First Responder Inspector

CHAPTER EIGHT
FIRE FLOW AND FIRE SUPPRESSION SYSTEMS

Part 2

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Welcome to Chapter 8 Part 2 “Fire Flow and Fire Suppression Systems”
In this part we will discuss:

- NFPA standards for sprinkler systems
- sprinkler systems design
- hydraulic calculations
- interconnection between sprinkler and fire alarm systems
- sprinkler system types including wet-pipe, dry-pipe, pre-action, and deluge
- sprinkler components
- dry and wet chemical extinguishing systems
- clean agent chemical systems
- CO2 systems
- sprinkler heads
- release mechanisms including glass bulb, fusible links, and solder pellets

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NFPA has 3 standards that govern the type of sprinkler system that is installed. These are:

- NFPA 13,
- NFPA 13R residential

and

- NFPA 13D dwelling

NFPA 13 is the Standard for the Installation of Sprinkler Systems. NFPA 13 protected buildings are considered ‘fully sprinklered’ and provide both life safety and property protection for the facility. This means there’s fire protection throughout the entire building, including unoccupied spaces such as attics and closets.

NFPA 13R protected facilities are considered ‘partially sprinklered’ and provide life safety and a moderate level of building protection. In other words, NFPA 13R requirements provide for a level of protection that allows occupants to escape a building in the event of a fire. Conversely, NFPA 13 provides protection to not only get people out but also to control or extinguish the fire – saving the building and its contents.

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Video

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NFPA 13D is a residential sprinkler designed for one- and two-family dwellings and manufactured homes. The intent is to provide an affordable sprinkler system in homes while maintaining a high level of life safety. The installer of the system must provide the owner with instructions on the inspection, testing and maintenance of the system but this is usually very simple and can be completed by the homeowner.

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With some specified sprinkler design considerations, the 2020 Edition of the National Building Code has expanded the permitted use of NFPA 13D to include rowhouses that contain more than two dwelling units. Rowhouses sprinklered to the requirements of NFPA 13D, rather than NFPA 13R, would not be permitted to have stacked units (i.e. one dwelling unit would not be permitted to be located above another), and 1 h fire separations, constructed to be continuous to the underside of the roof deck, would be required to be provided between suites.

The following video explains the water supply calculations for NFPA 13D systems.

Don't forget to check the reference document section of your Building and/or Fire code to determine which standards and which editions of those standard are in effect in your jurisdiction.

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Video

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The NFPA 13 standard specifies how much water is required to operate the sprinkler system. Pipe sizing and layout must ensure the required water volume and pressure will be available at the operating sprinkler heads. Sprinkler designers can do this by using a pipe schedule system, or by hydraulic calculations.

Sprinkler design by hydraulic calculation is more common than the pipe schedule system and conforms with the NFPA requirements based on occupancy type, type of hazard, and the amount of water and water pressure requirements for the operating sprinklers.

The traditional pipe schedule system, now over 100 years old, is still permitted for use today in light and ordinary hazard occupancy classes and small additions to extra hazard occupancies. The system specifies how many sprinklers a given pipe size can support, as well as the required sprinkler spacing. This pipe schedule system is not as accurate as the hydraulic calculation method and can lead to designs that are less cost effective.

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Hydraulic calculations are an especially important step when designing sprinkler systems since they ensure the flow rate established through the piping network will be enough to control fires effectively. Calculation procedures are established in model codes like NFPA 13.

In simple terms, the hydraulic calculation procedure verifies three basic elements of a fire suppression system:

- Water delivery requirements for suppression of a possible fire
- Available water supply
- The piping network and its associated friction losses

Most piping networks in fire suppression systems can be classified into three types, based on how individual pipes are arranged: tree, loop, or grid. They are summarized as follows:

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The tree configuration uses a main piping line that branches out into progressively smaller pipes, providing water to individual sprinkler heads. This is similar to how a tree has a trunk from which all branches grow. Water flows in one direction only and dead ends.

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Loop systems have a main pipe from which all others branch out. However, the main pipe returns to its starting point, completing a water loop.

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The grid configuration uses two main lines running parallel to each other, and smaller piping segments are connected to both. This provides more than one route for water to flow which reduces friction loss.

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Regardless of the piping configuration, design standards normally require the Hazen-Williams method to determine friction losses through the system. The calculation procedure is simpler for tree and loop configurations, to the point that a manual procedure is feasible, but grid systems normally require software to analyze and balance water flow through all possible paths.

Whatever piping configuration is used, computer design is the standard practice for modern fire protection systems since software allows component changes and recalculation in just a fraction of the time required with manual procedures.

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Sprinkler systems are complimentary to, and coordinated with, the building fire alarm system. Buildings equipped with an NFPA 13 or 13 R sprinkler system are required to have a fire alarm system. When water flows through the sprinkler system, or the control valves are tampered with, the fire alarm system will activate. A fire alarm system that includes water-flow indicating devices must be designed to notify the fire department that the sprinkler has been activated.

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There are four major classes of automatic sprinkler systems: wet-pipe systems, dry-pipe systems, preaction systems and deluge systems.

Although one type of system may be used throughout a building, it is not uncommon to see multiple types of systems being installed, depending on the materials being stored and the characteristics of the building.

Wet pipe systems are by far the most common, and most reliable, because they are simple, having only a few operating components. They are always fully charged with water, so when a sprinkler head releases, water is immediately discharged. Wet pipe systems are the least expensive to install and can usually be easily modified to accommodate building alterations or renovations. The downfall is they are subject to freezing.

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Older wet pipe systems were provided with a sprinkler system valve known as an alarm valve which is also known as a wet pipe valve. The valve's main purpose is to allow water to flow to a water motor gong once it has tripped, and to prevent false alarms due to pressure surges in the water supply. These functions today are largely provided by use of a listed back flow preventer and sprinkler flow switch and main drain assembly , making the provision of alarm valves unnecessary in modern wet pipe systems.

This drawing shows the components of a typical wet pipe sprinkler system. Although they seem complex, they are fairly simple and very reliable. Seldom is there an accidental discharge of water and most failures occur because of valves being turned off, a blockage in the distribution lines, or freezing. Having said that, occasionally a system does go off when not expected as shown in the following video.

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Video

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Dry pipe systems are the next most common type of sprinkler system. They are installed wherever water may freeze. Dry pipe systems are most often used in unheated areas of buildings, in parking garages and outside canopies attached to buildings. Most codes require the installation of dry systems unless the ambient temperature remains above 40 degrees F (4.5 degrees C). Some installations utilize a combination of wet and dry systems.

Dry pipe systems are pressurized with compressed air on the system side of a dry pipe valve. The dry pipe valve is a check valve which utilizes a clapper mechanism to prevent water from the supply side of the valve from flowing until the air pressure on the system side of the valve is released (as would occur in the event of a sprinkler activation). The valve is designed in such a way that it is bigger on the dry side of the clapper than on the supply side, in order to require a less air pressure to hold it closed.

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Video

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The disadvantages of dry systems are that they are more complex than wet systems and require more components which increases the potential for failure and the need for maintenance. The higher complexity also increases the installation and maintenance cost of the system.

In addition, because the piping is empty at the time the sprinkler operates, there is a time delay of up to 90 seconds in getting the water on the fire. Depending on the design, accelerators and/or exhausters may be required in order to shorten the time between sprinkler activation and water flow through the sprinkler. Accelerators aid by tripping the dry pipe valve faster, and exhausters aid by helping to exhaust the air out of the system pipes faster.

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Pre-action systems (also known as interlock systems) are specialized for use in locations where accidental activation is undesired, such as in art galleries, museums and data centers for protection of computer equipment from accidental water discharge. Pre-action systems are like dry systems except these systems require a “preceding” fire detection event, typically the activation of a heat or smoke detector prior to the release of water. Pre-action systems use a pre-action valve which opens upon receiving a signal from a fire detection device.

Pre-actions systems can be either single interlock or double interlock type. Single interlock systems will release water into the system pipes with the operation of a fire detection device. Double interlock systems require both a fire detection event, and an open sprinkler, before water will be released into the system piping. Both the single and the double interlock systems require a sprinkler to operate before water will flow.

A double interlock preaction system is further explained in the following video.

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Video

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Combination dry-pipe and preaction systems combine the essential features of both systems. The system piping contains air or nitrogen pressure. Upon activation of an alarm detection device, air is exhausted from the system and water fills the system piping. If a detection device should fail, the system functions as a dry pipe system.

A combined system is often used in areas that are unheated, or areas where the occupant requires that water not enter the system prior to the activation of a sprinkler heads. The system can be arranged to be activated by only one detection device type, or many.

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All sprinklers connected to the supply piping in deluge systems are open; and thus, provide a simultaneous application of water over the protected area once the sprinkler system valve is opened. These systems are used where rapid-fire suppression is critical, such as aircraft hangars or to protect industrial processes having a rapid-fire spread potential.

The sprinkler system valve used in deluge systems is called a deluge valve. Deluge valves are designed to be normally closed until signaled to operate by the activation of an alarm detection device. Upon activation, the valve opens, filling the system piping with water and quickly flowing out of the open sprinklers. Some deluge valves are connected to a separate pilot sprinkler system of pressurized air or water. When a sprinkler on the pilot system activates, the pressure drop is detected, and the deluge valve opens.

Deluge valves can also be opened manually.

The following short video depicts the operation of a deluge system.

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Video

Slide 25

When protecting electrical equipment, high value contents such as computers, books, documents; or hazards that are incompatible with water, such as reactive chemicals, a specialized type of extinguishing system may be required. There are a variety of specialized fire suppression systems available, including:

- Foam water fire sprinkler systems,
- Water mist systems,
- Dry and wet chemical systems,
- Clean agent Extinguishing Systems (or halogenated agents),

and

- Carbon Dioxide Extinguishing Systems

We will take a brief look at these systems in the next few slides.

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A foam water fire sprinkler system is a special application system, discharging a mixture of water and foam concentrate, resulting in a foam spray from the sprinkler. These systems are usually used with special hazards occupancies associated with high challenge fires, such as airport hangers. This video shows a foam system in action in a WestJet hanger.

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Video

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Water mist systems are used for special applications to absorb heat. This type of system is typically used where water damage may be a concern, or where water supplies are limited.

The objective is to control the fire by reducing thermal exposure and to suppress the fire by reducing the heat release rate. Studies have shown that water mist systems can be effective in controlling a room's temperature, which allows for a safe egress and reduced damage. The key to a water mist system working more proficiently than traditional fire sprinklers is the water droplet size. The smaller droplet size creates more droplets that will evaporate and turn to steam. The steam then absorbs more heat.

A water mist system raises the humidity in the room enough to inhibit the combustion process.

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Dry chemical extinguishing systems must meet the requirements of NFPA 17, Standard for Dry Chemical Extinguishing Systems. These systems use the same type of agents as in portable dry chemical extinguishers. The chemical is kept in tanks that are pressurized with either carbon dioxide or nitrogen. The dry agents used are:

Sodium bicarbonate, Potassium bicarbonate, urea-based bicarbonate, and Potassium Chloride, all of which are rated for B& C class fires only; and ammonium phosphate which is rated for A, B, and C class fires.

Dry chemical systems, along with wet chemical systems, are the most common type of special agent system and are most commonly used in industrial applications.

In addition to a manual discharge station, dry chemical systems also use fusible-link or other automatic initiation devices above the target hazard to activate the system as can be seen in the following video.

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Video

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Wet chemical extinguishing systems are often found in commercial cooking operations and must meet the requirements of NFPA 17A, Standard for Wet Chemical Extinguishing Systems. These systems use a proprietary liquid agent. The agent is not compatible with all purpose ABC type extinguishing agents. Therefore, only Class K, or Class B:C rated fire extinguishing agents should be used in and around this type of system. Wet chemical systems are actuated by the same methods as dry chemical systems.

Wet chemical systems, along with dry chemical systems are the most common type of special agent systems.

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Clean agent systems typically use carbon dioxide or halogenated gas in a total flooding type system to protect computers or sensitive electronics or documents. The purpose of these systems is to extinguish the fire without significantly damaging the contents being protected. These systems have a series of pre-discharge alarms to allow workers to evacuate the area, and abort buttons so that accidental activations can be aborted. Clean agent systems should be indicated as a zone on the building's fire alarm system so that responding fire department personnel will be made aware that a clean agent has discharged.

Prior to the 1990s, Halon 1301 was considered the best choice of clean agent as it was colourless, odorless, non-toxic and left no residue. Unfortunately, it was found that Halon had detrimental environmental effects which led to a manufacturing and import ban, and the installation of new Halon systems is not permitted. However, a stockpile of Halon exists, and the recharge of existing systems is permitted.

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Carbon dioxide, or CO2 as it is more commonly called, fixed fire suppression systems are primarily used to protect against fires involving flammable gases or liquids and electrical equipment. They work by totally flooding a room with carbon dioxide which displaces the oxygen in the room and smothers the fire.

These systems have a series of pre-discharge alarms to allow workers to evacuate the area, and abort buttons so that accidental activations can be aborted. These systems create an oxygen deficient atmosphere, which is immediately dangerous to life. As such, these systems should be indicated on the building fire alarm system so that responding fire fighters can manage the situation safely and effectively. They act quickly and leave no residue.

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We will now take a closer look at the different types and styles of sprinkler heads and their actuating mechanisms.

Sprinkler heads are the working end of the sprinkler system and serve two functions: to activate the system and to apply water to the fire. Sprinkler heads consist of

- a body (or frame), which contains the orifice,
- a thermal release mechanism that holds the cap in place,
- a cap,

and

- a deflector.

Sprinkler heads are designed to be mounted in one of three positions: upright, pendent, or sidewall. Upright sprinklers are installed above the supply pipe, pendent sprinklers are installed below the supply pipe, and sidewall sprinklers spray outward from a wall.

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Upright sprinkler heads, usually marked SSU for "Standard spray upright", are designed to be installed so that the water is directed upward towards a deflector that deflects the water downward in a circular spray pattern. Upright sprinkler heads are distinguishable because the deflector fins curve downward. So, the water comes out of the orifice and hits the deflector and is forced downward.

Pendant sprinkler heads, usually marked SSP for "standard spray pendant", hang down from the pipe and also spray water in a circle pattern. The deflector plate is almost flat with deep grooves.

Sidewall sprinklers have special deflectors so most of the water is directed outward, but some is directed back towards the wall.

Standard sprinkles have a ½ in. orifice, but other sizes are available. Obviously the larger the orifice the more water it can deliver.

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There are a variety of different types of sprinkler heads that have been designed to address specific needs. These include:

- Dry sprinklers heads – which are used in areas subject to freezing. These should be used where the temperature falls below 4.4 degrees C.
- Open sprinklers– in which the actuating elements have been removed. These are most often used with deluge systems where large quantities of water are required immediately.
- Corrosion-resistant sprinklers have a protective coating like wax or may be constructed of corrosion resistive materials like stainless steel. They are designed to resist exterior elements that attack a standard brass sprinkler. The level of corrosion resistance required is determined by the conditions that a sprinkler would experience during its lifetime in a corrosive environment. It is important to understand that corrosion resistance does not mean corrosion proof.

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- Nozzle sprinklers are sprinklers with specialized discharge patterns to protect specific areas
- Ornamental sprinklers are painted or plated by the manufacturer. Often, they are white or black to match the wall or ceiling or in some cases they can have a coating like chrome
- Flush sprinklers are sprinklers where the shank thread, is flush with the ceiling
- Recessed sprinklers are where the sprinkler, except the shank thread, is mounted in a recessed housing
- Intermediate level sprinklers are provided with shields to protect their operating elements from the cooling effect of water from sprinklers located above.

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- Residential sprinklers are designed to operate faster, use less water, and have a spray pattern that is designed to reach higher on the wall than a standard spray sprinkler. For these reasons, residential sprinklers are not interchangeable with standard sprinklers. The quick response thermal element allows residential sprinklers to operate quickly when compared to standard-response sprinklers. This means that water can be discharged into the fire area while the fire is relatively small. Residential sprinkler systems are designed to give occupants time to escape from a fire, and statistics compiled by the NFPA show that they reduce the rate of residential fire deaths by 81% while lowering property damage by 58% or more.

Reference:
American Fire Sprinkler Association – Sprinkler Age
https://sprinklerage.com/early-suppression-fast-response-sprinklers/
NFPA Stats
https://www.qrfs.com/blog/100-residential-fire-sprinkler-systems-guide-to-installing-home-fire-sprinklers-part-1/

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- Early suppression fast response sprinklers, also known as ESFR's, are ceiling mounted sprinklers normally used in warehouses that are designed to put large volumes of water on the fire. ESFR provides protection that exceeds that of in-rack systems. They have large orifices and sensitive heat collectors, so they operate quickly and deliver large volumes of water, Note the thin glass bulb. This provides a fast response. The quick-response thermal element allows sprinklers to operate in a timely fashion, compared to standard-response heads, so that water can be discharged into the fire area while the fire is relatively small.

- Large-drop sprinklers generate drops of water large enough to penetrate high velocity fire plumes. They are intended for the protection of high piled storage. The LD Sprinkler can provide a higher level of protection than standard spray sprinklers and, in some cases, can provide an economic advantage by eliminating the requirement for in-rack sprinklers.

Reference:
American Fire Sprinkler Association – Sprinkler Age
https://sprinklerage.com/early-suppression-fast-response-sprinklers/
NFPA Stats
https://www.qrfs.com/blog/100-residential-fire-sprinkler-systems-guide-to-installing-home-fire-sprinklers-part-1/

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Quick response sprinklers got their name from their slightly faster response time when compared to standard response sprinklers. Their only physical difference is the bulb size. The standard response sprinkler has a 5 mm glass bulb, and the quick response sprinkler has a 3 mm glass bulb. The smaller bulb improves activation time.

Quick response fire sprinklers are installed primarily in light-hazard applications like office buildings, schools, and residential occupancies. Quick response sprinklers discharge water higher on the walls to keep the fire from climbing and maintain lower ceiling temperatures. Cooler ceilings reduce the likelihood of flashover and slow a fire's rise within a building improving the possibility of safely evacuating the building.

Differences also exist in spacing, density, and placement of sprinklers within a quick response system compared to a standard response system.

Reference:
QRFS
https://www.qrfs.com/blog/1-fire-sprinklers-standard-response-vs-quick-response/

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Standard response sprinkler heads are the most common type of sprinkler heads. They are designed to pre-wet materials near a fire before the fire reaches them while simultaneously cooling adjacent areas to prevent the spread of fire. Standard response fire sprinklers are normally found in warehouses, factories, and other commercial or industrial buildings. Drenching the surrounding area slows the fire, buying critical time for the fire department to get on scene. Containing the fire in its original location and suppressing its growth are the focus.

Reference: QRFS
https://www.qrfs.com/blog/1-fire-sprinklers-standard-response-vs-quick-response/

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Extended Coverage sprinkler technology dates back to the 1970's and one of the most common applications is the Horizontal Sidewall Extended Coverage sprinklers that you often see protecting hotel bedrooms. However, more recently, manufacturers have developed Extended Coverage sprinklers for a wide range of Commercial & Industrial applications that can provide substantial cost savings.

In simple terms, an 'EC' sprinkler, provides an extended area of coverage compared to a

Standard Coverage sprinkler. Extended Coverage Sprinklers are intended for the protection of areas larger than those specified in standard installations for specific light, ordinary, or extra hazard occupancies. Extended coverage sprinklers are available in both standard response (EC) and quick response (QR-EC). Using extended coverage sprinkler heads allows for further distance between heads which provides flexibility in the overall sprinkler system design, covers more area, and can save money on installation because it uses less heads.

References:
41.51 of Intro to Automatic Sprinklers – Viking video- https://www.youtube.com/watch?v=hyeDA-Alx-c
Sprinklermatic University Intro to Automatic Sprinklers – Viking video-

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Sprinklers' heads are rated in accordance with their release temperature and the anticipated ambient temperature of the room in which they are installed. When the air around the head reaches a certain temperature – typically 57°, 79° , or 121° C the release device operates.

In the case of the glass bulb type, the liquid inside the bulb expands until the pressure causes the glass to break.

Fusible link fire sprinklers mirror the concept of glass bulb sprinklers but in their case, the glass and liquid are replaced by two metal plates held together by solder with a predetermined melting point.

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A frangible pellet sprinkler has a rod between the orifice cap and sprinkler frame. The rod is held in place by a pellet of solder under compression. When the solder melts, the rod moves out of the way of the orifice cap. The cap is pushed off by the water pressure in the piping network.

Frangible simply means easily broken or refers to objects which are made intentionally breakable.

While a typical sprinkler in an office building may be rated at 57 degrees C, a sprinkler installed near space heaters in the parking garage may be rated for a much higher temperature. Sprinkler temperature ratings unsuited for the ambient room temperatures in which they are installed could be too slow to react, or conversely, may cause accidental activations.

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This graph shows the NFPA requirements for sprinkler temperature ratings and colour codes relative to the maximum ambient temperatures around the sprinkler as measured at ceiling level.

With a few exceptions, NFPA 13 requires that sprinklers be colour coded so that it is possible to easily identify the temperature rating of the sprinkler. For glass bulb sprinklers, the liquid within the bulb is coloured based on the temperature rating. For sprinklers having a release mechanism other than glass bulbs, the frame arms, deflector, or coating material are options for applying the colour code.

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The most frequently used is the red or orange bulb type which is for ordinary temperatures and is set to between 57- and 77-degrees C. which is established as 30 degrees above normal ambient temperature for the room or area. The yellow or green bulbs are intermediate temperature bulbs set for between 79- and 107-degrees C. and the blue bulbs are set for a high temperature range from 121 to 149 degrees C.

Purple bulbs are set for Extra high temperatures between 163- and 191-degrees C. Anything above that temperature are black bulbs identified as very extra high or ultra-high temperature ranges.

The sprinkler head is chosen based on the maximum normal temperature of the room or area where it will be used. It should be rated at about 30 degrees above the maximum temperature that the sprinkler head will experience in normal conditions.

Reference:
NFPA 13

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The Canadian Automatic Sprinkler Association or Casa, says that Canada has one of the worst fire loss records in the industrialized world.

According to the National Fire Sprinkler Association in the US, there has never been a fire that claimed more than three lives due to fire or smoke in a sprinklered equipped building, except where the victims were in close proximity to the fire, or as a result of an explosion. Most fires in sprinkler equipped buildings are controlled by five or fewer sprinkler heads. In most cases only one sprinkler will be needed to prevent the growth and spread of a fire.

Reference:
CASA – NFSA

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That's the end of Part two of Fire Flow and Fire Suppression Systems.
In this part we discussed:

- The NFPA standards for sprinkler systems including NFPA 13 – 13 r for residential and 13d for single- and two-family dwelling
- Pipe schedule versus hydraulic calculations for sprinkler systems
- The traditional pipe calculations are still permitted in some situations, but hydraulic calculations are more common
- The interconnection of fire alarms and sprinkler systems
- Types of sprinkler systems including wet-pipe, dry-pipe, pre-action, and deluge
- Special types of sprinkler systems like foam, water mist, dry and wet chemical, and CO2
- Clean agent systems like halon
- We looked at sprinkler heads and the various types including upright, sidewall, and pendant
- Standard response and quick response heads
- Release mechanisms that include glass bulb, fusible links, and solder pellets
- Release temperatures and colour coding

Please move on to Part 3 where we will look at standpipe and hose systems and fire suppression system testing.