



**PDHonline Course M110 (4 PDH)**

---

# **Introduction to Fire Protection Systems**

*Instructor: Lawrence J. Marchetti, P.E.*

**2020**

**PDH Online | PDH Center**

5272 Meadow Estates Drive  
Fairfax, VA 22030-6658  
Phone: 703-988-0088  
[www.PDHonline.com](http://www.PDHonline.com)

An Approved Continuing Education Provider

# **MODULE – 3 PART II**

## **WATER BASED FIRE PROTECTION SYSTEMS**

In part 2 of this module we will introduce:

- Sprinkler head construction
- Concept of sprinkler head k-factor
- Sprinkler temperature ratings
- Sprinkler head configurations
- Sprinkler head types
- Sprinkler water supplies and hydraulics

Following successful completion of this module, the student should be able to:

- List the major construction components of a sprinkler head
- Have a fundamental understanding of the concept of sprinkler k-factor.
- List several temperature classifications for sprinkler heads.
- List three configurations of sprinkler heads, and the designation used to define the configuration.
- List at least four types of sprinkler heads.
- List the three major sources of water for sprinkler systems.

### ***SPRINKLER HEAD CONSTRUCTION***

The typical sprinkler head is constructed of a metal frame threaded into the sprinkler piping with a specific opening (orifice size) for the water to discharge through; a deflector to permit the water to be discharged into a specific pattern, and heat sensitive operating element to open the orifice upon the sensing of a pre-established level of heat as determined by the rating of the sprinkler fusible link. (An open sprinkler head, as used on a deluge system is similar in construction except that it does not contain a heat sensitive operating element).

## *SPRINKLER HEAD “ K- FACTOR”*

As discussed above, the water is discharged through an opening or orifice in the sprinkler head. The diameter and hydraulic characteristics of this orifice determine the flow and pressure characteristics of the sprinkler head. The numerical designation given to represent the hydraulic characteristic of a sprinkler head is called the k-factor. The k-factor for different sprinkler heads may range from  $k=5.6$  (standard  $\frac{1}{2}$ ” orifice) to  $k=14.0$  for ESFR sprinklers. The flow from a sprinkler may be determined from the following formula:

$Q = k \sqrt{p}$ , where  $Q$  is in gallons per minute (gpm),  $k$  is taken from manufacturer’s literature and  $p$  is the flow pressure in pounds per square inch (psig). For a typical sprinkler head with a  $k=5.6$ , and a flow pressure of 10 psig, the nominal discharge would be  $5.6\sqrt{10}$  or 17.7 gpm. NFPA requires a minimum of 7 psig at a conventional sprinkler but many special sprinklers (e.g. ESFR) may require as much as a minimum of 50 psig in order to operate properly. NFPA standards and manufacturer’s literature should always be reviewed prior to performing hydraulic calculations.

An increase in the k-factor of a sprinkler yields a higher flow (gpm), but lower pressure. Conversely, a decrease in the k-factor of a sprinkler yields a lower flow but higher pressure requirement.

The pressure at the sprinkler head ( $p$  in the formula above) is also critical for reasons other than the gpm flow from the sprinkler. The pressure at the sprinkler head affects the head discharge droplet size and spray pattern which are critical characteristics of the fire extinguishing performance of a sprinkler head. NFPA 13 and manufacturer’s literature should be consulted regarding this issue prior to design.

## *SPRINKLER TEMPERATURE RATINGS*

As discussed briefly, sprinkler heads activate by heat, usually accomplished by using a fusible link. The fusible link is a glass bulb filled with a low boiling point alcohol liquid or a metal alloy that seals the water opening (orifice) of the sprinkler. These fusible links are provided in a variety of

temperature ratings to withstand the maximum expected ceiling temperature without operating. For instance, a sprinkler head located within an office may have a fusible link rating of 135° F while the same type of sprinkler used in an unventilated attic space may be rated for 225°F. Sprinkler head fusible links also have different thermal response characteristics. Simply put, some sprinkler head fusible links are designed to operate “faster” than others and these are usually termed as “Quick Response Sprinklers”. (See the following sections for a discussion of these types of sprinklers).

NFPA has defined the following temperature classification of sprinklers:

135°F - 170°F	Ordinary
175°F - 225°F	Intermediate
250°F - 300°F	High
325°F - 375°F	Extra High
400°F - 475°F	Very Extra High
500°F – Above	Ultra High

NFPA has assigned specific sprinkler frame color codes as well as glass bulb color codes to assist in sprinkler temperature rating identification.

NFPA 13 has specific recommendations for the use of specific temperature classification sprinklers depending on the environment, and should be consulted before selecting a specific temperature rating.

### *SPRINKLER HEAD CONFIGURATIONS*

Generally, sprinkler heads are manufacturer in three basic configurations:

1. Upright Sprinklers- A standard spray sprinkler installed with the deflector above the frame so water flows upward from the orifice, striking the deflector, and discharging water in an “umbrella-shaped” upward pattern. These sprinklers are identified with the “SSU” (standard spray upright) designation on the deflector.
2. Pendent Sprinklers- A standard spray sprinkler installed with the deflector below the frame so water flows downward from the orifice,

striking the deflector, and discharging water in an “umbrella-shaped” downward pattern. These sprinklers are identified with the “SSP” (standard spray pendent) designation on the deflector.

3. Horizontal Sidewall Sprinkler- A spray sprinkler intended for installation near the wall and near the ceiling. The deflector is orientated parallel with the roof or ceiling and provides a water spray pattern outward in a quarter-spherical pattern. Flow arrows point the direction of flow on the sprinkler and mark it with the words “SIDEWALL”, and “TOP” to prevent improper installation.

### *SPRINKLER HEAD TYPES*

There are a variety of sprinkler heads in the market today that are too numerous to cover in this course. This section will cover the more common types of heads employed in fire sprinkler systems.

1. Quick Response Sprinklers- Sprinklers designed with a fast-acting heat actuating element and considered a special-purpose sprinkler. Application of this type of sprinkler may be limited to occupancy classification and hazard. Application of this type of sprinkler requires consultation with applicable codes.
2. Extended Coverage Sprinklers- A special service spray sprinkler designed to discharge water over a greater area than conventional sprinklers. (The actual maximum sprinkler coverage area is dictated by the specific sprinkler head listing provided by each manufacturer). Normally these sprinklers are intended for use in “Light Hazard Occupancies” with smooth level ceilings.
3. Quick Response/Extended Coverage Sprinklers- This sprinkler head combines the attributes of the sprinkler heads listed above and is also limited to “Light Hazard Occupancies”.
4. Large Drop Sprinklers- A special application sprinkler designed to discharge water in a downward umbrella-shaped pattern. However, the water discharge contains a higher percentage of “large” water droplets that are effective in penetrating high challenge fires. High challenge fires are characteristically quick, severe fires that generate

strong fire plumes and convective currents that deflect standard water droplets away before they can reach the seat of the fire. The larger droplets with a greater mass are more effective in penetrating the fire plume.

5. Institutional Sprinklers- Standard or special application sprinklers that provide tamper-resistive construction, have a low profile, and normally incorporate a “break-away” feature if excessive force is placed on the sprinkler. This type of sprinkler is normally used in correctional facilities and mental hospitals, and other occupancies where there is a threat of occupants tampering with the sprinkler or using the sprinkler head to harm themselves.
6. In-Rack Sprinklers- Standard or special sprinklers that are designed to protect combustibles stored on racks (e.g. within a warehouse) where conventional ceiling sprinkler head water discharge may not penetrate to the seat of the fire. Intermediate level sprinklers are in-rack sprinklers provided with a top canopy to prevent sprinklers located at a higher level from discharging on and cooling the fusible link of the lower level sprinklers.
7. Early Suppression Fast Response (ESFR) Sprinklers- Relatively new sprinkler technology introduced around 1990 that incorporates a fast response sprinkler with a large water volume output with a large droplet size. Generally, ESFR sprinklers are installed at the ceiling and in some situation can be applied as a sole means of fire suppression without the need for in-rack sprinklers. Generally these sprinklers are used to protect warehouses and distribution centers and require a water supply with sufficient pressure and volume to operate properly.

### *SPRINKLER SYSTEM WATER SUPPLIES*

The successful operation and effectiveness of any water based fire protection system rely on the water supply. Simply put, if the water supply cannot provide a sufficient volume of water at the required pressure, the system will not perform properly.

Generally there are two main types of water supplies for fire sprinkler systems:

1. Water supply from a municipal water distribution system.
2. Water supply from an on-site private water system (storage tank, lake, etc.)

A hydraulic analysis is normally provided on the water flow and pressure characteristics of an existing water supply to ensure sufficient water is available for fire protection. (New systems would incorporate fire protection use into the initial design). Often, this analysis will involve making hydrant flow tests near the protected building to determine the water system pressure and flow characteristics. If the water supply proves insufficient in either flow or pressure (or both), then other means of augmenting the water supply is required. For instance an automatic fire pump and/or elevated water storage tank can be used to boost pressure and/or volume.

Storage water tanks used for combined domestic and fire protection water usage, must provide sufficient allowance for reserve fire protection water to be available during periods of peak domestic demand. Additionally, water storage tanks must provide fire protection water for a sufficient duration.

Fire sprinkler systems are designed according to either a pipe schedule or hydraulic calculated type system.

The pipe schedule method generally consists of sizing piping based upon the number of sprinklers contained on the pipe and was developed based upon previous fire experience and adequacy of a water supply. The pipe schedule method is generally limited to smaller type systems and other restrictions as contained within NFPA 13, and is currently not normally used in sprinkler design.

The hydraulic calculation method requires an analysis of the available water supply and the proposed sprinkler piping layout and discharge density requirements. The piping is essentially sized to provide the required flow and pressure necessary at the design area on the sprinkler system. (The design area is defined as the hydraulically most remote portion of the sprinkler system. See NFPA 13 for more specific

information). The hydraulically calculated system usually results in a more economical and efficient piping design. The common calculation method utilizes the Hazen-Williams formula for determining hydraulic friction loss throughout the system. Numerous tables, charts, are available for use without performing tedious hand calculations. Typically, calculations are performed through the use of computer programs that permit the designer to model the piping configuration resulting in the most economical design.

NFPA 13 contains specific requirements for water supplies in addition to methods for testing municipal water supply system.