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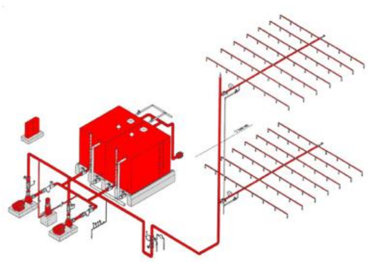
OM2025
Design for Fire Safety 1

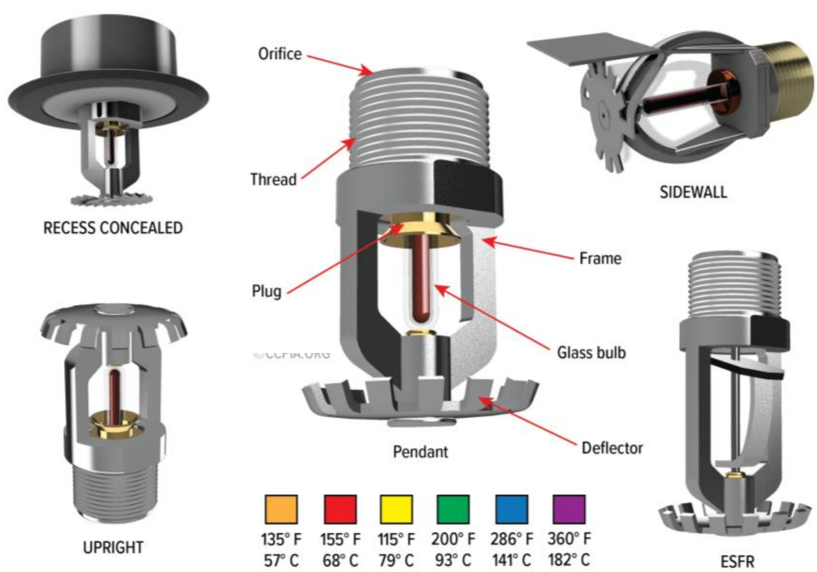


Chapter 3
Sprinkler System:
Design and Calculations

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

1

Temperature Rating and Components



Source: viking.com

2

- 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.

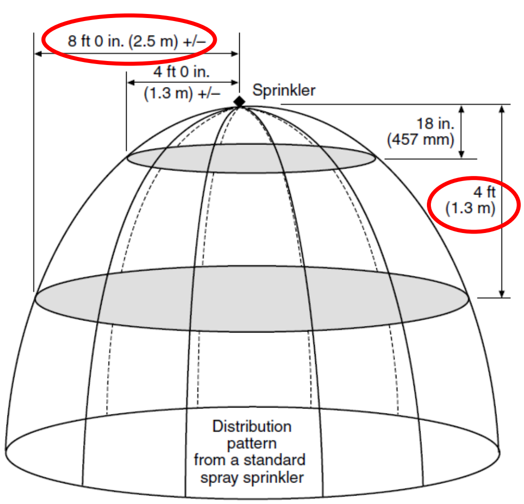
Source: ●

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.*

3

Discharge pattern of a sprinkler

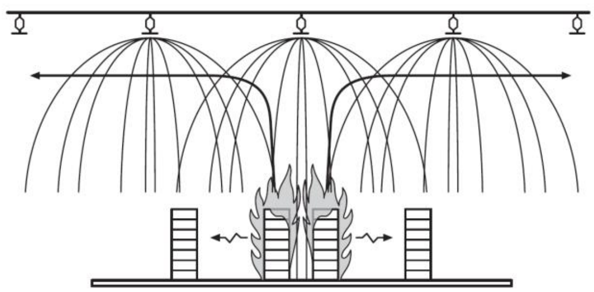


The figure shows the discharge pattern from a standard sprinkler head. Note that the **coverage area varies with the height**, however **as the coverage increases**, the **spray density will reduce**. Hence minimum spacing and height requirements are specified.

Source: ●

4

- The traditional method by which sprinkler systems control fires currently is being termed the "**fire control**" approach. This method anticipates that a certain number of sprinklers will be opened surrounding the fire area.
- The sprinklers immediately over the fire may not be able to actually extinguish the fire, they will work with other open sprinklers to cool the atmosphere and to prevent sprinklers outside the general vicinity of the fire from operating.



- In the meantime, the open sprinklers outside the immediate fire area also can be expected to pre-wet adjacent combustibles, helping to prevent the spread of fire.

Source: ●

5

Classification of Occupancies

NFPA 13

- The proper occupancy hazard classification for a given building or areas within a building by carefully reviewing the description for each occupancy hazard and by evaluating:
  - ❑ Quantity
  - ❑ Combustibility
  - ❑ Heat release
- The occupancy hazards provides a convenient means of categorizing the fuel loads and fire severity associated with certain building operation (detailed list is given in **Annex. A**).
  - ❑ **Light hazard: Office buildings, Schools, Residential occupancies, Public assembly**
  - ❑ **Ordinary hazard (G 1 & 2): Restaurant service areas (G1), Dry cleaners (G1), Electronic plants (G1), Libraries (G2), Repair garages (G2), Wood product assembly (G2)**
  - ❑ **Extra hazard (G 1 & 2): Combustible fluid use area (G1), Printing (G1), Upholstering with plastic foams (G1), Flammable liquids spraying (G2), Plastics processing (G2).**

Source: ■

6

BS EN 12845:2019

- Split into different Hazard Groups
  - ❑ Light Hazard (LH)
  - ❑ Ordinary Hazard (OH) – sub groups 1 to 4
  - ❑ High Hazard Process (HHP) - sub groups 1 to 4
  - ❑ High Hazard Storage (HHS) - sub categories 1 to 4
- Storage occupancy groups depend on goods stored, method of storage and height of storage.
- The higher the fire risk the greater the demand on a sprinkler installation to deliver sufficient quantities of water to ensure fire control (detailed list is given in **Annex. A**).

Source: △

7

Spacing requirement

Table 10.2.4.2.1(a) Protection Areas and Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Light Hazard

Construction Type	System Type	Maximum Protection Area ft²	Maximum Protection Area m²	Maximum Spacing ft	Maximum Spacing m
Noncombustible unobstructed	Hydraulically calculated	225	20	15	4.6
Noncombustible unobstructed	Pipe schedule	200	18	15	4.6
Noncombustible obstructed	Hydraulically calculated	225	20	15	4.6
Noncombustible obstructed	Pipe schedule	200	18	15	4.6
Combustible unobstructed with no exposed members	Hydraulically calculated	225	20	15	4.6
Combustible unobstructed with no exposed members	Pipe schedule	200	18	15	4.6
Combustible unobstructed with exposed members 3 ft (910 mm) or more on center	Hydraulically calculated	225	20	15	4.6
Combustible unobstructed with exposed members 3 ft (910 mm) or more on center	Pipe schedule	200	18	15	4.6
Combustible unobstructed with members less than 3 ft (910 mm) on center	All	130	12	15	4.6
Combustible obstructed with exposed members 3 ft (910 mm) or more on center	All	168	16	15	4.6
Combustible obstructed with members less than 3 ft (910 mm) on center	All	130	12	15	4.6
Combustible concealed spaces in accordance with 10.2.6.1.4	All	120	11	15 parallel to the slope 10 perpendicular to the slope*	4.6 parallel to the slope 3.0 perpendicular to the slope*

Source: ■

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Table 10.2.4.2.1(b) Protection Areas and Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Ordinary Hazard

Construction Type	System Type	Protection Area ft²	Protection Area m²	Maximum Spacing ft	Maximum Spacing m
All	All	130	12	15	4.6

Table 10.2.4.2.1(c) Protection Areas and Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Extra Hazard

Construction Type	System Type	Protection Area ft²	Protection Area m²	Maximum Spacing ft	Maximum Spacing m
All	Pipe schedule	90	8.4	12*	3.7*
All	Hydraulically calculated with density ≥0.25 gpm/ft² (10.2 mm/min)	100	9	12*	3.7*
All	Hydraulically calculated with density <0.25 gpm/ft² (10.2 mm/min)	130	12	15	4.6

Source: [redacted]

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Table 14.2.8.2.1 Protection Areas and Maximum Spacing of ESFR Sprinklers

	Ceiling/Roof Heights Up to 30 ft (9.1 m)				Ceiling/Roof Heights Over 30 ft (9.1 m)			
	Protection Area		Spacing		Protection Area		Spacing	
Construction Type	ft²	m²	ft	m	ft²	m²	ft	m
Noncombustible unobstructed	100	9	12	3.7	100	9	10	3.0
Noncombustible obstructed	100	9	12	3.7	100	9	10	3.0
Combustible unobstructed	100	9	12	3.7	100	9	10	3.0
Combustible obstructed	N/A		N/A		N/A		N/A	

Table 13.2.5.2.1 Protection Areas and Maximum Spacing for CMSA Sprinklers

Construction Type	Protection Area ft²	Protection Area m²	Maximum Spacing ft	Maximum Spacing m
Noncombustible unobstructed	130	12	12	3.7
Noncombustible obstructed	130	12	12	3.7
Combustible unobstructed	130	12	12	3.7
Combustible obstructed	100	9	10	3.0
Rack storage combustible obstructed	100	9	10	3.0
Rack storage unobstructed and noncombustible obstructed	100	9	12	3.7

Early suppression fast-response (**ESFR**) sprinklers

Chapter 14 (NFPA 13)

Control mode specific application (**CMSA**) sprinklers

Chapter 13 (NFPA 13)

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Type of hazard	Protection area A_S (MCS)	Maximum Spacing (S)
Light Hazard	225 ft^2 (**21 m^2**)	15 ft (**4.6 m**)
Ordinary Hazard	130 ft^2 (**12 m^2**)	15 ft (**4.6 m**)
Extra Hazard or High Hazard	90 - 130 ft^2 (**9 - 12 m^2**)	12-15 ft (**3.4- 4.6 m**)

Note: The above **table X** indicates a summary of the protection area and maximum spacing as recommended by NFPA 13. These are general guidelines provided for ease of calculations however specific guidelines to be followed by an individual for different types of construction and hazards. Actual spacing will be less than the maximum and should meet the discharge density requirements.

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Protection Areas per Sprinkler

The protection area of coverage per sprinkler (A_s) shall be determined as follows:

(1) **Along branch lines as follows:**

a) Determine distance between sprinklers (or to wall or obstruction in the case of the end sprinkler on the branch line) upstream and downstream

b) Choose the larger of either twice the distance to the wall or the distance to the next sprinkler

c) Define dimension as S

(2) **Between branch lines as follows:**

a) Determine perpendicular distance to the sprinkler on the adjacent branch line (or to a wall or obstruction in the case of the last branch line) on each side of the branch line on which the subject sprinkler is positioned

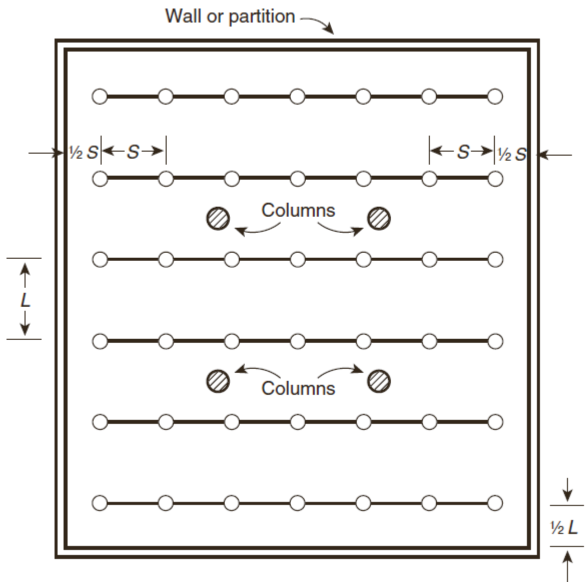
b) Choose the larger of either twice the distance to the wall or obstruction or the distance to the next sprinkler

c) Define dimension as L

Source: ■

12

S & L Dimensions



Source: ■

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- The protection area of coverage of the sprinkler shall be established by multiplying the S dimension by the L dimension, as follows:

$$A_s = S \times L$$

- The maximum area of coverage of any sprinkler shall not exceed 400 ft^2 (**37 m^2**).

Source: ■

14

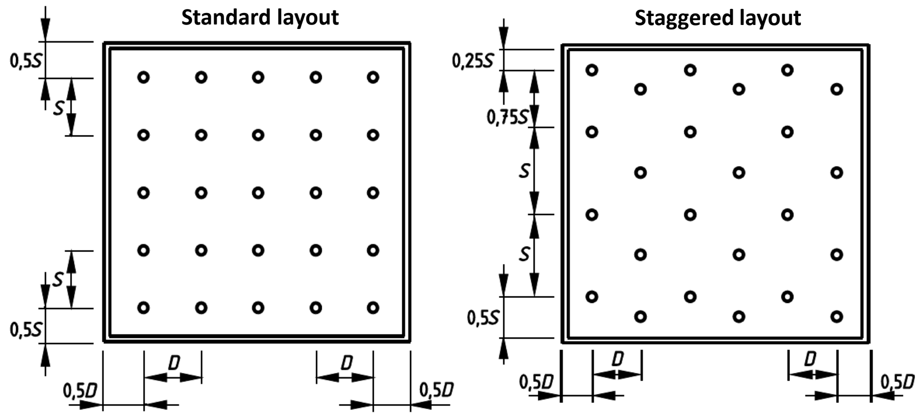

Table 19 — Maximum coverage and spacing for sprinklers other than sidewall

Hazard class	Maximum area per sprinkler	Maximum distances as shown in Figure 8 m		
		Standard layout	Staggered layout	
	m^2	S and D	S	D
LH	21,0	4,6	4,6	4,6
OH	12,0	4,0	4,6	4,0
HHP and HHS	9,0	3,7	3,7	3,7

Source: △

System Protection Area Limitations

- The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser or combined system riser shall be as follows:

1. **Light hazard** — 52,000 ft^2 (4830 m^2)
2. **Ordinary hazard** — 52,000 ft^2 (4830 m^2)
3. **Extra hazard** — 40,000 ft^2 (3720 m^2)
4. **In-rack Storage** — 40,000 ft^2 (3720 m^2)

- One riser system can be used **per protection area**. More riser to be used if area exceeds the given limitation.

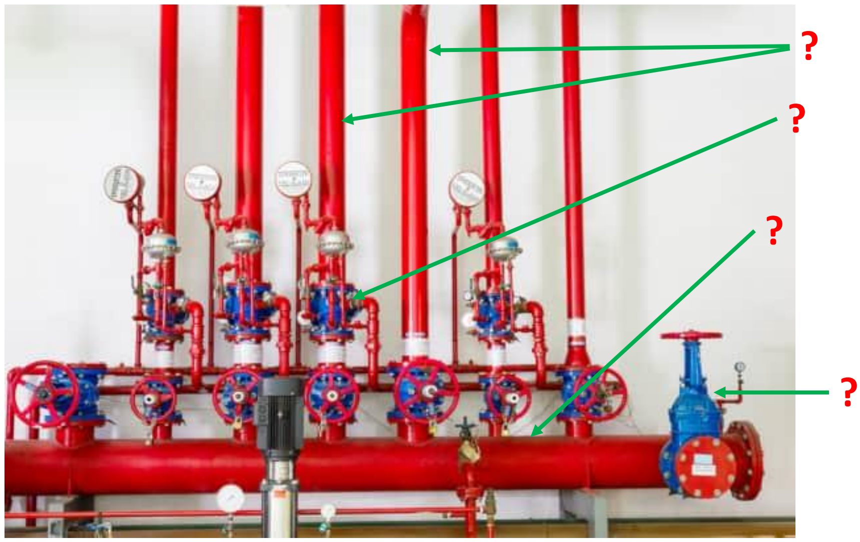

Figure: Multiple sprinkler risers may be installed within a fire pump room for the protection of a large facility

Source: https://qrfs.com

17

Basic steps involved in Sprinkler system design

A sprinkler system design for an occupancy will involve the following basic steps –

1. Determine the hazard occupancy classification.
2. Calculate total area of the occupancy.
3. Determine the actual distance between sprinkler head (S).
4. Determine the actual Distance between the ranges (L).
5. Calculate total number of sprinkler to be installed.
6. Determine the distance between the wall and the last sprinkler of the range.
7. Determine the parallel distance between wall and first range.

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Calculating – Total Water (flow & pressure) Requirement

Density/area

- The density/area method can be generally defined as a given amount of water (sprinkler discharge rate) over a specified area.
- This **given amount of water** is known as the **design density**, which is intended to provide cooling and wet adjacent surfaces with the goal of controlling an unintended fire until it can be fully extinguished by emergency services.
- Apart from this, most fire sprinkler system calculations are done utilizing
  - **hydraulic calculation or**
  - **pipe schedule method**
- **using software**, many are integrated into computer aided drafting (CAD) programs.

Source: ■

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Remote area

- When calculating the water demand needed for the system, it is crucial that the **correct location** should be chosen as the **remote area**.
- The area selected should be the **hydraulically most demanding,** which is often **physically the furthest point** from the sprinkler riser on the system.
- The steps in identifying the remote area involve determining the **area** (**square meters**) from the design criteria, applying the necessary **adjustments** to this **area**, calculating the **shape**, determining the **number of sprinklers necessary in the area**, and selecting those sprinklers that meet the **remoteness** and **shape criteria**.

Source: ■

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Why examine only the most remote area?

- The **logic** of examining only the **set number of heads at the most remote portion** of the building is as follows:
  - Keeping **pipe diameters** and **minimum water flow requirements** the same throughout the building, because of physics and hydraulics, if the minimum required **water pressure (bar) and flow (Lpm)** are met at the most remote section of the building, as you move closer to the riser, water **pressure and flow** will automatically be greater.
- When the remote area and number of sprinklers are correctly identified, it will ensure approximate water demand needed by the area of operation in the event of an unwanted fire.

Source: ■

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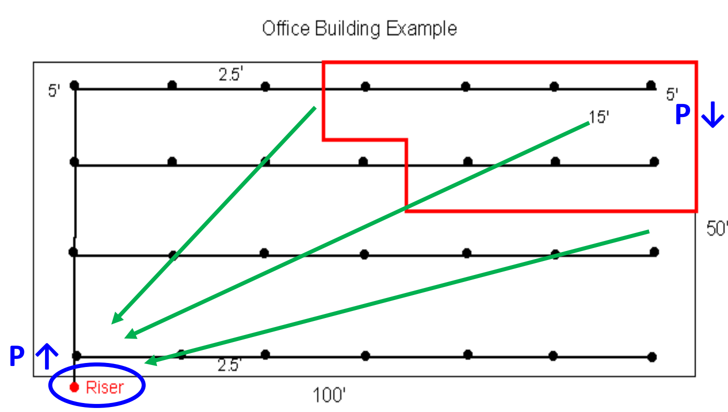

Figure: Example of Determining the Number of Sprinklers in the **Remote Area**.

Source: ■

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Identifying the remote area

- The steps in identifying the remote area involve:
  - Determining the area (square meters (m^2)) from the design criteria
  - Applying the necessary adjustments to this area, calculating the shape
  - Determining the number of sprinklers necessary in the area
  - Selecting those sprinklers that meet the remoteness and shape criteria.
- After determining the size of the remote area, we will need to determine its shape on the basis of number of sprinklers in a range pipe.
- Even when utilizing computer software, engineers and designers need to select these sprinklers correctly to ensure they accurately provide the water demand needed in the event of an unwanted fire.

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- The **water demand** for sprinklers shall be determined only from one of the following:
  - The density/area selected from Table 19.2.3.1.1 in accordance with the density/area method of 19.2.3.2.
  - For the evaluation or modification of existing systems, the density/area curves.

N **Table 19.2.3.1.1 Density/Area**

Hazard	Density/Area [gpm/ft²/ft² (mm/min/m²)]
Light	0.1/1500 or 0.07/3000* (4.1/140 or 2.9/280)
Ordinary Group 1	0.15/1500 or 0.12/3000* (6.1/140 or 4.9/280)
Ordinary Group 2	0.2/1500 or 0.17/3000* (8.1/140 or 6.9/280)
Extra Group 1	0.3/2500 or 0.28/3000* (12.2/230 or 11.4/280)
Extra Group 2	0.4/2500 or 0.38/3000* (16.3/230 or 15.5/280)

*When required by 19.2.3.1.5.

Source: ■

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- Obsolete method to determine water **density from the curves / graph:**
  - **Step a**: Find the total area to be protected, here the total floor area of the restaurant
  - **Step b**: Find the density (mm/min)

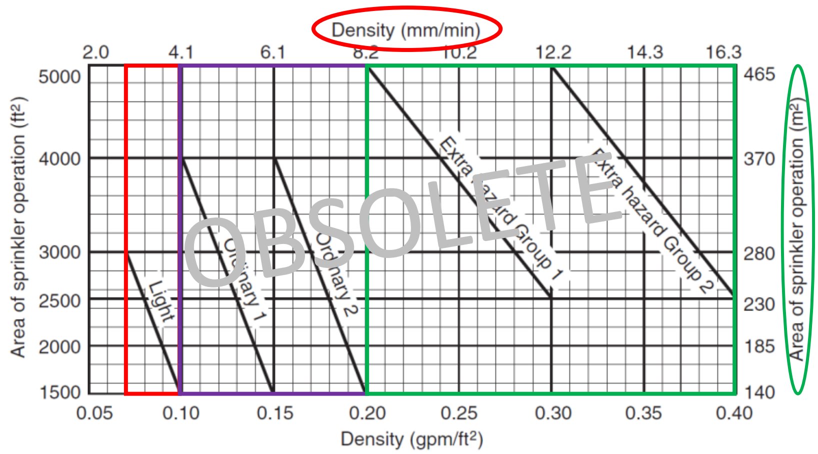

FIGURE 19.3.3.1.1 Density/Area Curves.

Source: ■

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Table 19.3.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Light hazard	0, 50, or 100	0, 190, or 380	100	380	30
Ordinary hazard	0, 50, or 100	0, 190, or 380	250	950	60–90
Extra hazard	0, 50, or 100	0, 190, or 380	500	1900	90–120

Source: ■

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Table represents K-factor for various sprinkler head orifice

Table 7.2.2.1 Sprinkler Discharge Characteristics Identification

Nominal K-Factor [L/min/(bar)$^{1/2}$]	K-Factor Range [L/min/(bar)$^{1/2}$]	Percent of Nominal K-5.6 Discharge	Thread Type
20	19–22	25	½ in. (15 mm) NPT
27	26–29	33.3	½ in. (15 mm) NPT
40	38–42	50	½ in. (15 mm) NPT
60	57–63	75	½ in. (15 mm) NPT
80	76–84	100	½ in. (15 mm) NPT
115	107–118	140	¾ in. (20 mm) NPT or ½ in. (15 mm) NPT
160	159–166	200	½ in. (15 mm) NPT or ¾ in. (20 mm) NPT
200	195–209	250	¾ in. (20 mm) NPT
240	231–254	300	¾ in. (20 mm) NPT
280	272–301	350	1 in. (25 mm) NPT
320	311–343	400	1 in. (25 mm) NPT
360	349–387	450	1 in. (25 mm) NPT
400	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: [redacted]

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Important formulas

- The Maximum Protection Area of a sprinkler shall be established by multiplying the S dimension by the L dimension, as follows:

$$A_s = S \times L$$

- No. of sprinklers to be selected in one branch $= \frac{1.2\sqrt{A}}{S_{AC}}$

- Number of sprinkler heads in remote area $= \frac{Design\ Area}{Calculated\ MCS\ (A_{S\_AC})}$

- Flow required per sprinkler head $Q = A_s \times Density$
- Water flow of the sprinkler in relation with K factor and pressure $Q = K\sqrt{P}$

- Total water required $= no.of\ sprinklers\ in\ remote\ area\ \times\ water\ flow\ per\ sprinkler\ \times firefighting\ duration$
- Hazen-Williams Formula to calculate,

Pressure loss due to friction $P_m = \left(\frac{Q^{1.85} \times L}{C^{1.85} \times d^{4.87}}\right) 6.05 \times 10^5$

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References and further reading

■ NFPA 13 (2019 ed. And 2022 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

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. Tabulate classification glass bulb colours of sprinkler heads on the basis of temperature rating.
2. Elaborate using a diagram – discharge pattern of a sprinkler is important in "fire control".
3. Explain the concept of maximum protection area (MPA) per sprinkler or Maximum Coverage per Sprinkler (MCS) using appropriate formula and diagram.
4. Sketch layouts of standard sprinkler and staggered sprinkler systems elaborating the difference between both.
5. Describe your understanding on the statement using appropriate example: "*It is important to evaluate and examine the remote area in the sprinkler network*".

6. All calculation-based examples:
   A. Total number of sprinklers.
   B. Total water (flow and pressure) requirement.

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Thank You…

Student’s Notes:

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