Chapter 3
Sprinkler System: Design and Calculations
Calculating Number of Sprinklers for an occupancy

Example 1

A restaurant dining area is to be protected with a sprinkler system where the width is 15 m and length is 22 m. Calculate total no. of sprinklers required in the facility to provide adequate fire protection.

Sample solution:

1. Hazard area classification: **OH (G1)**

2.

$Area\ of\ the\ facility\ =\ length\ \times width$

$= 22\ \times 15$

$= 330\ m^2$

3.

Maximum coverage or protection area per sprinkler $(\boldsymbol{MCS})$ $\boldsymbol{or}\ \boldsymbol{A_s}\ \boldsymbol{is}\ \boldsymbol{12\ m^2}$ (vide table X)

The restaurant service area is Ordinary hazard building hence **Maximum distance (spacing) between sprinklers in Ordinary hazard (S) is 4.6 m** as per table X.

$$No.of\ sprinklers\ required\ in\ one\ range = \frac{length}{spacing} = \frac{l}{S}$$

$$= \frac{22}{4.6}$$

$$= 4.7\ \cong 5\ sprinklers\ per\ range\ pipe$$

$$Actual\ distance\ between\ sprinkler\ heads\ (S_{AC}) = \frac{length}{No.of\ sprinklers\ in\ one\ range}$$

$$= \frac{22}{5}\ = 4.4\ m$$

4.

Since we know that maximum coverage area per sprinkler is, $A_s = S_{AC} \times L$

$12 = 4.4 \times L$

$$L = \frac{A_s}{S_{AC}}\ =\ 2.72\ m$$

$$No.of\ range\ pipes\ in\ the\ space\ or\ area = \frac{width}{L}$$

$$= \frac{15}{2.72}$$

$$= 5.51\ \cong 6\ range\ pipes$$

$$Actual\ distance\ between\ the\ range\ pipess\ (L_{AC}) = \frac{width}{no.of\ range\ pipes}$$

$$= \frac{15}{6} \quad = 2.5\ m$$

5.

$$Now, total\ number\ of\ sprinklers\ = (no.sprinklers\ in\ one\ range) \times (no.of\ range\ pipes)$$
$$= 5 \times 6$$
$$= \mathbf{30\ sprinklers}$$

In addition to the above calculation, if we have to calculate the distance of first sprinkler head and last range from the wall. (use the following calculation if asked in the question)

$$If\ S_{AC} = 4.4\ m, the\ distance\ between\ wall\ and\ the\ first\ sprinkler = \frac{S}{2}\ = 2.2\ m$$

$$If\ L_{AC} = 2.5\ m, the\ distance\ between\ wall\ and\ the\ last\ range = \frac{L}{2}\ = 1.25\ m$$

Self-practice:

Exercise 2

A theatre is decided to be protected with an automatic sprinkler system. The theatre's length is 40 m and width is 25 m. Answer the following using NFPA 13 / BS 12845:

A. Suggest the appropriate type of sprinkler heads for the theatre considering the maximum ambient ceiling temperature is 35°C.
B. Calculate total no. of sprinklers to be installed in the theatre.
C. Calculate the distance of the 1st sprinkler head and 1st range pipe from the wall.

Exercise 3

A 2-storey car parking having 110 m length, 75 m width and 5 m ceiling height per floor is recommended to be protected with automatic sprinkler system in accordance with NFPA13/BS 12845. Calculate total number of automatic sprinklers to be installed in the parking occupancy with actual spacing between the sprinklers. Draw a rough layout of sprinkler network along with the occupancy with appropriate units.

Exercise 4

A rubber processing industry having length of 85 m, width of 37 m and height of 5 m is decided to be protected with firefighting sprinkler system in accordance with NFPA 13.

A. Suggest the type of sprinkler heads considering 80°C as the maximum ambient ceiling temperature in process areas.
B. Determine the hazard classification of the building.
C. Calculate total number of sprinklers to be installed to provide adequate fire protection.
D. Draw a rough diagram (floor plan) comprising a sprinkler network with appropriate measurement and units.

Water Demand Calculations

Example 5

Following the calculation in example 1, when it was determined that **30** sprinklers are required to install in the restaurant seating area [OH (G1)], calculate total water demand (water flow and pressure) to provide adequate fire protection. Consider the following values:

- K factor = 80 $lpm/\sqrt{bar}$
- $Actual\ spacing\ between\ sprinkler\ heads\ (S_{AC}) = 4.4\ m$
- $Actual\ distance\ between\ range\ pipes\ (L_{AC}) = 2.5\ m$

Sample solution:

Continued from the last calculation (**vide example 1**)…

$Actual\ spacing\ between\ sprinkler\ heads\ (S_{AC}) = 4.44\ m$

$Actual\ distance\ between\ ranges\ (L_{AC}) = 2.5\ m$

$Total\ number\ of\ sprinklers\ in\ one\ range = 5\ sprinklers$

$Total\ number\ of\ ranges\ in\ the\ space = 6\ range\ pipes$

$Total\ number\ of\ sprinklers = 30\ sprinklers$

To determine maximum sprinklers operated at once, first remote area to be identified.

1.

Determine Density/Area from table 19.2.3.1.1.:

For the ordinary hazard (OH) G1 occupancy 6.1/140 mm/min/m^2 applies.

Where, Density = 6.1 mm/min and

Area = 140 m^2 is design area

2.

Number of sprinklers in the remote area $= \frac{Design\ Area}{Calculated\ MCS_{AC}\ (A_{SA})}$

$$= \frac{140}{S_{AC} \times L_{AC}}$$

$$= \frac{140}{4.4 \times 2.5}$$

$$= 12.72\ Sprinklers \cong 13\ Sprinklers$$

$Maximum\ No.of\ sprinklers\ to\ be\ selected\ on\ one\ branch$

$$= \frac{1.2\sqrt{A}}{S_{AC}}$$

$$= \frac{1.2\sqrt{140}}{4.44} = 3.19\ Sprinklers\ per\ range$$

At this point fire consultants may decide independently whether to sum-up selecting $4 + 4 + 3 + 2$ or $4 + 3 + 3 + 3$ to make-up to 13 sprinklers in the remote area.

3.

Minimum water flow required per sprinkler head

$Q = A_s \times D$

$= 12 \times 6.1$ (Here, A_s is obtained from table X, as recommended by the standard)

$= 73.2\ lpm\ per\ sprinkler$

4.

Total water required:

$= no.of\ sprinklers\ in\ remote\ area \times flow\ per\ sprinkler \times firefighting\ duration$

$= 13 \times 73.2 \times 60\ (duration\ from\ table\ 19.3.3.1.2)$

$= 57096\ l \cong 57100\ l\ or\ 57.1\ m^3$

5.

Minimum pressure required at the remotest sprinkler

Using $Q = K\sqrt{P}$ formula to calculate Pressure,

$P = \left(\frac{Q}{K}\right)^2$

$= \left(\frac{73.2}{80}\right)^2 = 0.837\ bar$

Note: When K factor is not provided in the question, K factor of 80 lpm/√bar is considered acceptable for light or ordinary hazard occupancy however any number between 160-320 lpm/√bar as K factor would be considered if occupancy is ordinary hazard having floor area grater, then 1000 m^2 or extra hazard.

Self-practice:

Example 5

A theatre having length of 40 m and width of 25 m is decided to be protected with automatic sprinkler system. Consultants determined that 54 sprinklers are sufficient to provide adequate fire protection. Calculate total water demand (water flow and pressure) for the sprinkler network considering,

1. $Actual\ spacing\ between\ sprinkler\ heads\ (S_{AC}) = 4.4\ m$
2. $Actual\ distance\ between\ ranges\ (L_{AC}) = 4.16\ m$
3. $K - factor = 60\ lpm/\sqrt{bar}$

Example 6

A library with large stack rooms having 135 m length and 60 m width is decided to be protected with an automatic sprinkler system. Answer the following to provide adequate fire protection by sprinkler system in accordance with NFPA 13 / BS 12845:

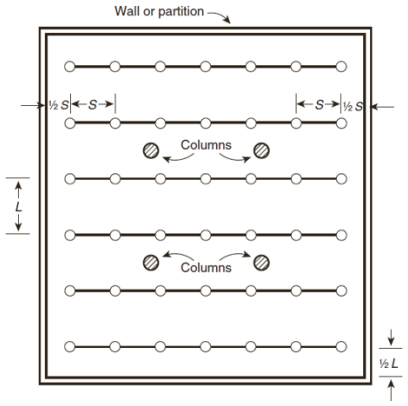
1. Determine the hazard category.
2. Suggest an appropriate type of sprinkler head considering maximum ceiling temperature is 40°C.
3. Calculate the total number of sprinkler heads to be installed with appropriate distance from wall.
4. Calculate the total water requirement (min. required pressure and water flow) by depicting the remote area on a diagram with appropriate units. Consider K factor = 160 $lpm/\sqrt{bar}$

Reference Tables and Useful Formulas

Type of hazard	Protection area A_S (MCS)	Maximum Spacing (S)
Light Hazard	225 ft² (**21 m²**)	15 ft (**4.6 m**)
Ordinary Hazard	130 ft² (**12 m²**)	15 ft (**4.6 m**)
Extra Hazard or High Hazard	90 - 130 ft² (**9 - 12 m²**)	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.

S & L Dimensions



- The protection area of coverage of the sprinkler shall be established by multiplying the S dimension by the L dimension, as follows:
  $$A_s = S \times L$$
- $Total\ number\ of\ sprinklers = (no.\ sprinklers\ in\ one\ range) \times (no.\ of\ ranges)$
- $No.\ of\ sprinklers\ to\ be\ selected\ in\ one\ branch = \frac{1.2\sqrt{A}}{S_{AC}}$
- $Number\ of\ sprinkler\ heads\ in\ remote\ area = \frac{Area\ of\ operation}{Calculated\ MCS\ (A_{SA})}$
- $Flow\ required\ per\ sprinkler\ head\ \ Q = A_s \times Density$
- $Flow\ of\ the\ sprinkler\ in\ relation\ with\ K\ factor\ and\ pressure\ \ Q = K\sqrt{P}$
- $Total\ water\ required = no.\ of\ sprinklers\ in\ remote\ area \times water\ flow\ per\ sprinkler \times firefighting\ duration$

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.

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

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.