New York | Tenants must be informed if home has or doesn't have fire sprinklers. Wood frame residences more than two stories must be sprinklered. |
| North Carolina | Townhomes must be sprinklered, or have two hour separations. |
| Oklahoma | Townhomes must be sprinklered. |

  

**Conclusion**

This course has presented a broad, wide-ranging overview of the fundamental concepts that make up the requirements for fire protection. There are more thorough documents readily available if the student has a desire for detailed knowledge on any particular topic discussed in this course. Lessons that would educate the student specifically on the design and specification of fire protection systems are not included. An in-depth course for designing fire sprinklers will be treated as a separate subject.