

OM2025

Design for Fire Safety 1



Chapter 2 Introduction to Sprinkler System

Students are required to note-down additional points taught or discussed in the classroom

1

INTRODUCTION

- A sprinkler is a **thermosensitive** device that is designed to discharge a **certain amount of water** in a **certain pattern**, is only activated when a fire generates a sufficient quantity of heat, and will control or suppress the fire once it has activated.
- The earliest sprinkler systems consisted of steel pipe networks with drilled holes or perforations provided along the length of pipe. This type of system often involved the use of a manually operated water supply. Additionally, the piping for these systems was often corroded, the holes were often plugged, and the water discharge from the pipe could generously be described as poor.

2

- The concept of employing a heat-actuated device dates back to approximately 1860. However, it was not until **1875** that **Henry Parmelee** incorporated this concept into a fire sprinkler device.
- The introduction of these new automatic sprinkler devices that did not require human intervention to initiate waterflow prompted greater acceptance and use of sprinkler systems for factories and storage facilities.
- The **insurance industry** in combination with the **Industrial Revolution** in the United States can be credited for promulgating and expanding the use of sprinkler systems. In old time, large-area, high-rise, high-value, and dense population structures soon became primary facilities where sprinkler systems would be of benefit.

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- **Automatic sprinkler** systems are designed to operate during the **early stages** of fire development and minimize the fire's overall impact.
- In addition, most systems are provided with an electrically supervised **waterflow alarm** that can automatically **notify the fire department** when the sprinkler system operates.
- Because of their effectiveness, various **building codes**, **insurance regulations**, and **local laws** require sprinkler systems in numerous types of buildings. If properly designed, installed, and maintained, sprinkler systems remain among the best options for providing cost-effective life safety and property protection.

4

SYSTEM COMPONENTS AND MATERIALS

- Maintaining integrity and reliability of a sprinkler system is accomplished in a number of ways. This includes restricting the types and quality of materials and components that comprise the system.
- The main components of an automatic sprinkler systems are:

Sprinklers

Piping and fittings

Valves

Hangers and bracing

Trim and attachments

- The process begins by selecting suitable sprinklers. Based on the flow demand, the piping and fittings are decided. Hangers and bracing are used to fix the system components to the building. The trim/ attachments refer to operational devices.

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SPRINKLER HEADS

- **Fusible link:** A common fusible-style automatic sprinkler operates when a metal alloy of predetermined melting point fuses.
- **Quartzoid bulb:** The small bulb, usually of glass, contains a liquid that does not completely fill the bulb, leaving a small air bubble trapped in it.



Source: ■

Source: viking.com

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TYPE OF SPRINKLER HEADS



UPRIGHT



PENDENT



RECESSED



CONCEALED



SIDEWALL

7

SPRINKLER DEFINITIONS

- **Automatic Sprinkler.** A fire suppression or control device that operates automatically when its heat-activated element is heated to its thermal rating or above, allowing water to discharge over a specified area.
- **Concealed Sprinkler.** A recessed sprinkler with cover plate.
- **Pendent Sprinkler.** A sprinkler designed to be installed in such a way that the water stream is directed downward against the deflector.
- **Recessed Sprinkler.** A sprinkler in which all or part of the body, other than the shank thread, is mounted within a recessed housing.
- **Sidewall Sprinkler.** A sprinkler having special deflectors that are designed to 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.

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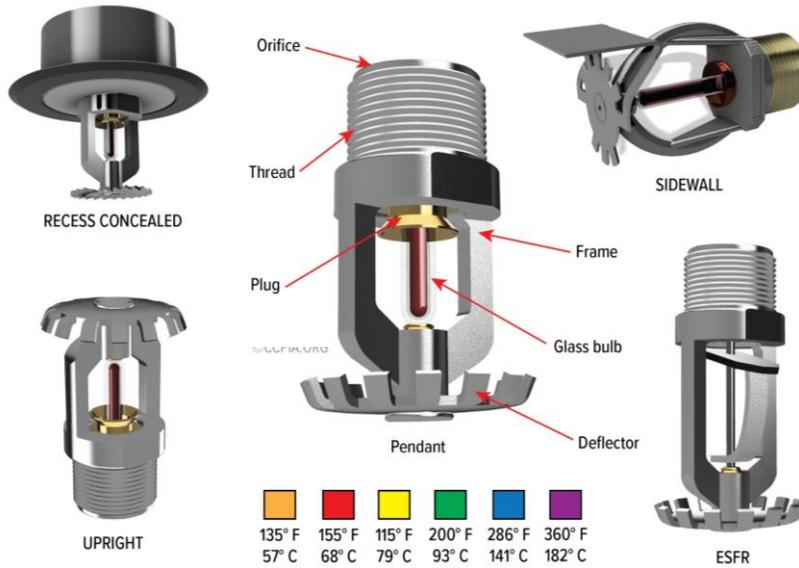
- **Upright Sprinkler.** A sprinkler designed to be installed in such a way that the water spray is directed upwards against the deflector.
- **Control Mode Specific Application (CMSA) Sprinkler.** A type of spray sprinkler that is capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific high-challenge fire hazards.
- **Early Suppression Fast-Response (ESFR) Sprinkler.** A type of fast-response sprinkler that has a thermal element with an RTI of 50 (meters-seconds)^{1/2} or less and is listed for its capability to provide fire suppression of specific high-challenge fire hazards.
- **Open Sprinkler.** A sprinkler that does not have actuators or heat-responsive elements.
- **Quick-Response (QR) Sprinkler.** A type of spray sprinkler that has a thermal element with an RTI of 50 (meter-seconds)^{1/2} or less and is listed as a quick-response sprinkler for its intended use.

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- **Residential Sprinkler.** A type of fast-response sprinkler having a thermal element with an RTI of 50 (meters-seconds)^{1/2} or less.
- **Spray Sprinkler.** A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.
- **Corrosion-Resistant Sprinkler.** A sprinkler fabricated with corrosion-resistant material, or with special coatings or platings, to be used in an atmosphere that would normally corrode sprinklers.

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Temperature Rating and Components



Source: viking.com

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- Glass-bulb sprinklers use the colour scheme. The liquid in a glass-bulb sprinkler is basically a low-boiling-point alcohol. The larger the bubble, the higher the operating temperature. The liquid is dyed the appropriate colour to correspond to the colour code system in the table.
- Sprinklers that have been coated with exterior material or painted must not be used.

Source: ●

Maximum Ceiling Temperature		Temperature Rating		Temperature Classification	Glass Bulb Colors
°F	°C	°F	°C		
100	38	135–170	57–77	Ordinary	Orange or red
150	66	175–225	79–107	Intermediate	Yellow or green
225	107	250–300	121–149	High	Blue
300	149	325–375	163–191	Extra high	Purple
375	191	400–475	204–246	Very extra high	Black
475	246	500–575	260–302	Ultrahigh	Black
625	329	650	343	Ultrahigh	Black

Source: NFPA 13, *Standard for the Installation of Sprinkler Systems*.

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Selection of a sprinkler

- There are several factors that affect a sprinkler's ability to control or extinguish a fire. These includes:
 - ✓ Thermal sensitivity.
 - ✓ Temperature ratings.
 - ✓ Orifice size.
 - ✓ Installation orientation.
 - ✓ Water distribution characteristics.
 - ✓ Special service conditions.

Source: ●

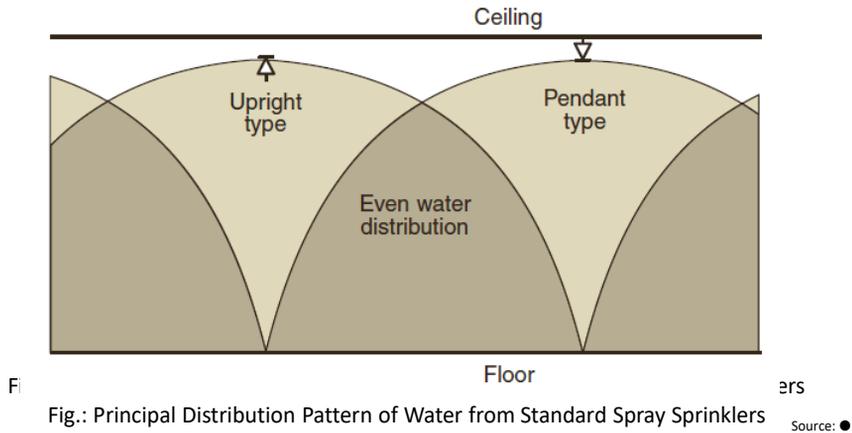
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- Automatic sprinklers were designed for uniform distribution of water over the area protected by one sprinkler and with wetting the ceiling.
- The design of the **DEFLECTOR** causes the solid stream of water issuing from the orifice of a standard sprinkler to break up to form an umbrella-shaped spray. The pattern is roughly that of a half-sphere filled with spray.
- Discharge is effective even in controlling fires on the ceiling above the sprinklers because of the improved **cooling effect of the spray**, better **high-level water distribution**, and **decreased exposure to the ceiling** because of more effective direct discharge of water on burning materials below

Source: ●

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- Standard spray sprinklers are made for installation in an upright or pendent position and must be installed in the position for which they are designed.
- Standard spray sprinklers are designed to be installed and operated in their proper position—that is, upright or pendent, as sometimes indicated by a stamping on the deflector bearing the appropriate word or the letters **SSU (spray sprinkler upright)** or **SSP (spray sprinkler pendent)**.



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SPRINKLER IDENTIFICATION

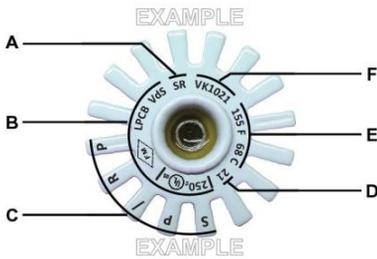


Figure – 1 Markings

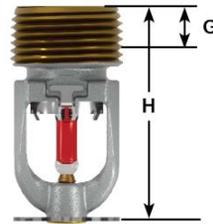


Figure – 2: Dimensions

Ref	Description	Value
A	Response type	SR: Standard Response
B	Listings and Approvals	See sections 3 and 5
C	Sprinkler type	SP/RP: Standard Pendent/Recessed Pendent
D	Manufacture date (year)	See marking
E	Nominal temperature rating	See marking
F	Manufacturers Sprinkler Identification Number (SIN)	VK2021
G	Nominal pipe engagement	7/16" (11 mm)
H	Height	2" (51 mm)

Source: <https://www.vikinggroupinc.com>

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Sprinklers With Specific Application

Response speed and fire sprinklers

- Quick response, residential, and early suppression fast response (ESFR) fire sprinklers all use “fast-response” elements, making them all “**fast-response sprinklers.**”
- A fast-response element is a fusible link or bulb that responds more quickly to temperature changes.
- **Quick response** sprinklers are nearly **identical** to **standard response** (SR) sprinklers—the only difference is the fast-response element.
- **Residential sprinklers**, while also fast response, are fundamentally different from **QR and SR sprinklers**—and most of the difference from QR is in the deflector.

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ESFR Sprinklers

- The early suppression fast response (ESFR) sprinkler was developed in the late 1980s and came into widespread use starting in the 1990s for **storage occupancies**.
- The ESFR sprinkler was developed to provide fire suppression for **high-challenge storage occupancies**, usually without the use of in-rack sprinklers. Whereas **most sprinklers** are designed to provide **fire control** (and achieve fire suppression as a by-product of good design and extra safety factors), the **ESFR sprinkler** is designed **specifically** to provide **fire suppression**.

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- Although the ESFR sprinkler has many advantages, it **does not work for all types of buildings and ceiling** construction, so architects and building owners need to make sure that the building and potential **obstructions** at the **ceiling** are closely coordinated with the sprinkler installation.

Source: ●



VKS20 - ESFR
Upright Sprinkler
(K14)



VK510 - ESFR
Pendent Sprinkler
(K25)



VK5141 - ESFR
Pendent Sprinkler
(K28)

Source: viking.com

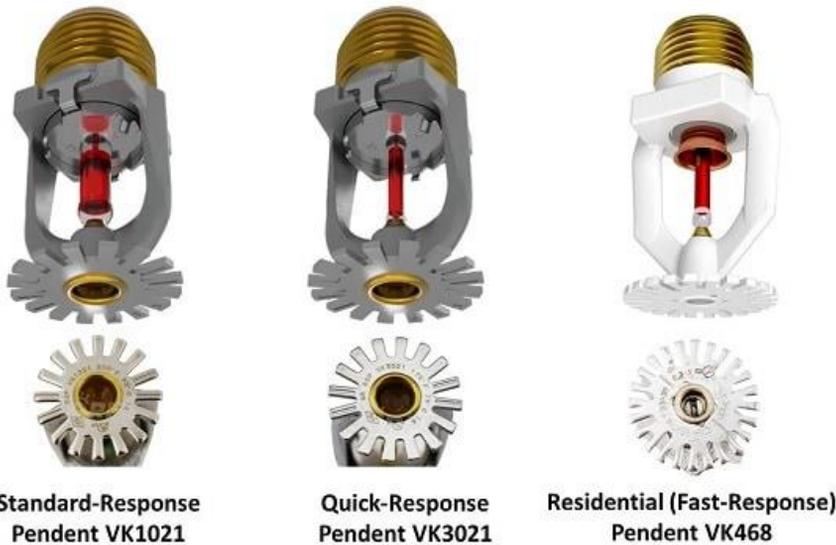
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Quick Response (QR) Sprinkler

- A type of spray sprinkler that has a thermal element with an **RTI of 50** (meter-seconds)^{1/2} or less and is listed as a quick-response sprinkler for its intended use.
- A quick-response sprinkler is **similar to a standard response sprinkler**, except that it possesses a **fast-response operating element**, so when exposed to the same temperature change, a quick response sprinkler will operate **faster than a standard response sprinkler**. QR sprinkler technology was developed from residential sprinkler technology.
- QR sprinklers are tested against the same criteria as standard-response sprinklers. NFPA 13 defines “fast-response” and “standard response” sprinklers based on these RTI values (3.3.205.4):
 - Fast response sprinklers have **RTIs of 50 or less**.
 - Standard response sprinklers have **RTIs of 80 or more**.

Source: 0

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Source: 0

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Control Mode Specific Application (CMSA) sprinkler

- These are designed for applications such as **storage occupancies**. These designs, along with most other types of sprinklers, are intended to **control the fire, not suppress it**.
- CMSA sprinklers are a type of spray sprinkler that can produce **characteristic large water droplets** and that is listed for its **capability to provide fire control** of specific **high-challenge fire hazards**.
- This term is meant to incorporate a wide variety of sprinklers capable of fire control in high challenge fire scenarios. Note that CMSA Sprinklers are **tested** for use in **specific storage configurations** and need to be used in accordance with their listing.
- You might hear some people refer to **CMSA sprinklers as large-drop sprinklers**.

Source: 0

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A: Extended Coverage Upright Sprinkler (CMDA/CMSA)
 B: Standard Response High Challenge® Upright Sprinkler CMSA
 C: Standard Response CMSA Pendent Sprinkler

Source: 0

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Sprinklers' K-factor and Different Orifice Sizes

- For many years, sprinklers have been manufactured with different orifice sizes to achieve different flows at available pressures. One of these characteristics is the K-factor, which describes the size and angle for the inlet of the sprinkler's orifice.
- The smaller the orifice size, the lower the flow that will discharge from the sprinkler when it opens. The characteristic used for measuring the **size of the orifice** is called the **K-factor**, and it represents the mathematical constant relating the flow from the sprinkler at the available pressure as indicated in the following formula:

$$Q = K\sqrt{P}$$

where

Q = Flow in lpm (L /min)

K = Flow constant **K-factor**

P = Pressure in bar

Source: ●

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- Sprinklers with K-factors less than 80 have traditionally been considered small orifice sprinklers. Sprinklers with K-factors larger than 80 traditionally have been referred to as large, extra large, and very extra-large orifice sprinklers.
- Sprinklers with K-factors of **80 lpm/(bar)^{1/2} or 5.6 gpm/(psi)^{1/2}** are still very commonly used in **light hazard** and **ordinary hazard occupancies**.

Table 7.2.2.1 Sprinkler Discharge Characteristics Identification

Nominal K-Factor [gpm/(psi) ^{1/2}]	Nominal K-Factor [L/min/(bar) ^{1/2}]	K-Factor Range [gpm/(psi) ^{1/2}]	K-Factor Range [L/min/(bar) ^{1/2}]	Percent of Nominal K-5.6 Discharge	Thread Type
1.4	20	1.3–1.5	19–22	25	½ in. (15 mm) NPT
1.9	27	1.8–2.0	26–29	33.3	½ in. (15 mm) NPT
2.8	40	2.6–2.9	38–42	50	½ in. (15 mm) NPT
4.2	60	4.0–4.4	57–63	75	½ in. (15 mm) NPT
5.6	80	5.3–5.8	76–84	100	½ in. (15 mm) NPT
8.0	115	7.4–8.2	107–118	140	¾ in. (20 mm) NPT or ½ in. (15 mm) NPT
11.2	160	10.7–11.7	159–166	200	½ in. (15 mm) NPT or ¾ in. (20 mm) NPT
14.0	200	13.5–14.5	195–209	250	¾ in. (20 mm) NPT
16.8	240	16.0–17.6	231–254	300	¾ in. (20 mm) NPT
19.6	280	18.6–20.6	272–301	350	1 in. (25 mm) NPT
22.4	320	21.3–23.5	311–343	400	1 in. (25 mm) NPT
25.2	360	23.9–26.5	349–387	450	1 in. (25 mm) NPT
28.0	400	26.6–29.4	389–430	500	1 in. (25 mm) NPT

Note: The nominal K-factor for dry-type sprinklers are used for sprinkler selection. See 27.2.4.10.3 for use of adjusted dry-type sprinkler K-factors for hydraulic calculation purposes.

Source: ● ■

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Measuring sprinkler response with RTI

- Fast-response bulbs and links were initially developed for **residential sprinklers** and systems but soon applied to **commercial settings**, leading to the development of the **now-ubiquitous QR sprinkler**.

But who decides what “fast-response” is?

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- A sprinkler’s response speed is measured, as Viking explains, with a plunge test performed as part of its listing requirements.
- In this test, a sprinkler is suddenly inserted into a “**plunge oven**”—really, a glorified convection oven—that circulates air at a constant high temperature.
- The time between insertion and activation (in other words, when the bulb bursts or the link solders) determines the response time index (**RTI**).
- See more: <https://www.youtube.com/watch?v=t5iPPSYQqmw>

Source: 

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- RTI essentially measures how long it takes for the sprinkler's bulb or link to go from room temperature to activation temperature. **The shorter this time, the lower the RTI.**
- NFPA 13 defines “**fast-response**” and “**standard-response**” sprinklers based on these RTI values (**3.3.205.4**):
 - **Fast response** sprinklers have RTIs of **50 or less**.
 - **Standard response** sprinklers have RTIs of **80 or more**.
- Remember, “**fast-response**” is an umbrella term with three different types of sprinklers beneath it: QR, residential, and early-suppression fast-response (**ESRF**)

Source: 0

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PIPE AND TUBE

- A number of piping materials are acceptable for use in sprinkler systems. Steel, copper, and nonmetallic pipe materials are currently in use in various occupancies.
- **Steel Pipe.** Steel pipe has been a viable option for use in sprinkler systems.
- **Copper Pipe.** Copper tube was first discussed as an optional material for sprinkler systems. Concern over the failure of solder materials or the brazing materials used to join the copper tube was expressed as being a potential failure point of the system during a fire.

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- **Nonmetallic Pipe.** There are two types of plastic pipe for use in sprinkler systems.
 - **Polybutylene (PB):** An obvious concern with plastic pipe is failure when exposed to fire and even its possible contribution to fire growth. This concern was addressed by requiring the pipe to be installed behind a protective membrane.
 - **Chlorinated Polyvinyl Chloride (CPVC):** A second type of nonmetallic pipe, was introduced in 1986.
- The regulations include a number of conditions and restrictions while non-metallic pipes are used.
 - It can be installed only in light-hazard occupancies.
 - Can be used in all wet pipe systems but limited for dry pipe and pre-action systems.
 - Must be installed behind a thermal barrier.
 - Can be used with listed quick-response (QR) sprinklers, where the QR sprinklers are installed within 8 in. (203 mm) of the ceiling.
 - Must be joined with listed fittings or materials
 - Not permitted to be installed in concealed combustible spaces

Source: ●

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The Hazen–William formula,
$$P_m = 6.05 \left(\frac{Q_m^{1.85} \times L}{C^{1.85} \times d_m^{4.87}} \right) 10^5$$

TABLE 27.2.4.8.1 Hazen–Williams C Values

<i>Pipe or Tube</i>	<i>C Value*</i>
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Galvanized steel (dry systems including preaction)	100
Galvanized steel (wet systems including deluge)	120
Plastic (listed) all	150
Cement-lined cast- or ductile iron	140
Copper tube, brass or stainless steel	150
Asbestos cement	140
Concrete	140

*The authority having jurisdiction is permitted to allow other C values.

Source: ●

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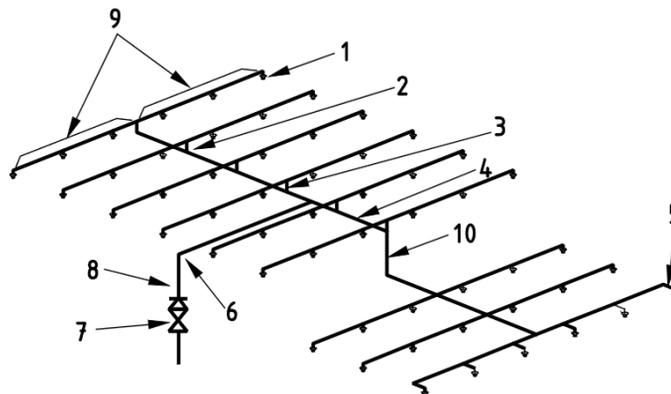
TYPES OF SPRINKLER NETWORK

- Sprinkler system, is described as a combination of underground and overhead piping that is connected to an automatic water supply. The piping is specially sized or hydraulically designed with that portion of the piping within the building generally located overhead.
- Sprinklers are attached to the overhead piping in a systematic pattern.
- Most sprinkler systems fall within one of four categories. These include
 - (1) wet pipe
 - (2) dry pipe
 - (3) pre-action
 - (4) deluge

Source: ■

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Sprinkler Network



Key

1	sprinkler head	6	main distribution pipe
2	riser	7	control valve set
3	design point	8	riser
4	distribution pipe spur	9	range pipes
5	arm pipe	10	drop

Figure: Main elements of a sprinkler network (Source: Δ)

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Wet Pipe System

- Wet pipe systems contain water under pressure at all times and utilize a series of closed sprinklers.
- When a fire occurs and produces a sufficient amount of heat to activate one or more sprinklers, because an automatic water supply is mandated, water immediately discharges from the open sprinklers.
- Wet pipe systems should be the first choice of designers and installers because they are more inherently reliable and less costly to maintain.

Source: ●

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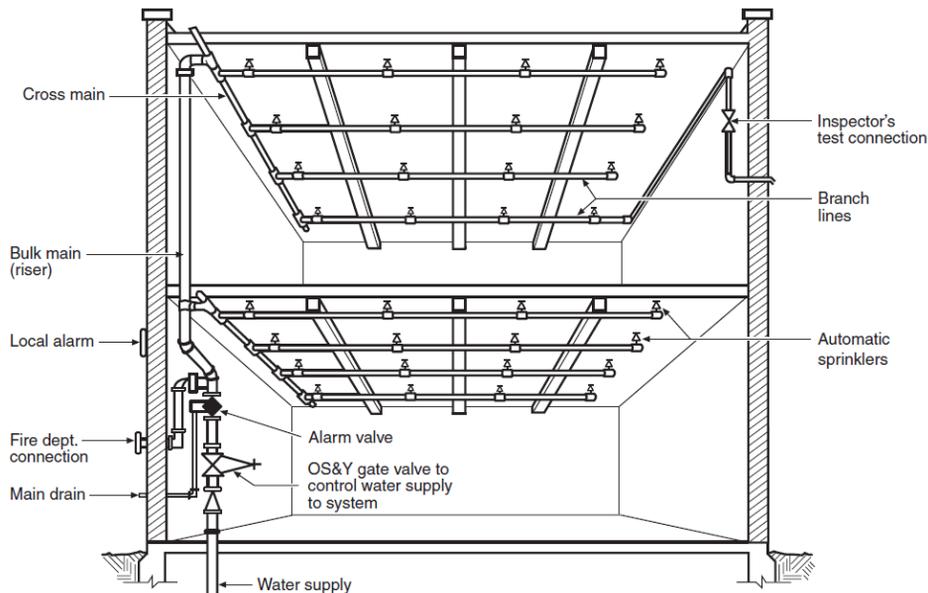


Figure: Sketch showing the different components of a typical **wet** type sprinkler system.

Note-down the typical terms used for the sprinkler network.

Source: ●

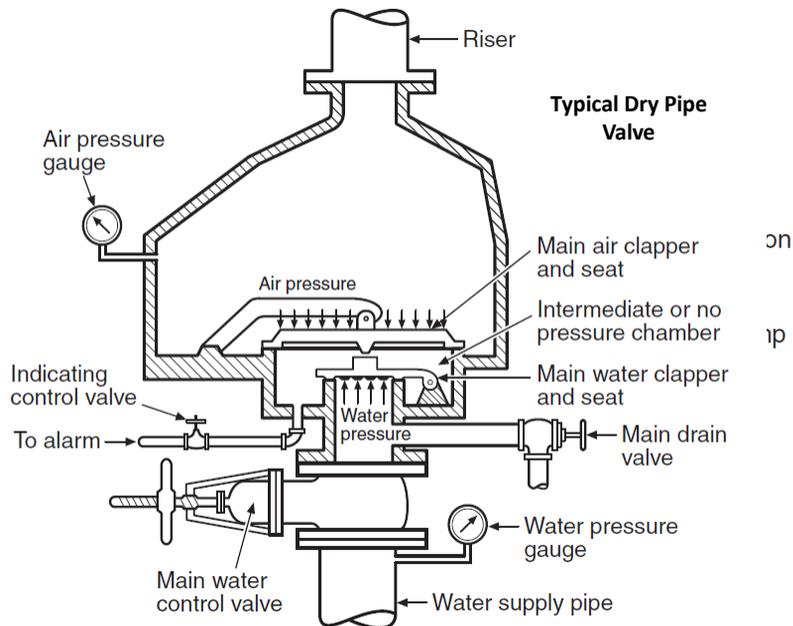
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Dry Pipe System

- These systems should only be used when system components will be exposed to temperatures below 40°F (4°C).
- System piping contains no water prior to system activation but rather is charged with air or nitrogen under pressure. If a fire occurs and a sufficient amount of heat is generated, one or more sprinklers operate, causing system air pressure to drop.
- Once the air pressure falls below a predetermined level, the dry pipe valve opens, allowing water to flow through the system to the open sprinklers.
- Dry pipe systems are more complex than wet pipe systems. They require a reliable air and water supply sources, too.

Source: ●

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Source: ●

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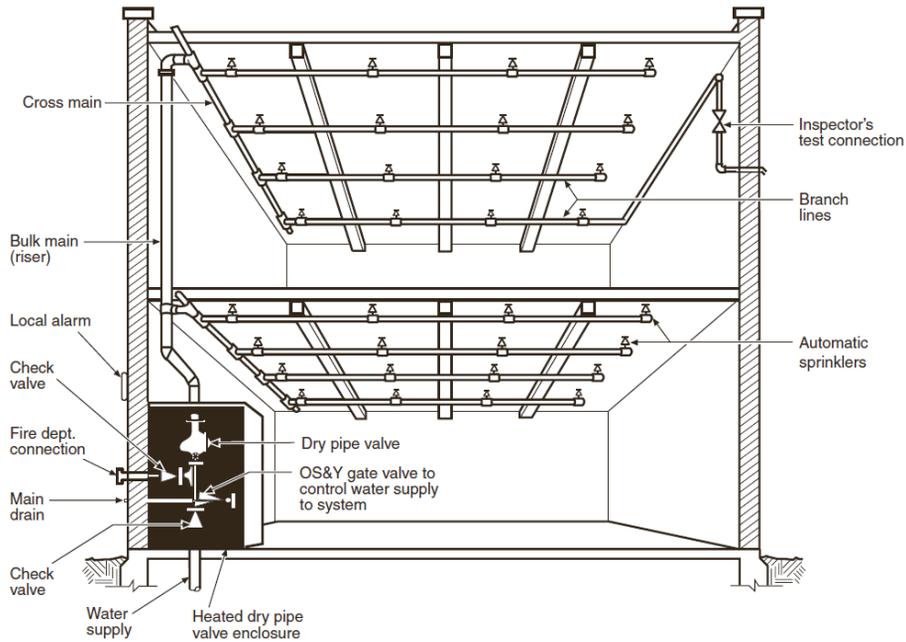


Fig.: Sketch showing the different components of a typical **dry** type sprinkler system.

Source: ●

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Pre-action System

- Similar to a dry pipe system, preaction system piping is also charged with air under pressure rather than water.
- Two Triggers are there for a pre-action system
 - **Trigger 1-** at the time of a fire the Heat detectors connected to the system activates (Separated from Sprinkler heads) and allows the water to enter into a dry pipe and act as wet system
 - **Trigger 2-** The bulb breaks at a specific temperature and water flows out to extinguish the Fire
- Water will not discharge from the system until a fire has generated a sufficient quantity of heat to cause operation of one or more sprinklers. Pre-action systems are typically found in spaces containing computer or communications equipment, museums, and other facilities where inadvertent water leakage from system piping is of major concern.

Source: ●

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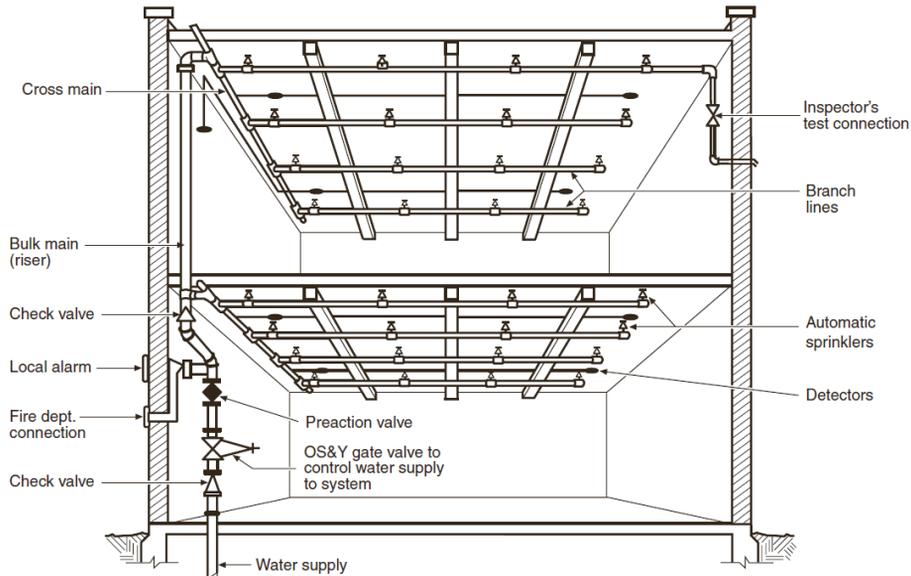


Fig.: Sketch showing the different components of a typical PREACTION type sprinkler system.

Source: ●

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Deluge Systems

- Deluge systems, as the name implies, deliver large quantities of water over specified areas in a relatively short period of time. These systems are used to protect against rapidly growing and spreading fires. Sprinklers used in a **deluge system do not contain thermally sensitive operating elements and are referred to as open sprinklers (spray heads)**.
- A deluge valve controls the system water supply and is activated by a **supplemental fire detection system**.
- As water reaches each sprinkler in the system, it is immediately discharged from the whole system.
- The system is also used for situations in which thermal damage is likely to occur in a relatively short period of time. Aircraft hangars, tank farms are the area of application of deluge systems.

Source: ●

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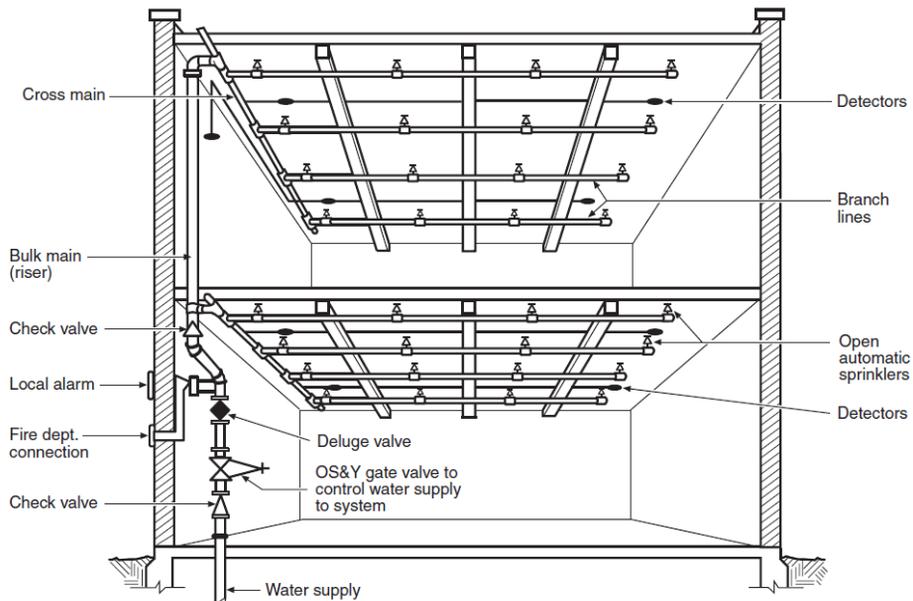


Figure: Sketch showing the different components of a typical **deluge** type sprinkler system.

Note-down the typical terms used for the sprinkler network.

Source: ●

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Sprinkler Piping Configurations

The choice between piping configuration is often determined by **type of the occupancy**, **size and geometry of the space** to be protected, **number of sprinkler heads**, **type of the network** preferred, **economics** and the available **water supply**.

1. Tree type.
2. Looped type.
3. Gridded type.
4. Combination type.

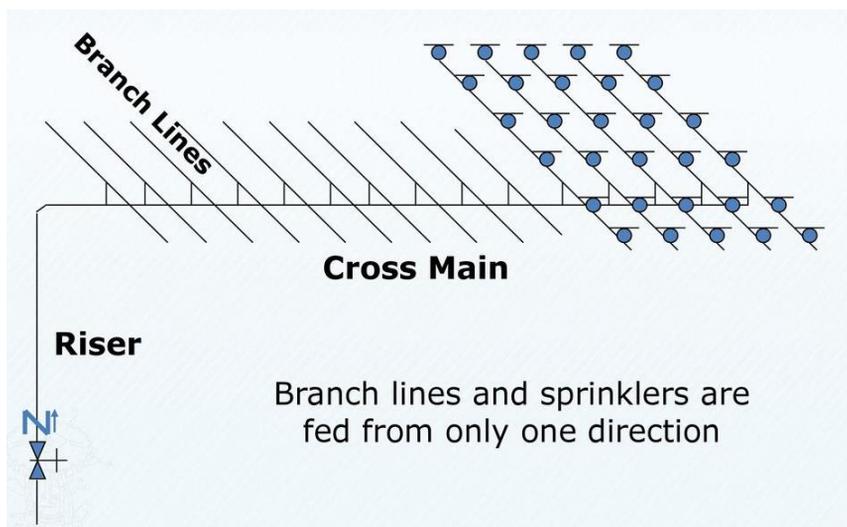
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Tree type

- Often called as dead end system connected with a central branch pipe.
- Water is delivered through a cross main, which acts like the trunk of a tree.
- Sprinklers are located on branch lines attached to the cross main. They are the least efficient type of sprinkler system with regards to friction loss in the piping, but they are the simplest to install.
- The hydraulic calculations associated with tree systems are the most basic and can be done by hand.

Source: ●

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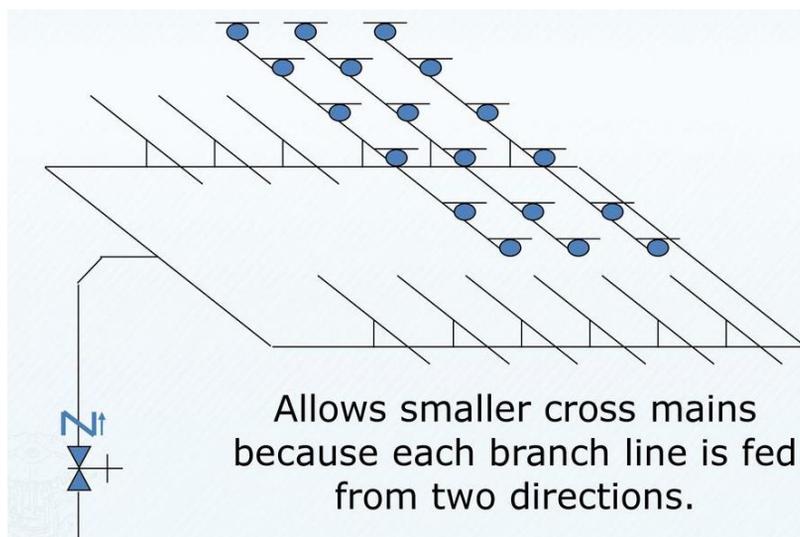
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Loop type

- Primary main makes a loop to supply branch lines. It is often called circuit system as well.
- The looped mains split the water supply into 2 paths for the water to flow from the source to the branch line that is supplying the flowing sprinklers.
- Splitting flow reduces friction and pressure loss and thus increasing hydraulic efficiency.
- A looped sprinkler system possesses better hydraulic characteristics than a tree system.

Source: ●

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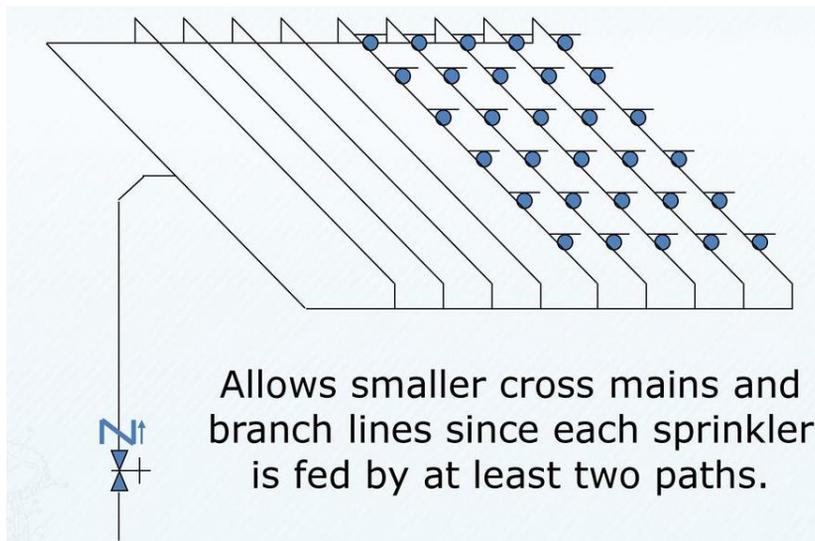
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Grid type

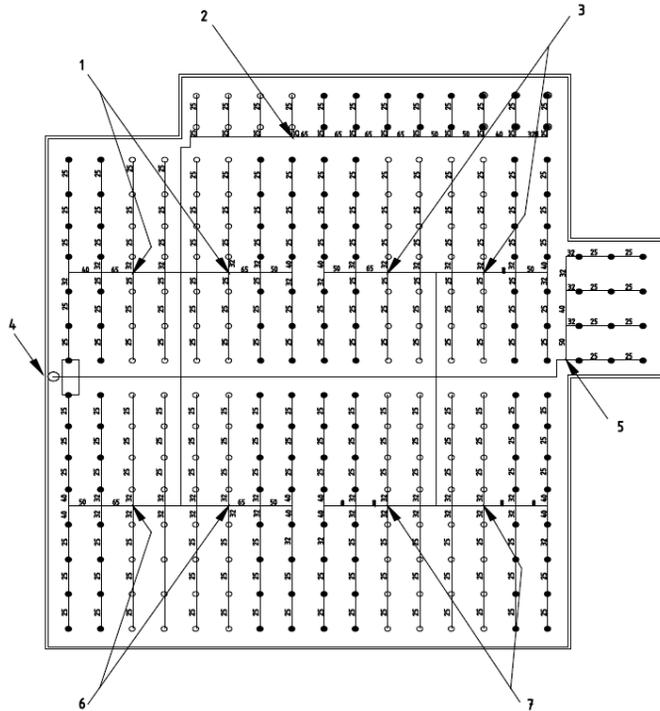
- Grid systems are typically used where there is a very high sprinkler water demand. It is important to remember grid system configuration **cannot be used with dry, double interlock (pre-action)**, because excessive amounts of air can remain trapped in the system piping, which significantly delays water from reaching the operating sprinklers
- There may be excessive time delay due to large network and the complexity of the system.
- This multiple-path design reduces the potential for pressure loss through the system piping compared with other system configurations. Due to the complex nature of the hydraulic calculations involved, the use of **computer hydraulic programs** is almost always necessary in evaluating the piping grid.

Source: ●

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Exercise:
Example of a sprinkler network designed using pipe-schedule method.

Source: BS EN 12845 (2015+2019)

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References and further reading

- NFPA 13 (2019 Ed.) Standard for the installation of Sprinkler system, National Fire Protection Association.
- △ BS EN 12845 (2015) Fixed firefighting systems —Automatic sprinkler systems— Design, installation and maintenance, BSI Standards Publication.
- A. E. Cote (2008) Fire Protection Handbook, National Fire Protection Association
- ☒ Fire Service Manual - Volume 3 (1998) Fire Safety- Fire Protection of Buildings, TSO
- Scott Martorano (2006) Automatic Sprinkler Thermal Sensitivity: Clarifying the Terms Fast Response and Quick Response, Viking Technical Article, Viking.

NFPA 101 Life safety code (2022)

M. J. Hurley (2016) SFPE Handbook of Fire Protection Engineering Society of Fire Protection Engineers Springer, New York

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Revision Questions

1. Identify components of a sprinkler network.
2. Outline various types of sprinkler heads and their purpose.
3. Sprinkler definitions.
4. Identify the factors that affect a sprinkler's ability to control or extinguish a fire.
5. Discuss the difference between QR Sprinklers, CMSA sprinklers and ESFR sprinklers.
6. Discuss your point of view on consideration of "K factor " while designing sprinkler system.
7. Outline the types of piping materials acceptable for use in sprinkler systems
8. Elaborate types of sprinkler networks on the basis of their operation mechanism.
9. Critically analyse various types sprinkler piping configurations with appropriate drawings.

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Thank You...

Student's Notes:

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