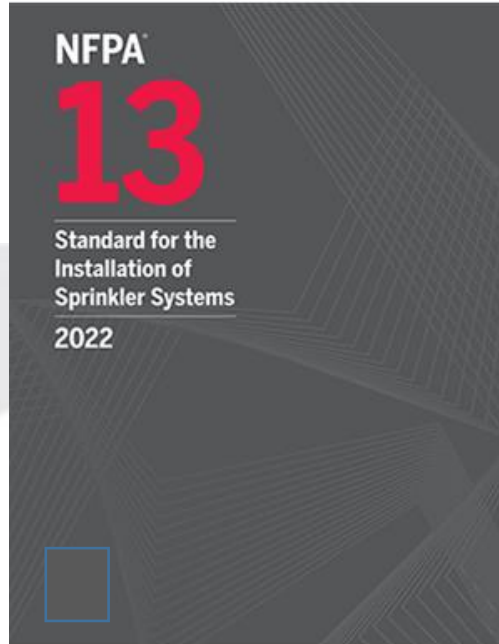




CALCULATIONS FOR FIRE SPRINKLER SYSTEMS IN STORAGE APPLICATIONS PER NFPA 13



Water Demand Calculation using CMDA/CMSA/ESFR and a special approach



Water demand & Hydraulic calculations for Rack Sprinklers

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Water Demand Calculation for CMDA/CMSA/ESFR Sprinklers for storage applications

Example: 1

Type of Facility : Storage Warehouse

Type of Ceiling Sprinkler :

- Option 01 : CMDA
- Option 02 : CMSA
- Option 03 : ESFR
- Option 04 : Using Alternate Approach per Chapter 24

Type of Commodity: Class 4, Pallatized

Height of storage: 30 feet

Height of ceiling: 35 feet

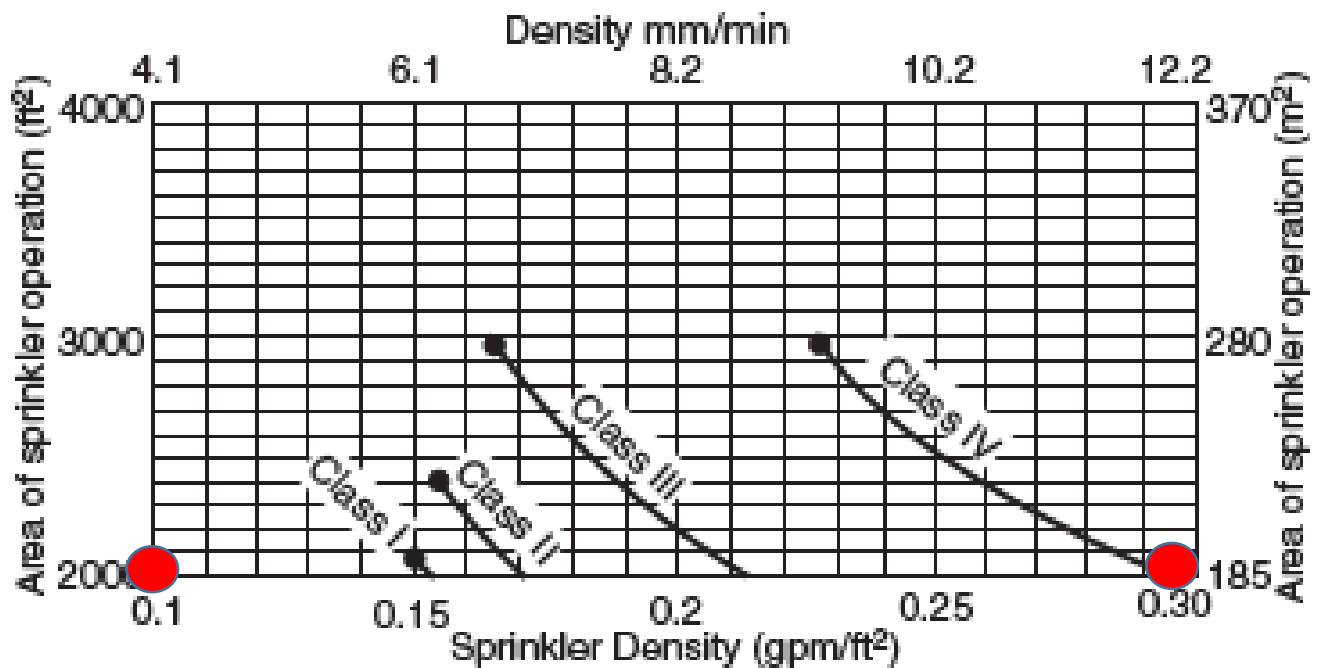
Type of System: Wet

Calculate Water Demand for all 4 options and Compare

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Option 01 : With CMDA Sprinklers

Let us refer NFPA 13, 2019, Chapter 21, Cl. 21.2 Figure 21.2.2.



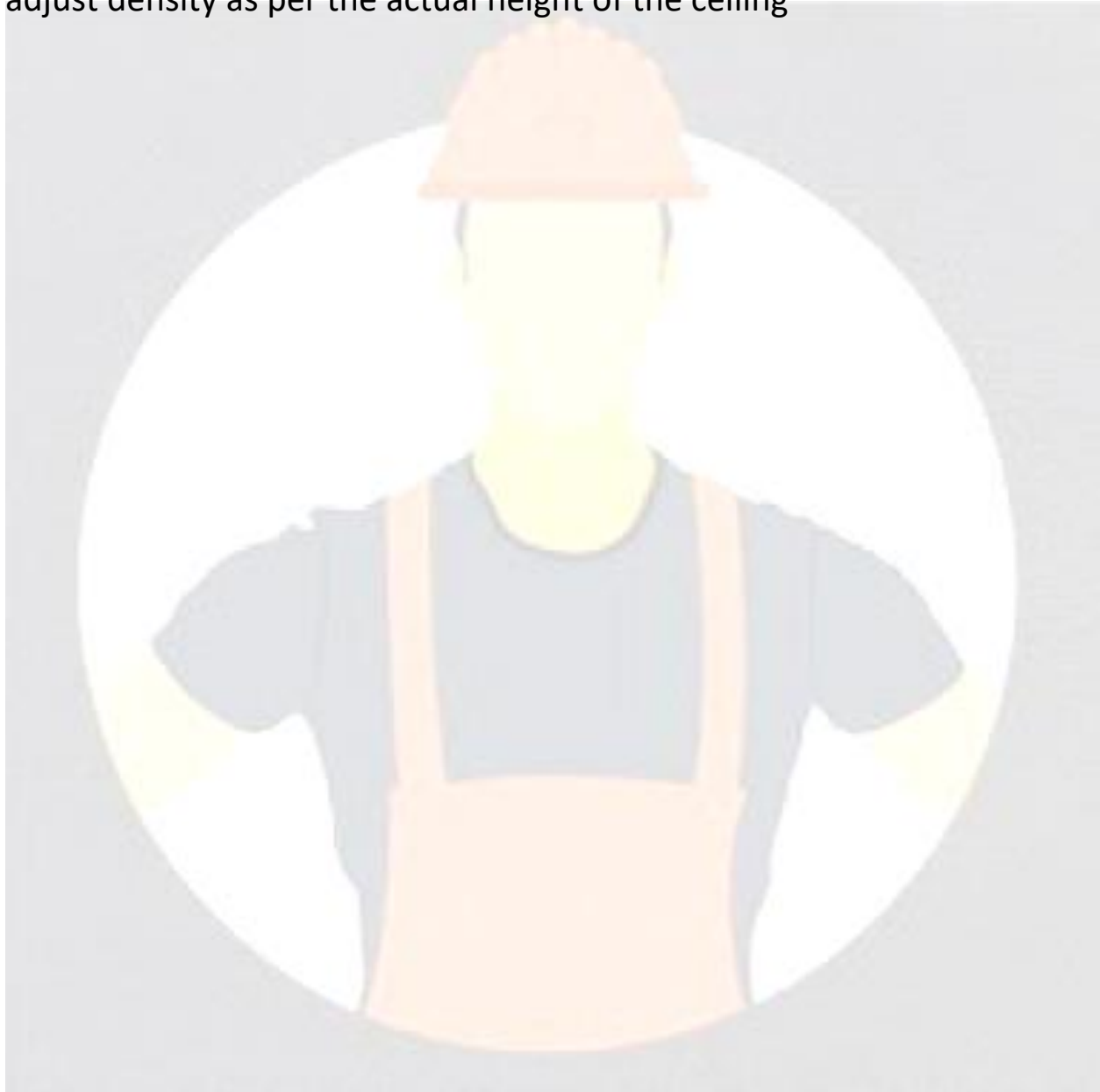
From above figure ;

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Density = 0.30 GPM / sf

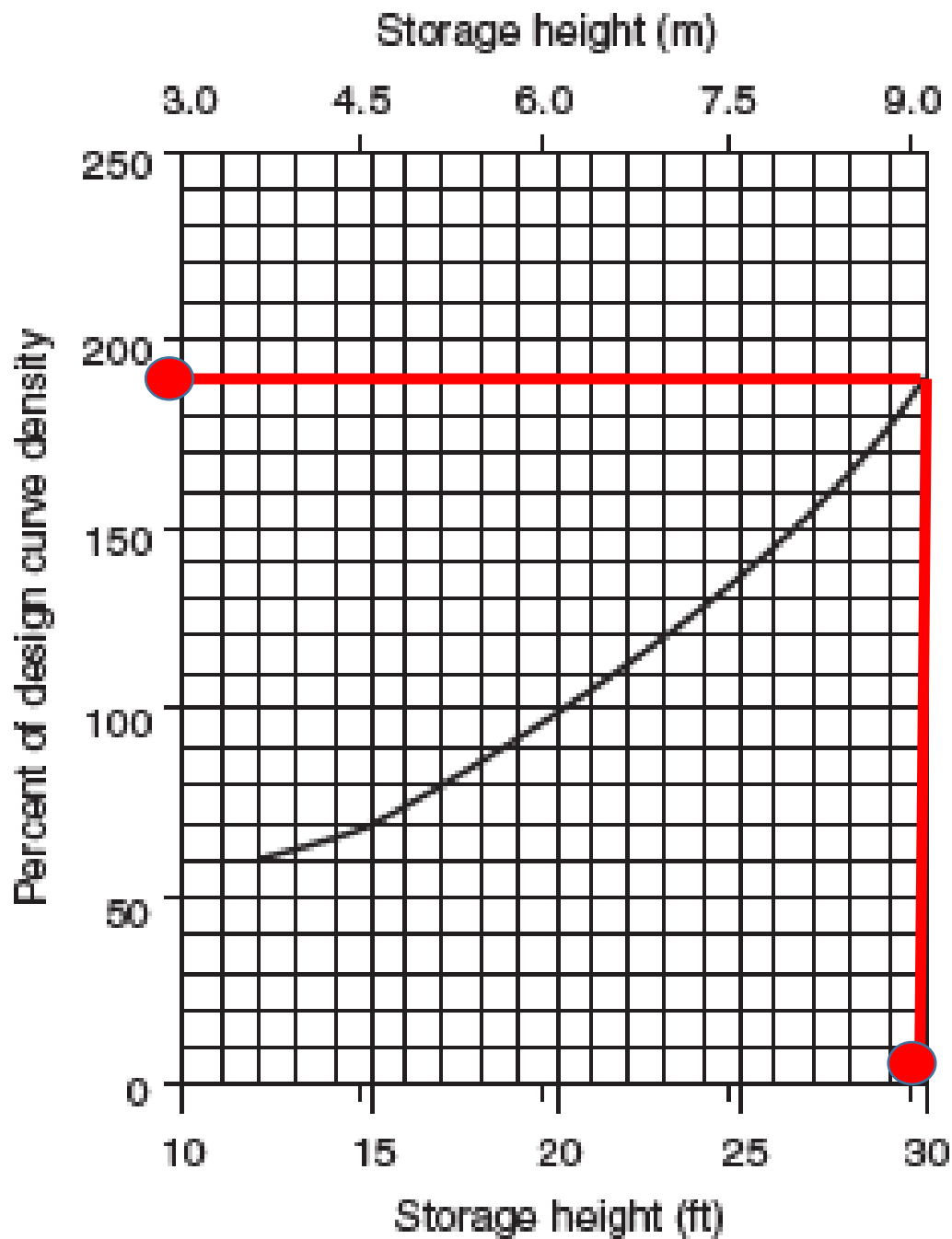
Area of operation = 2000 SF

Note that the above figure is with ceiling height of 20 ft we need to adjust density as per the actual height of the ceiling



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

And we will do that using below figure;



Adjusted density = $1.9 \times 0.30 = 0.57$ gpm / sf

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Now, Hose stream allowances and water supply duration we can select from table 20.12.2.6 as shown below



TABLE 20.12.2.6 Hose Stream Allowance and Water Supply Duration

Commodity	Sprinkler Type	Sprinkler Spacing Type	Number of Ceiling Sprinklers in Design Area ^a	Size of Design Area at Ceiling	Hose Stream Allowance		Water Supply Duration (minutes)
					gpm	L/min	
Class I-IV Commodities, Group A plastics, idle wood pallets, idle plastic pallets and miscellaneous storage	Control mode density/area (CMDA)	Standard and extended-coverage	NA	Up to 1200 ft ² (112 m ²)	250	950	60
				Over 1200 ft ² (112 m ²) up to 1500 ft ² (140 m ²)	500	1900	90
				Over 1500 ft ² (140 m ²) up to 2600 ft ² (240 m ²)	500	1900	120
				Over 2600 ft ² (240 m ²)	500	1900	150
	Control mode specific application (CMSA)	Standard	Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150
		Extended-coverage	Up to 6	NA	250	950	60
			Up to 8 ^b	NA	250	950	60
			Over 6 to 8	NA	500	1900	90
			Over 8 to 12	NA	500	1900	120
	Early suppression fast response (ESFR)	Standard	Over 12	NA	500	1900	150
			Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150

Hose allowances is 500 GPM over 2000 SF for 120 Min.

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

As the density is greater than 0.34 GPM/sf hence sprinklers with the K

Sprinkler demand (GPM)	Hose demand (GPM)	Total Flow (GPM)	Duration (Minutes)	Total Gallons
2000 x 0.57 = 1140 GPM	500	1640	120	196,800

factor 11.2 or greater needs to be used.

- K11.2 (160) @ 100 ft² = 26 psi (1.8 bar)
- K16.8 (240) @ 100 ft² = 11.5 psi (0.8 bar)

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY



Option 02 : With CMSA Sprinklers

Let us refer NFPA 13, 2019, Chapter 22, Cl. 22.2 Table 22.2

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

TABLE 22.2 CMSA Sprinkler Design Criteria for Palletized and Solid-Piled Storage of Class I Through Class IV Commodities (Encapsulated and Nonencapsulated)

Configuration	Commodity Class	Maximum Storage Height		Maximum Ceiling/Roof Height		K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure					
		ft	m	ft	m				psi	bar				
Palletized	Class I or II	25	7.6	30	9.1	11.2 (160) Upright	Wet	15	25	1.7				
							Dry	25	25	1.7				
						16.8 (240) Upright	Wet	15	10	0.7				
							Dry	25	15	1.0				
						19.6 (280) Pendent	Wet	15	16	1.1				
				25.2 (360) Pendent	Wet	15	10	0.7						
				35	11	11.2 (160) Upright	Wet	15	25	1.7				
							Dry	25	25	1.7				
						16.8 (240) Upright	Wet	15	15	1.0				
							Dry	25	15	1.0				
		25.2 (360) Pendent	Wet			15	23	1.6						
		30	9.1	35	11	19.6 (280) Pendent	Wet	15	25	1.7				
				40	12	25.2 (360) Pendent	Wet	15	23	1.6				
				35	11	40	12	19.6 (280) Pendent	Wet	15	30	2.1		
						25.2 (360) Pendent	Wet	15	23	1.6				
		Class III	25	7.6	30	9.1	11.2 (160) Upright	Wet	15	25	1.7			
								Dry	25	25	1.7			
							16.8 (240) Upright	Wet	15	15	1.0			
	Dry							25	15	1.0				
	19.6 (280) Pendent						Wet	15	16	1.1				
	25.2 (360) Pendent						Wet	15	10	0.7				
	35						11	11.2 (160) Upright	Wet	15	25	1.7		
									Dry	25	25	1.7		
								16.8 (240) Upright	Wet	15	15	1.0		
									Dry	25	15	1.0		
	25.2 (360) Pendent				Wet	15	23	1.6						
	30				9.1	35	11	19.6 (280) Pendent	Wet	15	25	1.7		
						40	12	25.2 (360) Pendent	Wet	15	23	1.6		
						35	11	40	12	19.6 (280) Pendent	Wet	15	30	2.1
								25.2 (360) Pendent	Wet	15	23	1.6		
	Class IV				20	6.1	30	9.1	11.2 (160) Upright	Wet	20	25	1.7	
											15	50	3.4	
		16.8 (240) Upright	Wet	20					15	1.0				
				15					22	1.5				
		19.6 (280) Pendent	Wet	15					16	1.1				
		25.2 (360) Pendent	Wet	15			10	0.7						
		40	12	25.2 (360) Pendent			Wet	15	23	1.6				
		25	7.6	30			9.1	16.8 (240) Upright	Wet	15	22	1.5		
								19.6 (280) Pendent	Wet	15	16	1.1		
				25.2 (360) Pendent			Wet	15	10	0.7				
				40			12	25.2 (360) Pendent	Wet	15	23	1.6		
		30	9.1	35			11	19.6 (280) Pendent	Wet	15	25	1.7		
	40			12	25.2 (360) Pendent	Wet	15	23	1.6					
	35	11	40	12	19.6 (280) Pendent	Wet	15	30	2.1					
			25.2 (360) Pendent	Wet	15	23	1.6							

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

TABLE 20.12.2.6 Hose Stream Allowance and Water Supply Duration

Commodity	Sprinkler Type	Sprinkler Spacing Type	Number of Ceiling Sprinklers in Design Area ^a	Size of Design Area at Ceiling	Hose Stream Allowance		Water Supply Duration (minutes)
					gpm	L/min	
Class I-IV Commodities, Group A plastics, idle wood pallets, idle plastic pallets and miscellaneous storage	Control mode density/area (CMDA)	Standard and extended-coverage	NA	Up to 1200 ft ² (112 m ²)	250	950	60
				Over 1200 ft ² (112 m ²) up to 1500 ft ² (140 m ²)	500	1900	90
				Over 1500 ft ² (140 m ²) up to 2600 ft ² (240 m ²)	500	1900	120
				Over 2600 ft ² (240 m ²)	500	1900	150
	Control mode specific application (CMSA)	Standard	Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150
		Extended-coverage	Up to 6	NA	250	950	60
			Up to 8 ^b	NA	250	950	60
			Over 6 to 8	NA	500	1900	90
			Over 8 to 12	NA	500	1900	120
			Over 12	NA	500	1900	150
	Early suppression fast response (ESFR)	Standard	Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150

From the above two tables

Number of design sprinklers = 15

Hose stream allowances = 500 GPM

Duration = 90 Min.

K factor = 19.6

Min. Operating Pressure = 30 psi

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

So, $Q = 19.6 \times (30)^{1/2} = 107.35 \text{ GPM}$

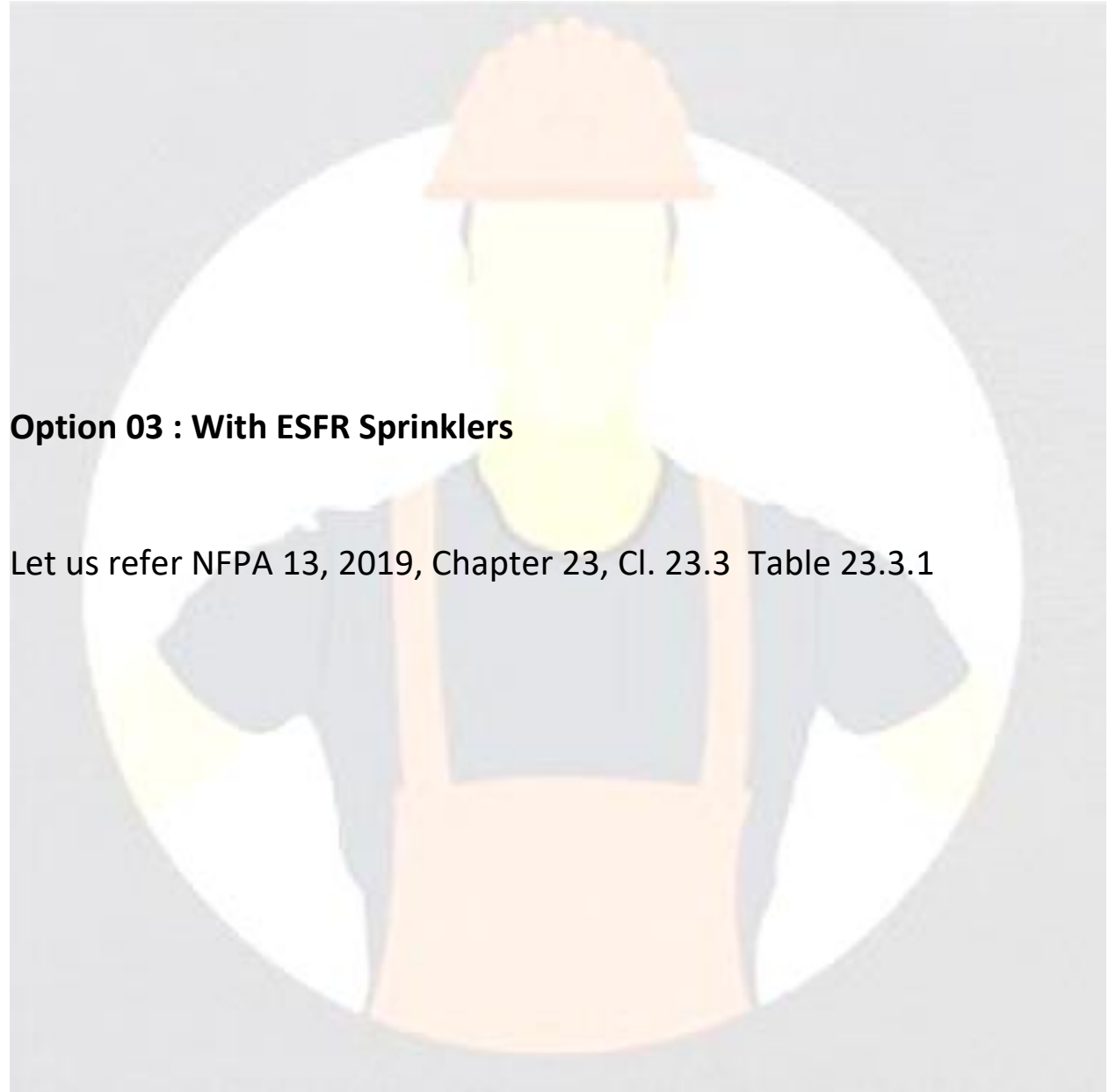
Sprinkler demand (GPM)	Hose demand (GPM)	Total Flow (GPM)	Duration (Minutes)	Total Gallons
15 x 107.35	500	2110.25	90	189,922
= 1610	+	=	×	=



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Option 03 : With ESFR Sprinklers

Let us refer NFPA 13, 2019, Chapter 23, Cl. 23.3 Table 23.3.1



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

TABLE 23.3.1 ESFR Protection of Palletized and Solid-Piled Storage of Class I Through Class IV Commodities

Commodity	Maximum Storage Height		Maximum Ceiling/ Roof Height		Nominal K-Factor	Orientation	Minimum Operating Pressure	
	ft	m	ft	m			psi	bar
Class I, II, III, or IV, encapsulated and nonencapsulated (no open-top containers)	20	6.1	25	7.6	14.0 (200)	Upright/pendent	50	3.4
					16.8 (240)	Upright/pendent	35	2.4
					22.4 (320)	Pendent	25	1.7
					25.2 (360)	Pendent	15	1.0
	25	7.6	30	9.1	14.0 (200)	Upright/pendent	50	3.4
					16.8 (240)	Upright/pendent	35	2.4
					22.4 (320)	Pendent	25	1.7
					25.2 (360)	Pendent	15	1.0
			32	10	14.0 (200)	Upright/pendent	60	4.1
					16.8 (240)	Upright/pendent	42	2.9
	30	9.1	35	11	14.0 (200)	Upright/pendent	75	5.2
					16.8 (240)	Upright/pendent	52	3.6
					22.4 (320)	Pendent	35	2.4
					25.2 (360)	Pendent	20	1.4
	35	11	40	12	16.8 (240)	Pendent	32	2.2
					22.4 (320)	Pendent	40	2.7
					25.2 (360)	Pendent	25	1.7
	35	11	45	14	22.4 (320)	Pendent	40	2.7
					25.2 (360)	Pendent	40	2.7
	40	12	45	14	22.4 (320)	Pendent	40	2.7
					25.2 (360)	Pendent	40	2.7



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

TABLE 20.12.2.6 Hose Stream Allowance and Water Supply Duration

Commodity	Sprinkler Type	Sprinkler Spacing Type	Number of Ceiling Sprinklers in Design Area ^a	Size of Design Area at Ceiling	Hose Stream Allowance		Water Supply Duration (minutes)
					gpm	L/min	
Class I–IV Commodities, Group A plastics, idle wood pallets, idle plastic pallets and miscellaneous storage	Control mode density/area (CMDA)	Standard and extended-coverage	NA	Up to 1200 ft ² (112 m ²)	250	950	60
				Over 1200 ft ² (112 m ²) up to 1500 ft ² (140 m ²)	500	1900	90
				Over 1500 ft ² (140 m ²) up to 2600 ft ² (240 m ²)	500	1900	120
				Over 2600 ft ² (240 m ²)	500	1900	150
	Control mode specific application (CMSA)	Standard	Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150
		Extended-coverage	Up to 6	NA	250	950	60
			Up to 8 ^b	NA	250	950	60
			Over 6 to 8	NA	500	1900	90
			Over 8 to 12	NA	500	1900	120
	Early suppression fast response (ESFR)	Standard	Up to 12	NA	250	950	60
			Over 12 to 15	NA	500	1900	90
			Over 15 to 25	NA	500	1900	120
			Over 25	NA	500	1900	150

From above tables :

Number of design sprinklers = 12

Hose stream allowances = 250 GPM

Duration = 60 Min.

K factor selected = 25.2

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Min. Operating Pressure = 20 psi

So, $Q = 25.2 \times (20)^{1/2} = 113 \text{ GPM}$

Sprinkler demand (GPM)	Hose demand (GPM)	Total Flow (GPM)	Duration (Minutes)	Total Gallons
12x 113	250	1606	60	96360
= 1356	+	=	×	=



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Option 04 : Using Alternative Sprinkler Design

TABLE 24.2.1 Extended Coverage, CMSA [K-factor 25.2 (360)] Sprinkler Design Criteria for Palletized and Solid-Piled Storage of Class I Through Class IV and Cartoned Nonexpanded Plastic Commodities

Storage Arrangement	Commodity Class	Maximum Storage Height		Maximum Ceiling/Roof Height		K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure	Maximum Coverage Area
		ft	m	ft	m					
Palletized and solid-piled	Class I through Class IV, encapsulated and nonencapsulated, and cartoned nonexpanded plastics	20	6.1	30	9.1	25.2 (360) Upright/pendent	Wet	6	30 psi (2.1 bar)	12 ft × 12 ft (3.7 m × 3.7 m) 144 ft² (13 m²)
		20	6.1	30	9.1	25.2 (360) Upright/pendent	Wet	6	30 psi (2.1 bar)	14 ft × 14 ft (4.3 m × 4.3 m) 196 ft² (18 m²)
		25	7.6	30	9.1	25.2 (360) Upright/pendent	Wet	6	30 psi (2.1 bar)	12 ft × 12 ft (3.7 m × 3.7 m) 144 ft² (13 m²)
		25	7.6	30	9.1	25.2 (360) Upright/pendent	Wet	6	30 psi (2.1 bar)	14 ft × 14 ft (4.3 m × 4.3 m) 196 ft² (18 m²)
		25	7.6	35	11	25.2 (360) Upright/pendent	Wet	8	40 psi (2.7 bar)	12 ft × 12 ft (3.7 m × 3.7 m) 144 ft² (13 m²)
		25	7.6	35	11	25.2 (360) Upright	Wet	8	40 psi (2.8 bar)	14 ft × 14 ft (4.3 m × 4.3 m) 196 ft² (18 m²)
		30	9.1	35	11	25.2 (360) Upright/pendent	Wet	8	40 psi (2.8 bar)	12 ft × 12 ft (3.7 m × 3.7 m) 144 ft² (13 m²)
		30	9.1	35	11	25.2 (360) Upright	Wet	8	40 psi (2.8 bar)	14 ft × 14 ft (4.3 m × 4.3 m) 196 ft² (18 m²)

Let us refer NFPA 13, 2019, Chapter 24, Cl. 24.2 Table 24.2.1

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

TABLE 24.4.1 *Hose Stream Allowance and Water Supply Duration*

Sprinkler Type	Sprinkler Spacing Type	Number of Sprinklers in Design Area	Hose Stream Allowance		Water Supply Duration (minutes)
			gpm	L/min	
Control mode density/area and CMSA	Standard	Up to 12	250	950	60
		Over 12 to 15	500	1900	90
		Over 15 to 25	500	1900	120
		Over 25	500	1900	150
	Extended coverage	Up to 6	250	950	60
		Up to 8	250	950	60
		Over 6 to 8	500	1900	90
		Over 8 to 12	500	1900	120
ESFR	Standard	Over 12	500	1900	150
		Up to 12	250	950	60
		Over 12 to 15	500	1900	90
		Over 15 to 25	500	1900	120
		Over 25	500	1900	150

From the above tables :

Number of design sprinklers = 08

Hose stream allowances = 250 GPM

Duration = 60 Min.

K factor selected = 25.2

Min. Operating Pressure = 40 psi

So, $Q = 25.2 * (40)^{(1/2)} = 159 \text{ GPM}$

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

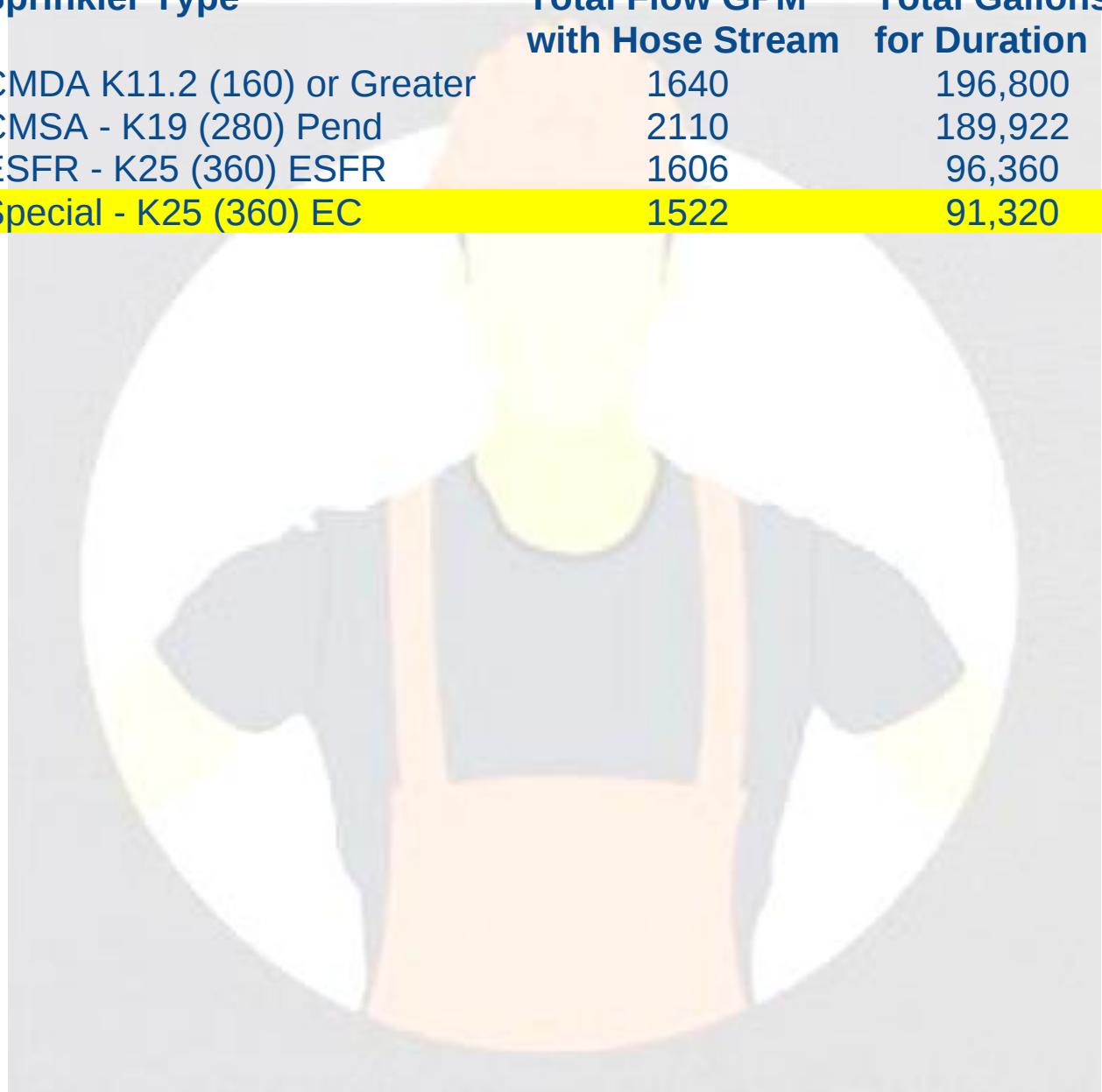
Sprinkler demand (GPM)	Hose demand (GPM)	Total Flow (GPM)	Duration (Minutes)	Total Gallons
8 x 159	250	1522	60	91,320
= 1275				



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Summary:

Sprinkler Type	Total Flow GPM with Hose Stream	Total Gallons for Duration
CMDA K11.2 (160) or Greater	1640	196,800
CMSA - K19 (280) Pend	2110	189,922
ESFR - K25 (360) ESFR	1606	96,360
Special - K25 (360) EC	1522	91,320



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

In Rack Sprinklers :

How Many In rack Sprinklers will open in case of fire ?

Depends on,

- Number of levels of in-racks
- Type of sprinklers at the ceiling (CMDA/CMSA/ESFR)

**A) For Commodity Class 1 to 4 & Storage Height upto 25 ft.
If Spray or CMSA Sprinklers at the ceiling**

In Accordance with Cl. 16.1.6.5,

- (1) Six sprinklers where only one level of in-rack sprinklers is installed to protect Class I, Class II, or Class III commodity
- (2) Eight sprinklers where only one level of in-rack sprinklers is installed to protect Class IV commodity
- (3) Ten sprinklers (five on each of the top two levels) where more than one level of in-rack sprinklers is installed to protect Class I, Class II, or Class III commodity
- (4) Fourteen sprinklers (seven on each of the top two levels) when more than one level of in-rack sprinklers is installed to protect Class IV commodity

No. of In rack Spr Level	Type of Commodity	No. of Sprinklers	Notes
1	Class 1,2 or 3	6	
1	Class 4	8	
2	Class 1,2 or 3	10	5 on each level
2	Class 4	14	7 on each level

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Example : 02

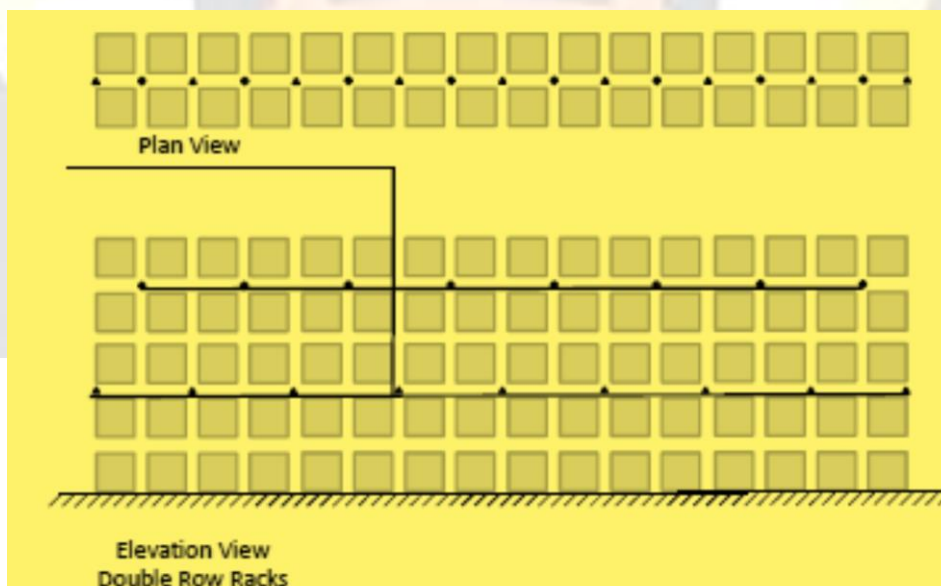
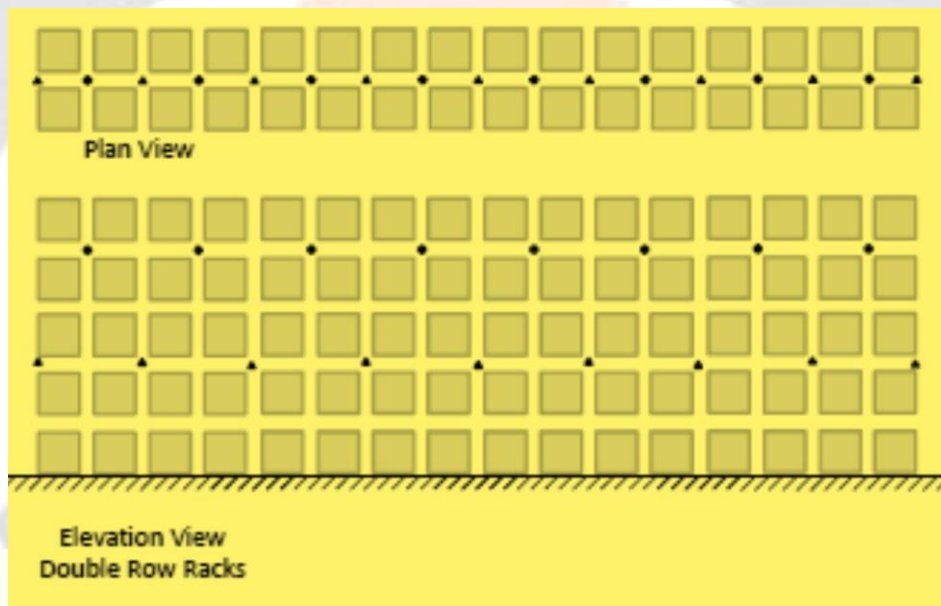
Type of Facility : Storage Warehouse

Type of Ceiling Sprinkler : CMSA, K 11.2

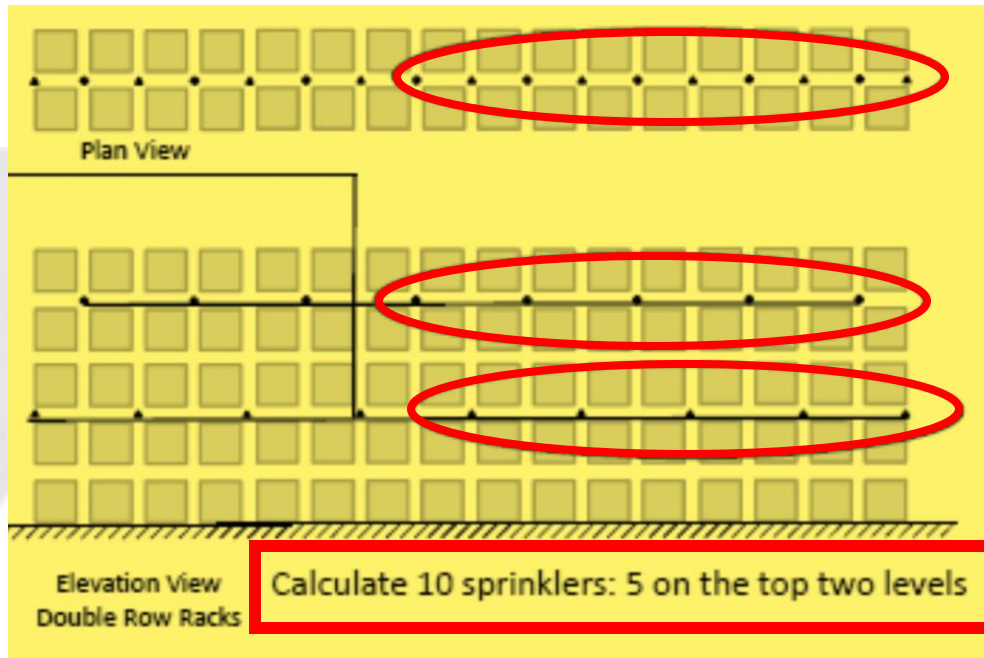
Type of Commodity : Class 3

No. of Rack Sprinklers Level – 02

Type of System : Wet



MECHSOFT ENGINEERING DESIGN AND CONSULTANCY



**B) For Commodity Class 1 to 4 & Storage Height over 25 ft.
If Spray or CMSA Sprinklers at the ceiling
In Accordance with Cl. 16.1.6.5,**

- (1) Six sprinklers where only one level of in-rack sprinklers is installed to protect Class I, Class II, or Class III commodity
- (2) Eight sprinklers where only one level of in-rack sprinklers is installed to protect Class IV commodity
- (3) Ten sprinklers (five on each of the top two levels) where more than one level of in-rack sprinklers is installed to protect Class I, Class II, or Class III commodity
- (4) Fourteen sprinklers (seven on each of the top two levels) when more than one level of in-rack sprinklers is installed to protect Class IV commodity

No. of In rack Spr Level	Type of Commodity	No. of Sprinklers	Notes
1	Class 1,2 or 3	6	
1	Class 4	8	
2	Class 1,2 or 3	10	5 on each level
2	Class 4	14	7 on each level

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

C)For Group A Plastics

Storage of any height (upto and over 25 ft)

In accordance, 17.1.5.6

- (1) Eight sprinklers where only one level of in-rack sprinklers is installed
- (2) Fourteen sprinklers (seven on each of the top two levels) when more than one level of in-rack sprinklers is installed

No. of In rack Spr Level	Type of Commodity	No. of Sprinklers	Notes
1	Group A Plastic	8	
More than 1	Group A Plastic	14	7 on each level

D)For Group A Plastics

In accordance, 18.5.3

18.5.3 Water demand for sprinklers installed in racks shall be based on simultaneous operation of the most hydraulically remote 12 sprinklers where only one level is installed in racks.

No. of In rack Spr Level	Type of Commodity	No. of Sprinklers	Notes
1	Rubber Tire	12	
More than 1	Rubber Tire	14	7 on each level

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Min. Flow and Pressure Requirement for Rack Sprinkler :

What is the min. Operating Sprinkler at rack Sprinklers ?

For Class 1 to 4 Commodity for storage upto 25 ft. (Cl. 16.2.1.4.4)

Depends on,

– Type of sprinklers at the ceiling (CMSA/ESFR)

If spray sprinklers or CMSA sprinklers at the ceiling

Min. Operating Pressure = 15 psi

Hence for $k = 5.6$, $Q = 21.7$ GPM

for $k = 8.0$, $Q = 31$ GPM

for $k = 11.2$, $Q = 43.2$ GPM

For Class 1 to 4 Commodity for storage Over 25 ft. (Cl.table 16.3.1.1)

If spray sprinklers or CMSA sprinklers at the ceiling

Min. $Q = 30$ GPM

Hence for $k = 5.6$, $P = 28.7$ psi

for $k = 8.0$, $P = 14.1$ psi

for $k = 11.2$, $P = 7.2$ psi

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Group A Plastics Spray Sprinklers at Ceiling :

For storage up to 25 ft, depends on the in-rack configuration selected from the Figures:

- Figure 17.2.1.2.1(b) & (f): 15 psi
- Figure 17.2.1.2.1(c), (d) and (e):
 - 15 psi when sprinklers are at every other flue intersection
 - 15 psi for k-8 and 30 psi for k-5.6 when sprinklers are at every flue

For storage over 25 ft:

- 30 gpm regardless of situation

Group A Plastics ESFR Sprinklers at Ceiling

- Must use k-8.0 or K- 11.2 quick response, ordinary temperature sprinkler
- 60 gpm (17.3.3.4.1)
- 56.3 psi

Rubber Tire Storage

- 18.5.4
 - 30 psi
 - 30.7 gpm for k-5.6 sprinkler
 - 43.8 gpm for k-8.0 sprinkler
 - 61.3 gpm for k-11.2 sprinkler

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Hydraulic Calculations Steps for In Rack Sprinklers :

Step : 01 - Calculate number and location of open sprinklers in the hydraulically most remote area.

Step : 02 - Start at most remote sprinkler and work towards the water supply calculating flows and pressures

Step : 03 - Adding pressure increases due to friction loss

Step : 04 - Add flows from other open sprinklers encountered on the way

Step : 05 – Adjust the Elevation changes

Example- 03 :

Type of Facility : Storage Warehouse

Type of Rack- 5 tier double row rack

Type of Ceiling Sprinkler : CMSA, K 8.0

Type of In Rack Sprinkler : Rack, K 5.6

Width of Aisle : 8 ft.

Type of Commodity : Class 3, Encapsulated

No. of Rack Sprinklers Level – 02

Type of System : Wet

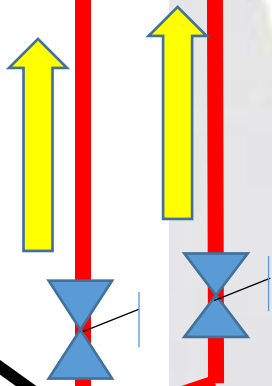
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System Layout :

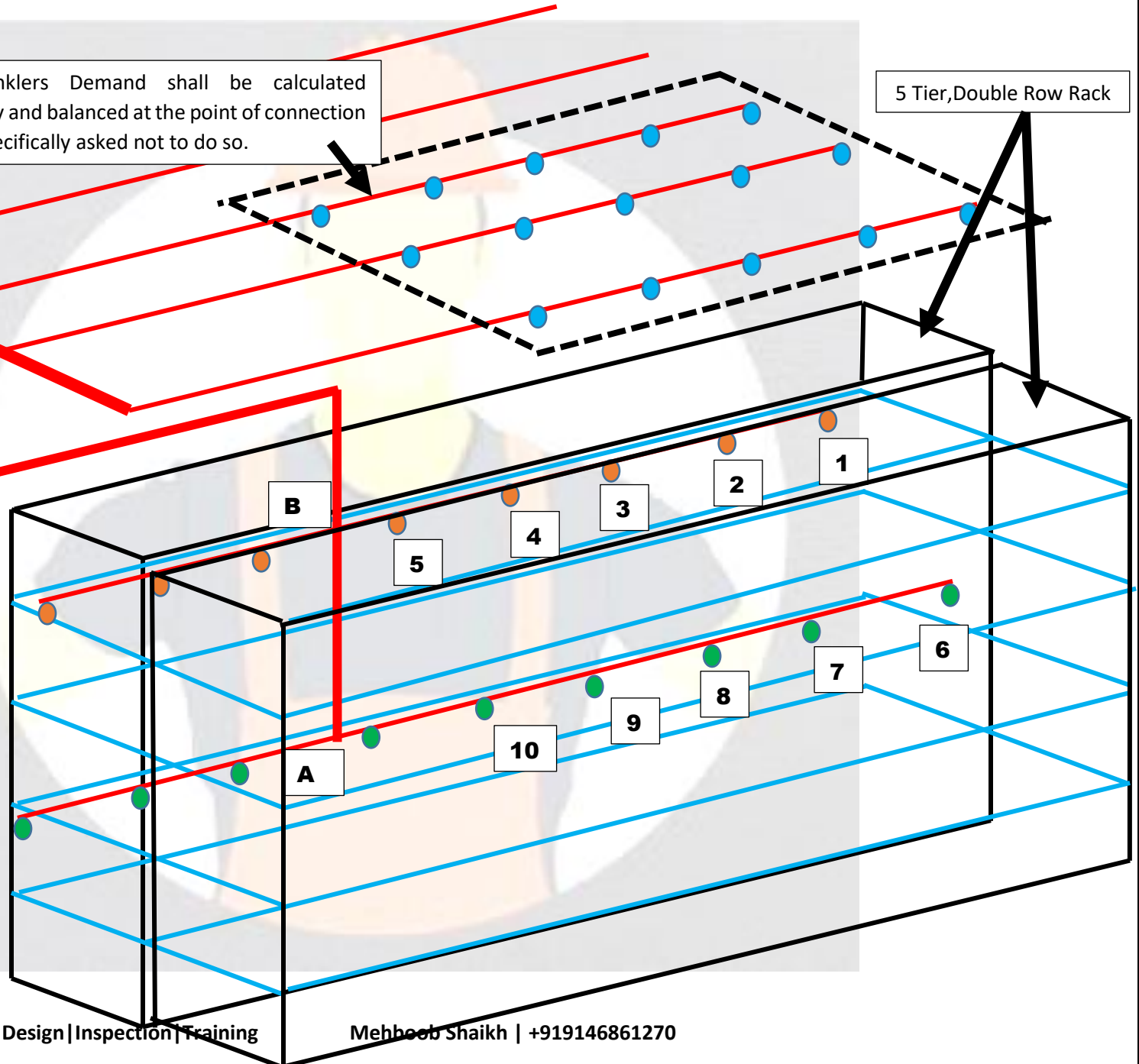
OH Sprinklers Demand shall be calculated separately and balanced at the point of connection unless specifically asked not to do so.

5 Tier, Double Row Rack

Point of Connection at which flow balancing to be done



C



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Hydraulic Calculations Sheet- Manual

IN RACK SPRINKLER SYSTEM HYDRAULIC CALCULATION									
Reference : NFPA 13- 2013, Chapter 23 (PLANS AND CALCULATIONS)									
Node-1	Elev-1	K- Factor	Flow added this step(q)	Nominal ID	Fittings- Quantity and Length	L- ft	C Factor	Total(Pt)	Notes
Node-2	Elev-2		Total Flow (Q)	Actual ID		F-ft T- ft	Pf per foot (psi) $4.52 \cdot Q^{1.85} / C^{1.85} / d^{4.87}$	Elev(Pe) Frict(Pf)	
1	20	5.6	21.700	1.25	1T	10.00 6.00	120.000 0.040	15.000	Q1 = 21.70 gpm & P1 = 15 psi
2	20		21.700	1.38		16.00		0.637	
2	20	5.6	22.144	1.25	1T	10.00 6.00	120.000 0.146	15.637	
3	20		43.844	1.38		16.00		2.339	
3	20	5.6	23.743	1.25	1T	10.00 6.00	120.000 0.326	17.976	
4	20		67.587	1.38		16.00		5.210	
4	20	5.6	26.965	2.00	1T	10.00 10.00	120.000 0.084	23.186	
5	20		94.552	2.07		20.00		1.682	
5	20	5.6	27.926	2.50	1T	10.00 12.00	120.000 0.057	24.868	Flow at Node B
B	20		122.478	2.47		22.00		1.263	
6	10	5.6	21.689	1.25	1T	10.00 6.00	120.000 0.040	15.000	
7	10		21.689	1.38		16.00		0.636	
7	10	5.6	21.689	1.25	1T	10.00 6.00	120.000 0.143	15.000	
8	10		43.377	1.38		16.00		2.294	
8	10	5.6	23.288	1.25	1T	10.00 6.00	120.000 0.317	17.294	
9	10		66.665	1.38		16.00		5.079	
9	10	5.6	26.488	1.25	1T	10.00 6.00	120.000 0.589	22.372	
10	10		93.153	1.38		16.00		9.431	
10	10	5.6	31.581	2.00	1T	10.00 10.00	120.000 0.140	31.804	Flow at Node B
A	10		124.734	2.07		20.00		2.809	
A	10	0	0.000	2.50	1T	10.00 12.00	120.000 0.211	34.612	Total Flow at Node A+ Node B
B	20		247.213	2.47		22.00		4.633	
B	20	0	0.000	2.50	1T, 3E, 1CV	150.00 31.00	120.000 0.211	34.915	Total Flow at C
C	15		247.213	2.47		181.00		38.113	
								75.193	

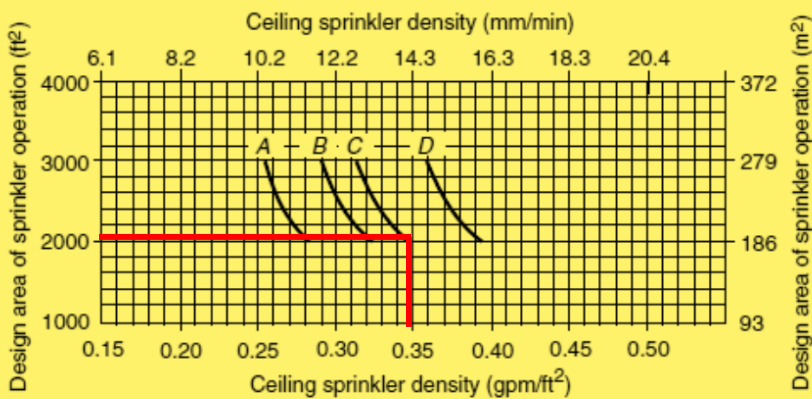
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Calculation for Over Head Sprinklers :

In accordance with table 16.2.1.3.2

Table 16.2.1.3.2 Continued

Height	Commodity Class	Encapsulated	Aisles*		Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
						With In-Rack Sprinklers			Without In-Rack Sprinklers		
			ft	m		Figure	Curves	Apply Figure 16.2.1.3.4.1	Figure	Curves	Apply Figure 16.2.1.3.4.1
Over 22 ft (6.7 m) up to and including 25 ft (7.6 m)	I	No	4	1.2	No	16.2.1.3.2(a)	C and D	No	16.2.1.3.2(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	1 level	16.2.1.3.2(e)	C and D		—	—	—
			8	2.4			A and B				
	II	No	4	1.2	No	16.2.1.3.2(b)	C and D		16.2.1.3.2(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(e)	C and D		—	—	—
			8	2.4			A and B				
	III	No	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(f)	C and D		—	—	—
			8	2.4			A and B				



Curve Legend

A — 8 ft (2.44 m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

B — 8 ft (2.44 m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

Curve Legend

C — 4 ft (1.22 m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

D — 4 ft (1.22 m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

FIGURE 16.2.1.3.2(f) Single- or Double-Row Racks — 20 ft (6.1 m) High Rack Storage — Sprinkler System Design Curves — Class III Encapsulated Commodities — Conventional Pallets.

- Figure 16.2.1.3.2(f); Curve “C”
- 0.345 gpm per sq ft over 2000 sq ft

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

In accordance with Cl. 16.2.1.3.4.4

16.2.1.3.4.4 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) protected with ceiling sprinklers and with more than the minimum required level of in-rack sprinklers, but not in every tier, densities obtained from design curves shall be permitted to be reduced 20 percent, as indi-

Reduce by 20% due to extra level of in-rack sprinklers (see 16.2.1.3.4.4)
Here, required level of in rack sprinklers are ONE however, in actual we have TWO

After calculation, Let's say, ceiling sprinkler demand at Point "C" is:

– 665 gpm at 84 psi

Lets Put Demands Together

- Ceiling
- 665 GPM @ 84 PSI

- In Rack
- 247 at 75 PSI

- Can't add flows unless the pressure is the same
- Adjusting the lower pressure situation to the higher pressure is called "Balancing the Flows"

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Steps to Balance the Flows :

- Calculate the two demands separately from the most remote point to the node where they connect
- Get the k-factor for the lower pressure situation
- Apply the k-factor to the higher pressure to get the new flow:
- Add the two flows together

Step 01 :

- Calculate the two demands separately from the most remote point to the node where they connect

a. In-Racks: 247 gpm at 75 psi

b. Ceiling: 665 gpm at 84 psi

Step 02 :

- Get the k-factor for the lower pressure situation

In Racks are the lower situation in this case,

$$K = \frac{Q}{\text{Sq.rt } P}$$
$$K = \frac{247}{\text{Sq.rt } 75}$$
$$K = 28.52$$

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Step 03 :

Apply the K-factor to the higher pressure,

$$Q = K \times \text{Sq. rt. } (P)$$

$$Q = 28.52 \times \text{Sq. rt. } (84)$$

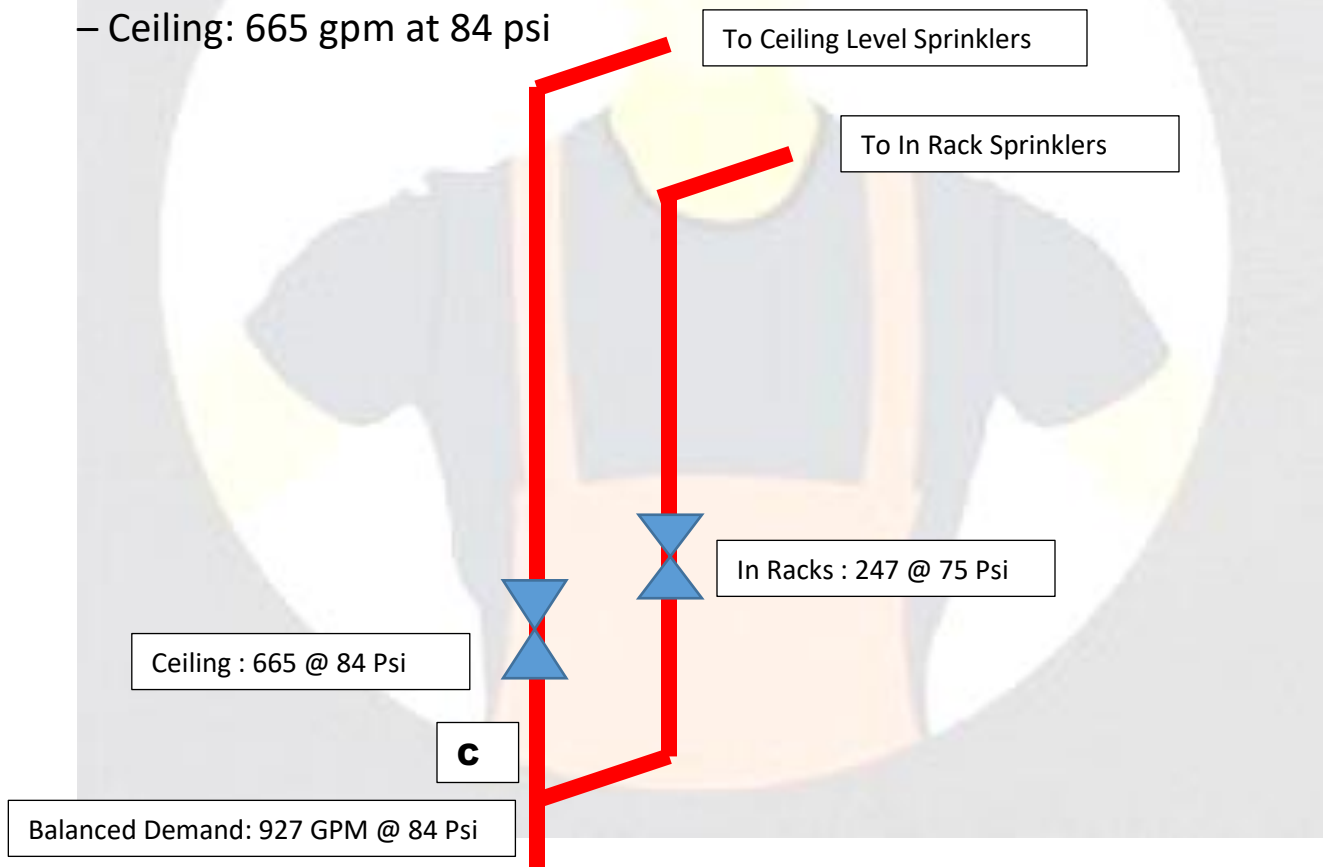
$$Q = 261.4 \text{ GPM}$$

Step 04:

Add the flows together

– In-Racks: 262 gpm at 84 psi

– Ceiling: 665 gpm at 84 psi



Therefore, Total Combined demand = 927 GPM @ 84 psi

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Example : 04

Type of Facility : Storage Warehouse

Type of Rack : Single Row

Type of Commodity : Class 1, Encapsulated

Width of Aisle : 2.4 Mtr.

Storage Height = 20 feet

Type of Ceiling Level Sprinkler = Ordinary temperature

What is the required Density for ceiling sprinklers ?

Lets refer to NFPA 13 2019 Chapter 25, table 25.2.3.2.1

Table 25.2.3.2.1 Determining Appropriate Ceiling-Level Protection Criteria Figure for Single- or Double-Row Racks of Class I Through Class IV Commodities — Storage Height Over 12 ft (3.7 m) Up to and Including 25 ft (7.6 m)

Storage Height	Commodity Class	Encapsulated	Aisle Width*		No. of In-Rack Sprinkler Levels	Appropriate Figure and Curves		
			ft	m		Figure	Curves	Apply Figure 25.2.3.2.4.1
Over 12 ft (3.7 m) and up to and including 20 ft (6.1 m)	I	No	4	1.2	1 Level	25.2.3.2.3.1(a)	C and D	Yes
			8	2.4			A and B	
	I	Yes	4	1.2	1 Level	25.2.3.2.3.1(e)	C and D	Yes
			8	2.4			A and B	
		No	4	1.2		25.2.3.2.3.1(b)	C and D	
			8	2.4			A and B	
	II	Yes	4	1.2		25.2.3.2.3.1(e)	C and D	Yes
			8	2.4			A and B	
		No	4	1.2		25.2.3.2.3.1(c)	C and D	
			8	2.4			A and B	
	III	Yes	4	1.2		25.2.3.2.3.1(f)	C and D	Yes
			8	2.4			A and B	
		No	4	1.2		25.2.3.2.3.1(d)	C and D	
			8	2.4			A and B	
	IV	Yes	4	1.2		25.2.3.2.3.1(g)	C and D	Yes
			8	2.4			A and B	
		No	4	1.2		25.2.3.2.3.1(d)	C and D	
			8	2.4			A and B	

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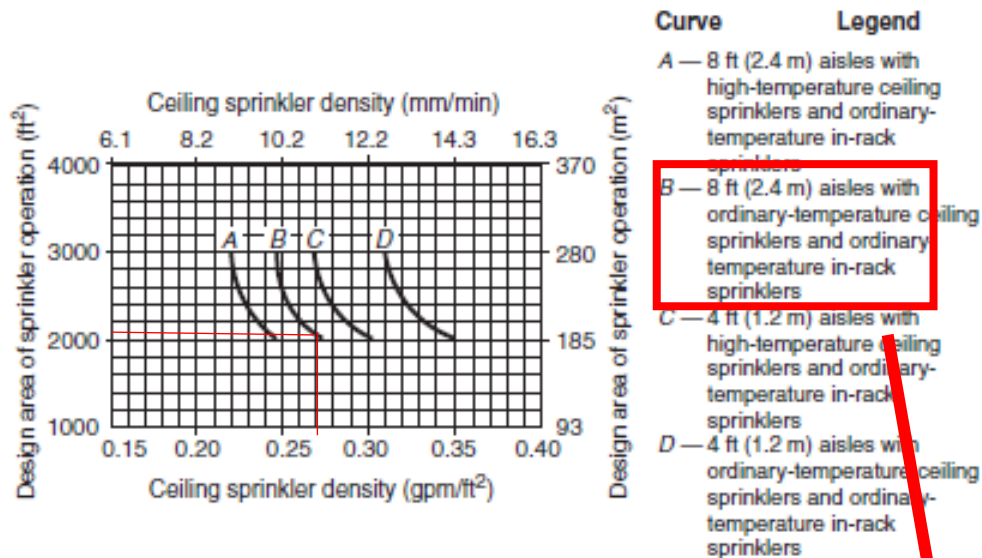
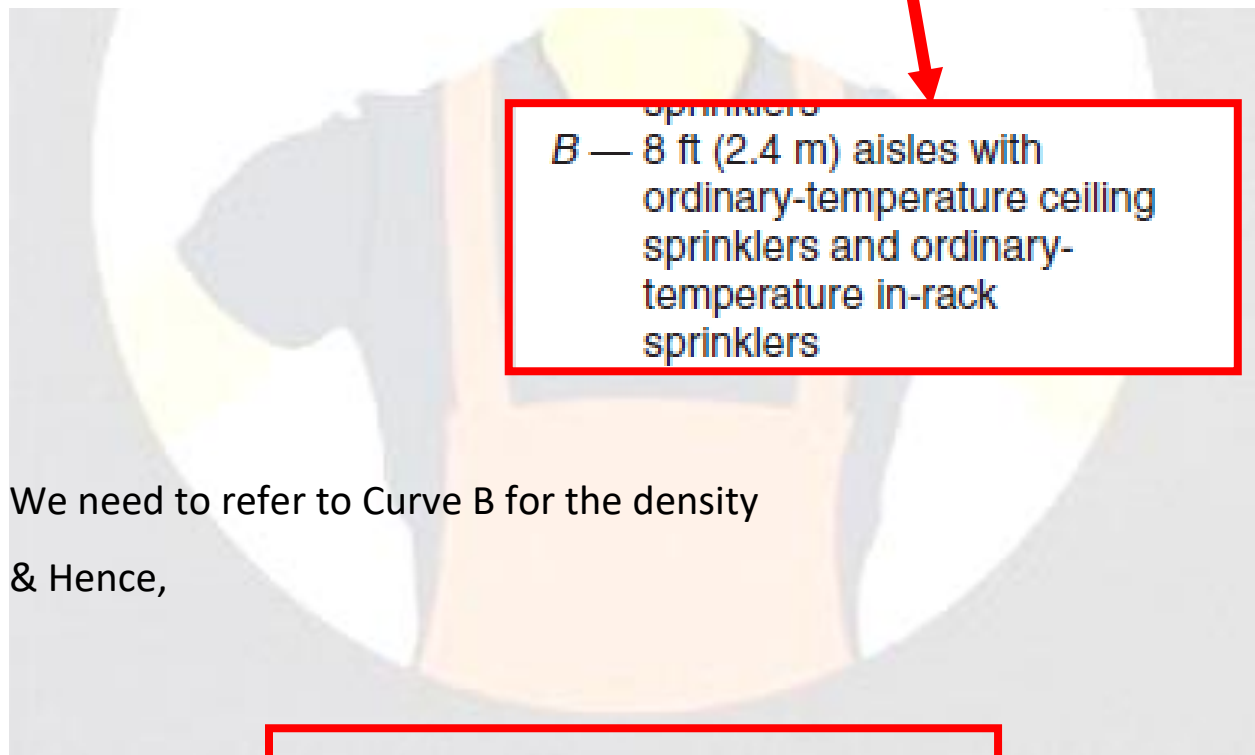


FIGURE 25.2.3.2.3.1(e) CMDA Sprinkler System Design Curves — Single- or Double-Row Racks — 20 ft (6.1 m) High Rack Storage — Class I and Class II Encapsulated Commodities — Conventional Pallets.



We need to refer to Curve B for the density
& Hence,

Required Density = 0.27 gpm /sf
Area of Operation = 1000 sf

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Example: 05

Type of Facility: Storage Warehouse

Type of Rack : Double Row Rack

Type of Commodity : Class 3, encapsulated

Width of Aisle : 2.4 Mtr.

Storage Height = 24 feet

Height of Ceiling = 30 feet

Calculate the Total demand in gallons

Lets refer NFPA 13 2019 table 25.2.3.2.1

Table 25.2.3.2.1 Continued

Storage Height	Commodity Class	Encapsulated	Aisle Width*		No. of In-Rack Sprinkler Levels	Appropriate Figure and Curves		
			ft	m		Figure	Curves	Apply Figure 25.2.3.2.4.1
Over 22 ft (6.7 m) and up to and including 25 ft (7.6 m)	I	No	4	1.2	1 Level	25.2.3.2.3.1(a)	C and D	No
			8	2.4			A and B	
		Yes	4	1.2		25.2.3.2.3.1(e)	C and D	
			8	2.4			A and B	
	II	No	4	1.2		25.2.3.2.3.1(b)	C and D	
			8	2.4			A and B	
		Yes	4	1.2		25.2.3.2.3.1(e)	C and D	
			8	2.4			A and B	
	III	No	4	1.2		25.2.3.2.3.1(c)	C and D	
			8	2.4			A and B	
		Yes	4	1.2		25.2.3.2.3.1(f)	C and D	
			8	2.4			A and B	
	IV	No	4	1.2		25.2.3.2.3.1(d)	C and D	
			8	2.4			A and B	
		Yes	4	1.2		25.2.3.2.3.1(g)	C and D	
			8	2.4			A and B	

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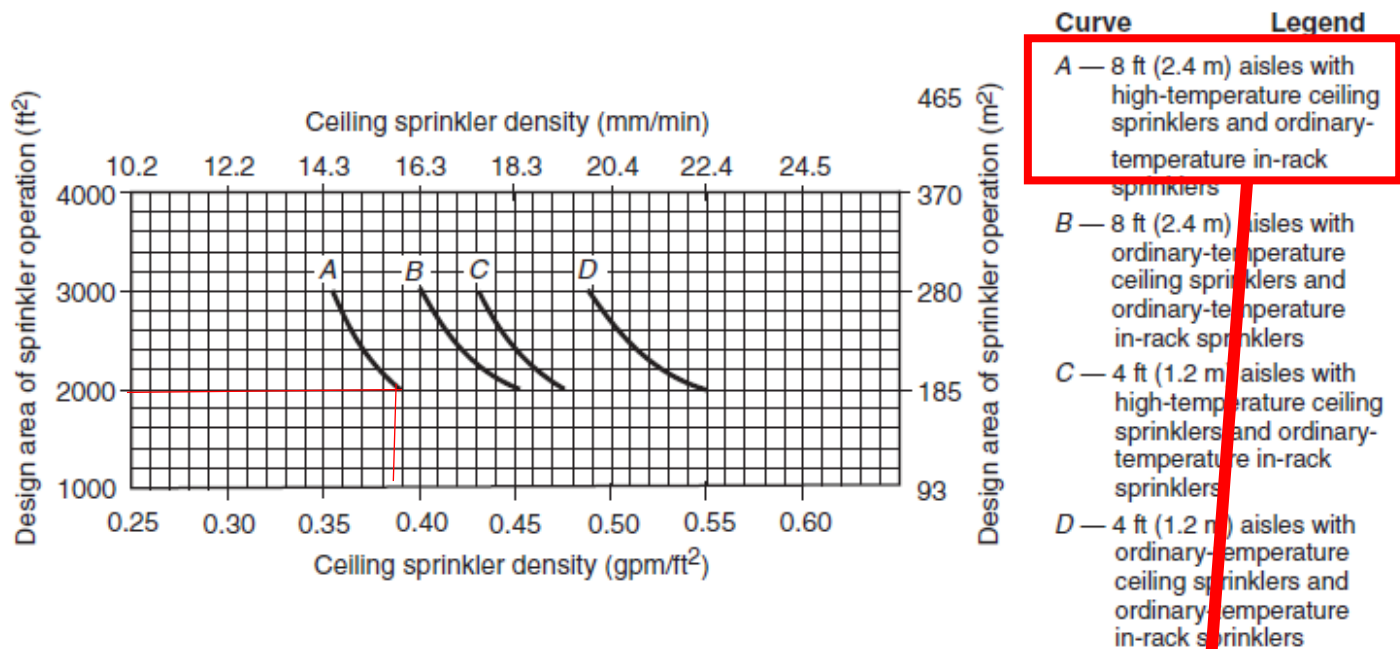


FIGURE 25.2.3.2.3.1(g) CMDA Sprinkler System Design Curves — Single- or Double-Row Racks — 20 ft (6.1 m) High Rack Storage — Class IV Encapsulated Commodities — Conventional Pallets.

A — 8 ft (2.4 m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

Density selected from above Curve = 0.39 gpm/sf

Area of Operation = 2000 SF

CMDA Sprinkler Demand = 2000 x 0.39 = 780 GPM

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Ceiling Sprinkler with CMSA option :

Table 25.2.4.2.1 CMSA Ceiling-Level Sprinkler Design Criteria for Rack Storage of Class I Through Class IV Commodities (Encapsulated and Nonencapsulated) Supplemented with In-Rack Sprinklers

Storage Arrangement	Commodity Class	Maximum Storage Height		Maximum Ceiling/Roof Height		K-Factor/Orientation	Type of System	No. of Ceiling Sprinklers in the Design	No. of Required Levels of In-Rack Sprinklers	Minimum Ceiling Sprinkler Operating Pressure	
		ft	m	ft	m					psi	bar
Single-, double-, and multiple-row racks (no open-top containers)	I or II	30	9.1	35	11	11.2 (160) Upright	Wet	20	One level	25	1.7
							Dry	30	One level	25	1.7
						16.8 (240) Upright	Wet	20	One level	15	1
							Dry	30	One level	15	1
	III	25	7.6	30	9.1	11.2 (160) Upright	Wet	15	One level	25	1.7
							Dry	25	One level	25	1.7
						16.8 (240) Upright	Dry	25	One level	15	1
				35	11	11.2 (160) Upright	Wet	15	One level	25	1.7
							Dry	25	One level	25	1.7
						16.8 (240) Upright	Wet	15	One level	15	1
							Dry	25	One level	15	1
	IV	25	7.6	30	9.1	11.2 (160) Upright	Wet	15	One level	50	3.4
				35	11	11.2 (160) Upright	Wet	20	One level	50	3.4
								15	One level	75	5.2
						16.8 (240) Upright	Wet	20	One level	22	1.5
								15	One level	35	2.4

Selected K factor for CMSA sprinkler = 11.2

Minimum Pressure = 50 psi

Discharge (Q) = $11.2 \times (50)^{(1/2)}$

Q = 79.19 GPM

Total Discharge = $79.19 \times 15 = 1187$ GPM

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Ceiling Sprinkler with ESFR option :

Table 25.2.5.1.1 ESFR Ceiling-Level Sprinkler Design Criteria for Rack Storage of Class I Through Class IV and Group A Plastic Commodities (Encapsulated and Nonencapsulated) Supplemented with In-Rack Sprinklers

Storage Arrangement	Commodity Class	Maximum Storage Height		Maximum Ceiling/Roof Height		K-Factor	Orientation	No. of Ceiling Sprinklers in the Design	No. of Required Levels of In-Rack Sprinklers	Minimum Ceiling Sprinkler Operating Pressure	
		ft	m	ft	m					psi	bar
Single-, double-, and multiple-row racks (no open-top containers)	Class I, II, III or IV, encapsulated or nonencapsulated, cartoned nonexpanded and exposed	25	7.6	45	14	14.0 (200)	Pendent	12	One level	90	6.2
	nonexpanded plastics					16.8 (240)	Pendent	12	One level	63	4.3

Selected K Factor for sprinkler = 14. 0

Min. Pressure = 90 psi

Number of sprinklers = 12

Discharge per sprinkler = $14 \times (90)^{1/2}$

= 132 GPM

Total Discharge = 132 x 12

Total discharge = 1594 GPM

MECHSOFT ENGINEERING DESIGN AND CONSULTANCY

Example: 06

Type of Commodity : Class 3, Encapsulated

Storage Height : 35 feet

Building Height : 40 feet

Type of Rack Arrangement : Double row Rack

Aisle Width : 4 feet

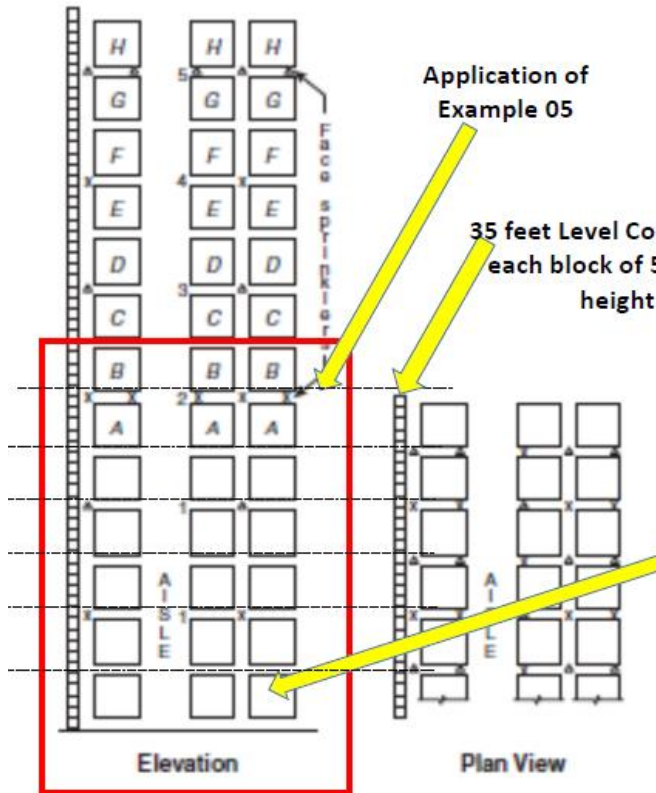
Type of Sprinkler System : Wet Type

Determine Requirement of in rack sprinklers and its water demand.

Table 25.9.2.2.1 Double-Row Racks of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height with Aisles 4 ft (1.2 m) or More in Width Protected by CMDA Sprinklers at Ceiling Level

Commodity Class	In-Rack Sprinklers Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing ^{a,b}		Figure	Maximum Storage Height	Stagger
	Longitudinal Flue ^c	Face ^{d,e}			
I	Vertical 20 ft (6.1 m), Horizontal 10 ft (3.0 m) under horizontal barriers	None	25.9.2.2.1(a)	30 ft (9.1 m)	No
	Vertical 20 ft (6.1 m), Horizontal 10 ft (3.0 m)	Vertical 20 ft (6.1 m), Horizontal 10 ft (3.0 m)	25.9.2.2.1(b)	Higher than 25 ft (7.6 m)	Yes
I, II, III	Vertical at 10 ft (3.0 m) or at 15 ft (4.6 m) and at 25 ft (7.6 m)	None	25.9.2.2.1(c)	30 ft (9.1 m)	Yes
	Vertical 10 ft (3.0 m), Horizontal 10 ft (3.0 m)	Vertical 30 ft (9.1 m), Horizontal 10 ft (3.0 m)	25.9.2.2.1(d)	Higher than 25 ft (7.6 m)	Yes
	Vertical 20 ft (6.1 m), Horizontal 10 ft (3.0 m)	Vertical 20 ft (6.1 m), Horizontal 5 ft (1.5 m)	25.9.2.2.1(e)		Yes
	Vertical 25 ft (7.6 m), Horizontal 5 ft (1.5 m)	Vertical 25 ft (7.6 m), Horizontal 5 ft (1.5 m)	25.9.2.2.1(f)		No
	Vertical 20 ft (6.1 m), Horizontal 10 ft (3.0 m) under horizontal barriers with two lines of staggered in rack sprinklers		25.9.2.2.1(g)		Yes

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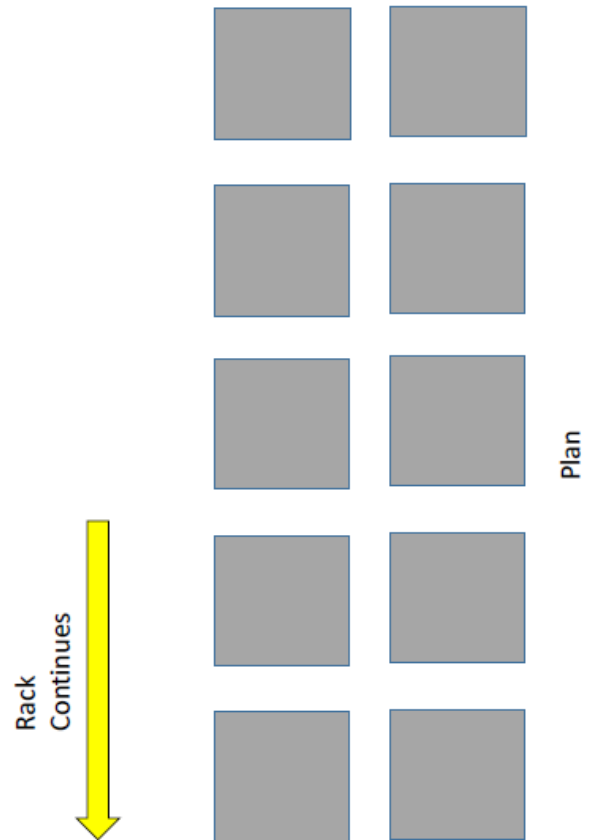
Notes:

1. Sprinklers labeled 1 shall be required where loads labeled A represent the top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled B or C represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled D or E represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled F or G represent top of storage.
5. Sprinklers labeled 1, 2, 3, 4, and 5 shall be required where loads labeled H represent top of storage.
6. For storage higher than represented by loads labeled H, the cycle defined by Notes 3, 4, and 5 is repeated with stagger as indicated.
7. The indicated face sprinklers shall be permitted to be omitted where commodity consists of unwrapped or unpackaged metal parts on wood pallets.
8. Symbol A or x indicates sprinklers on vertical or horizontal stagger.
9. Each square represents a storage cube measuring 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. (450 mm) up to 10 ft (3.0 m). Therefore, there could be as few as one load or as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.0 m) apart vertically.

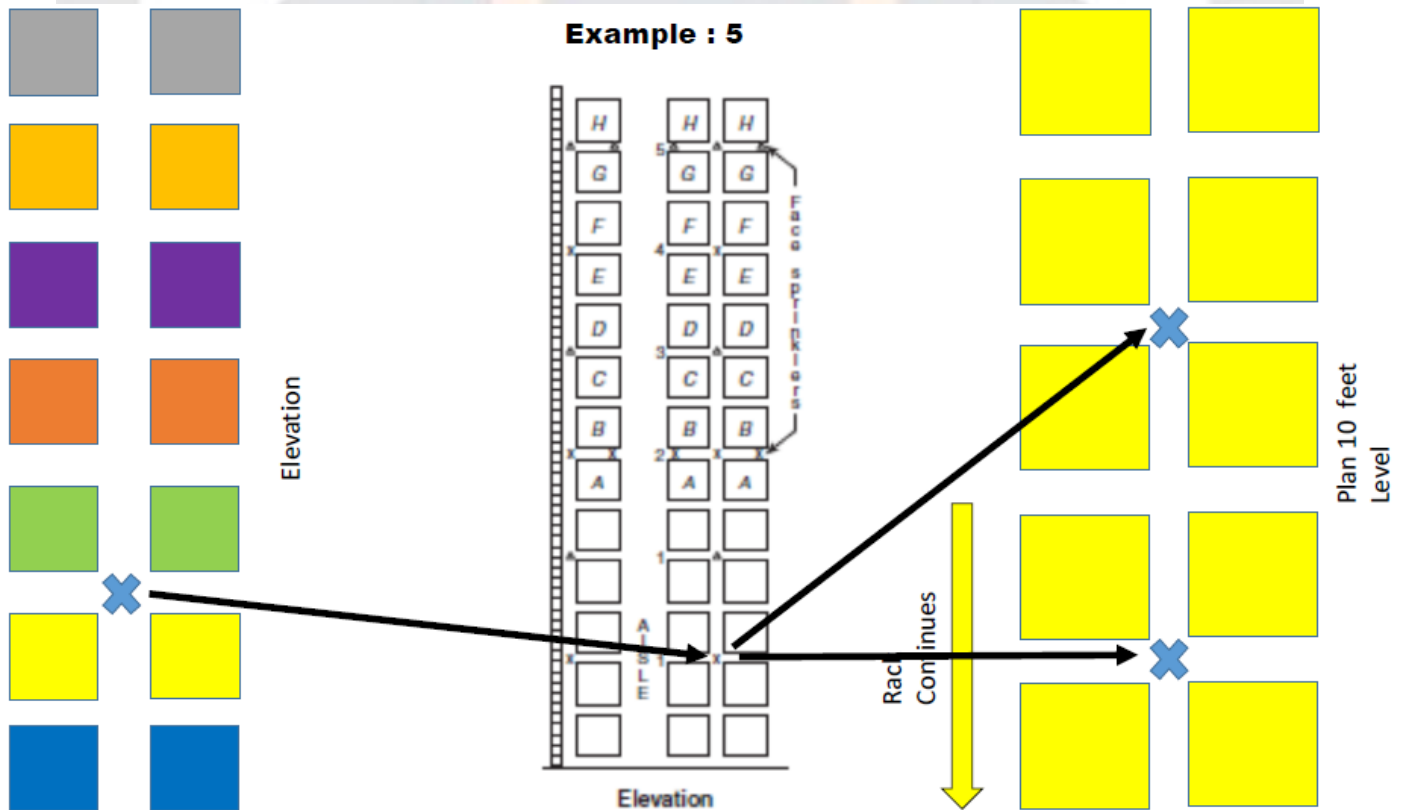
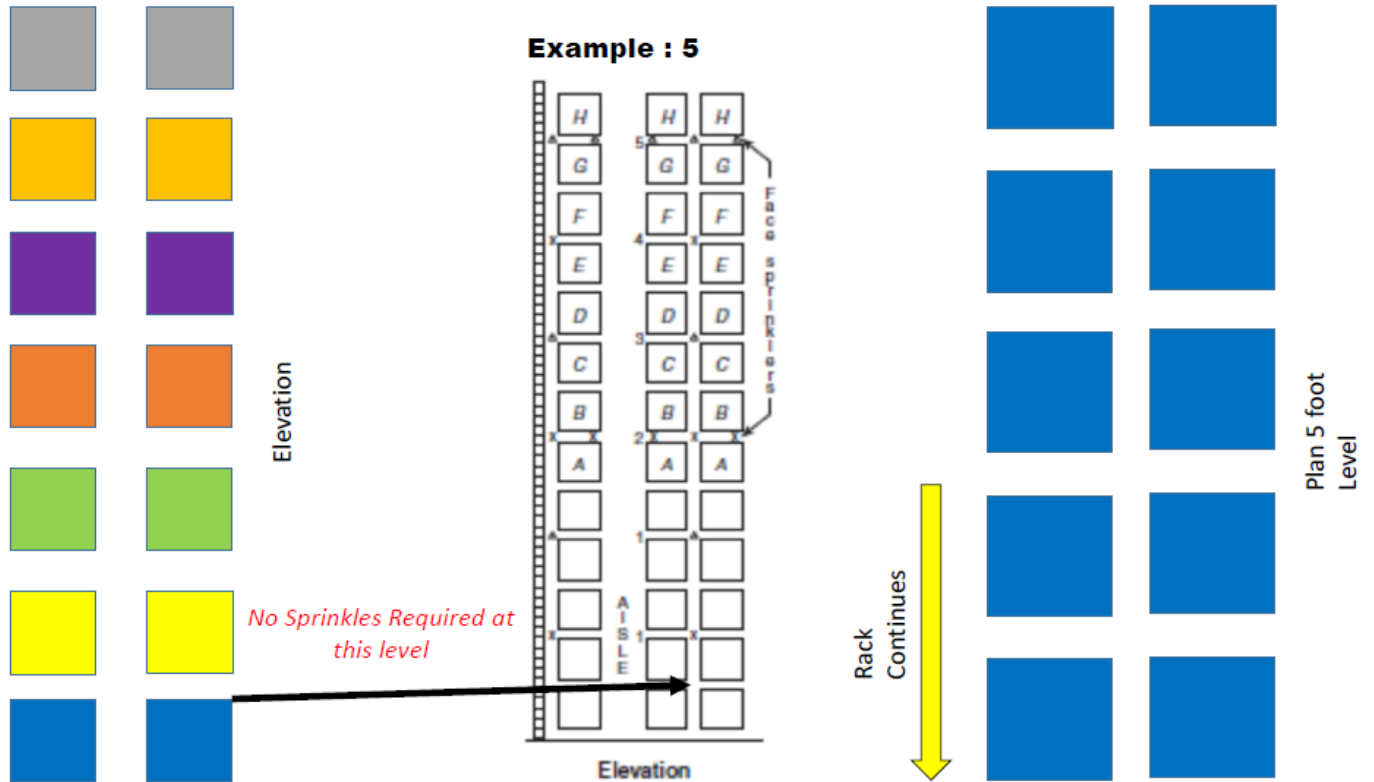
FIGURE 25.9.2.1(d) In-Rack Sprinkler Arrangement, Class I, II, or III Commodities, Storage Height Over 25 ft (7.6 m) — Option 1.



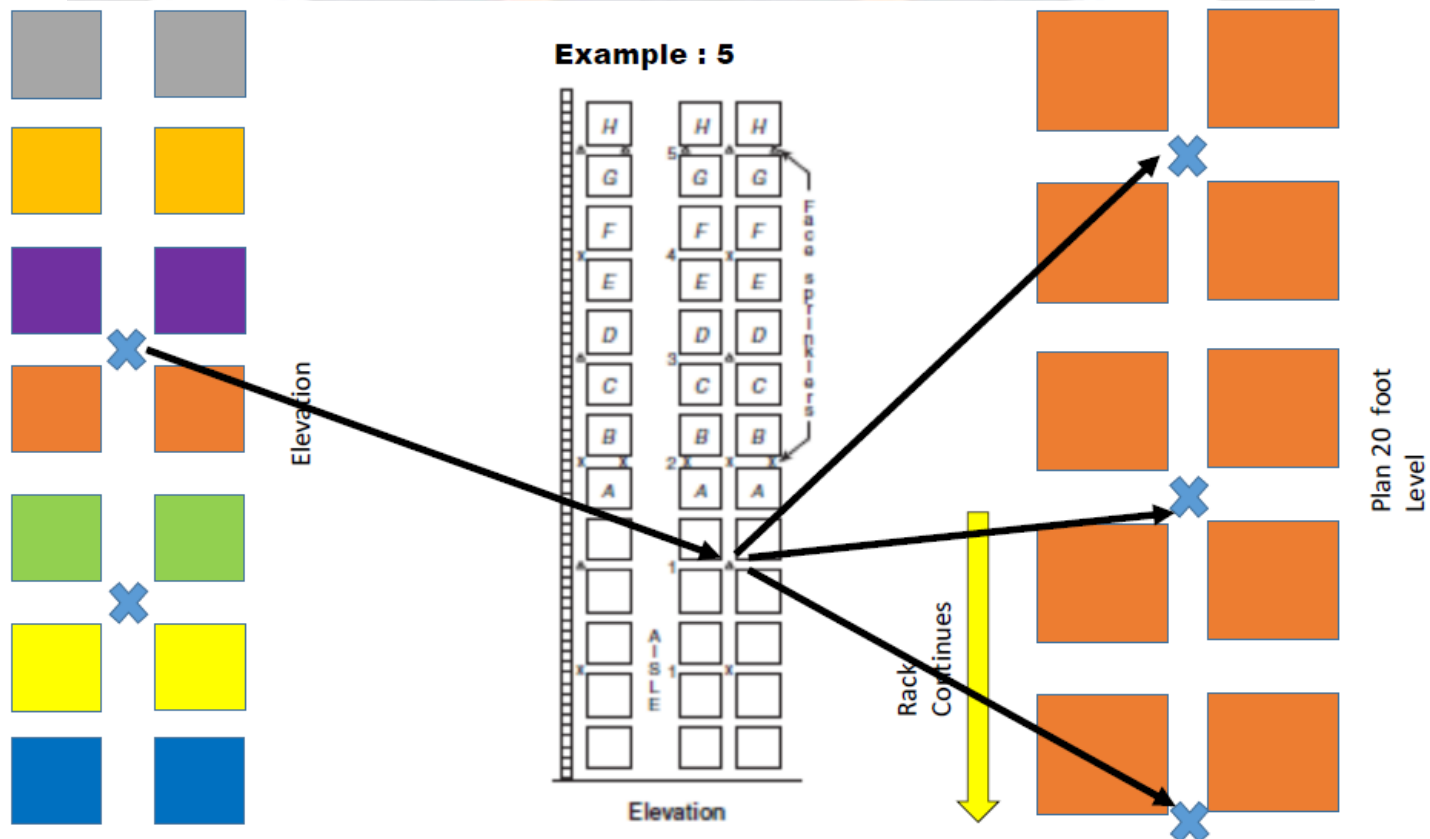
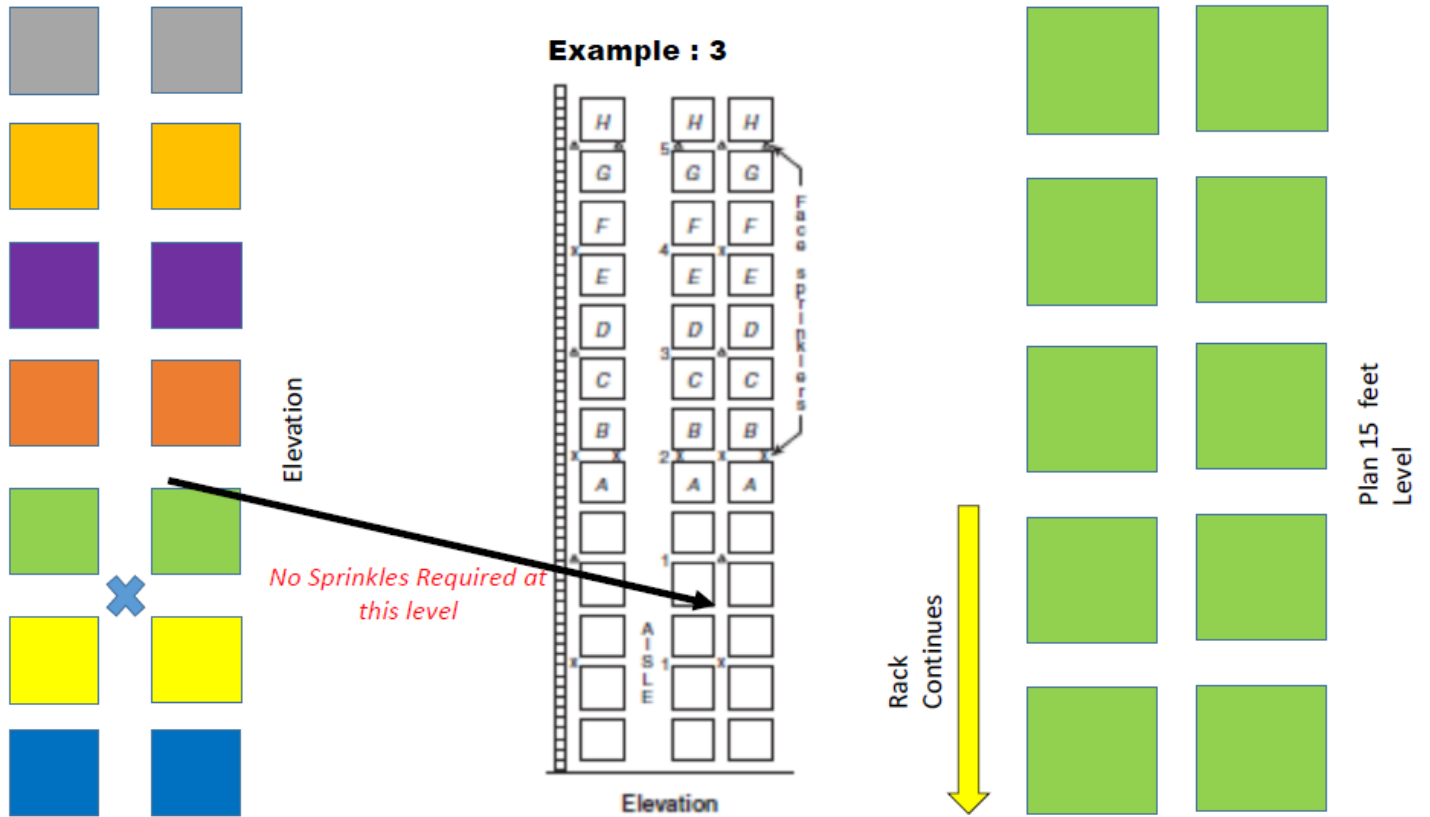
Example : 5



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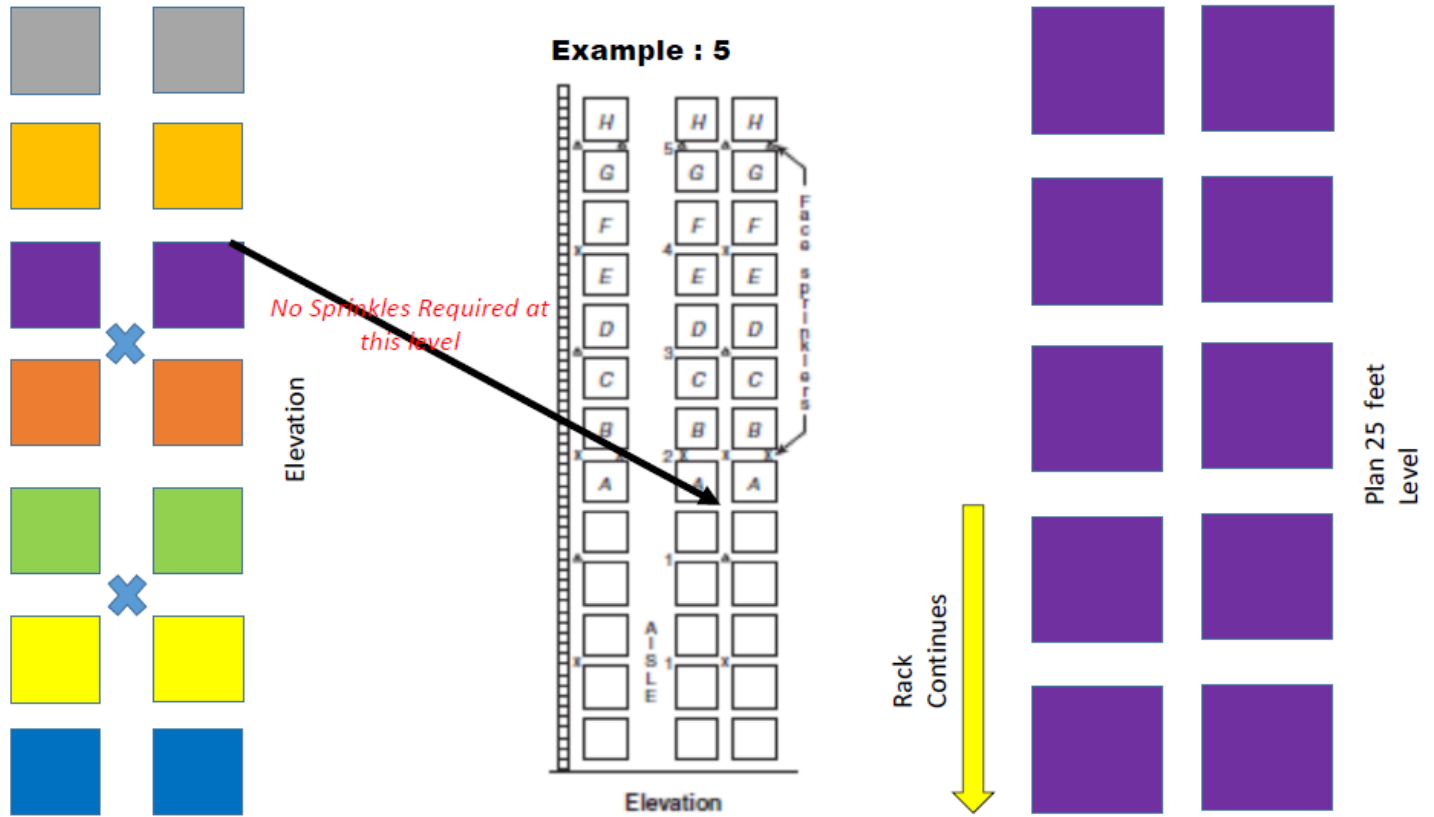


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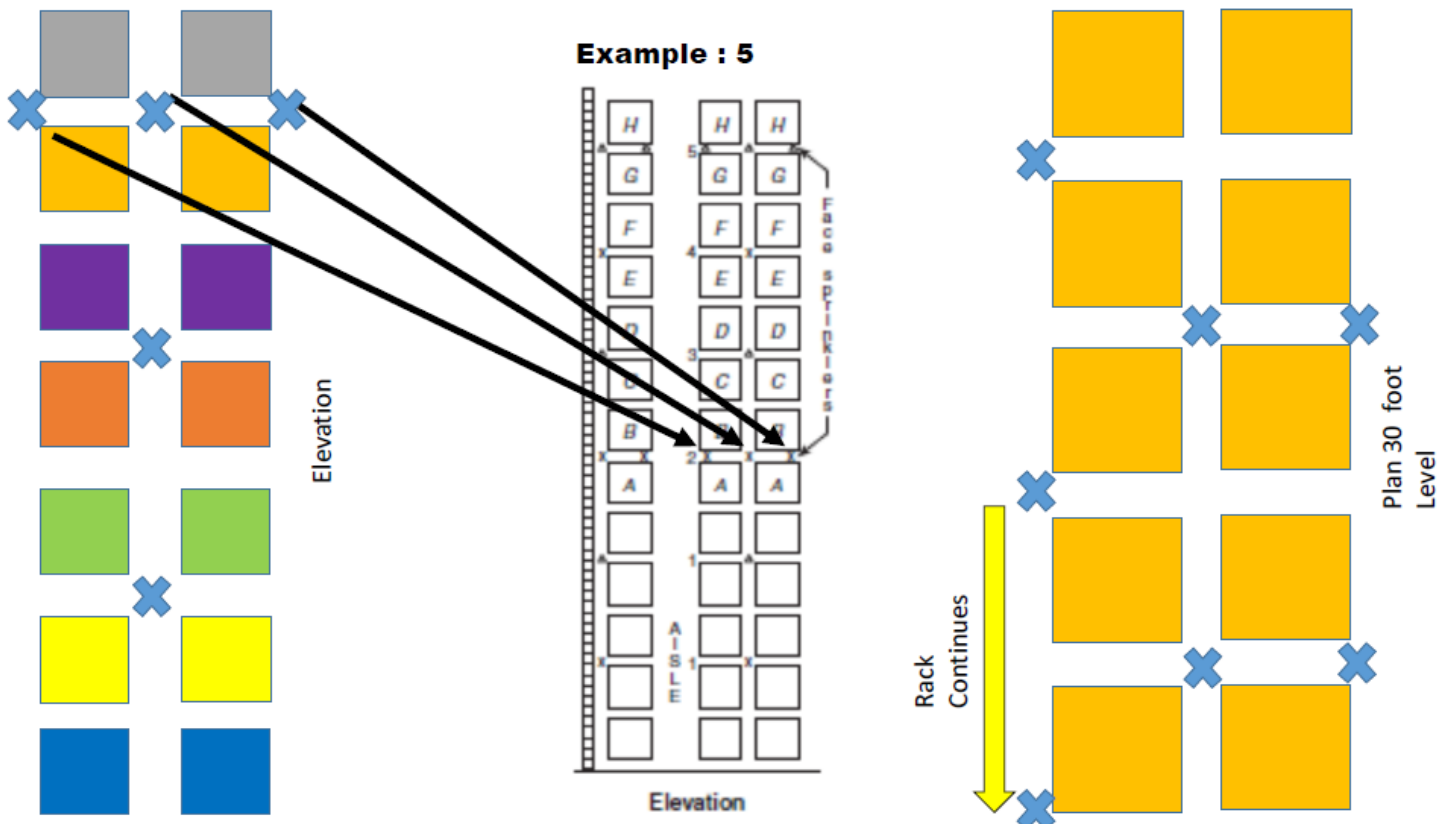


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Example : 5



Example : 5



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Water Demand Calculation :

Table 25.12.2.1 In-Rack Sprinkler System Design: Number of In-Rack Sprinklers

Type of Storage	Commodity Class	Rack Type	Ceiling Sprinkler Type	No. of Required In-Rack Sprinkler Levels	No. of In-Rack Sprinklers in the Design
Miscellaneous	Class I through IV, Group A plastics, and rubber tires	Any	Any	Any	4
Storage not meeting the definition of miscellaneous	Class I through III	Solid shelf	Any	One	6
			Any	More than one	10 (5 on each of the top two levels)
		Open	CMDA	One	6
			CMDA	More than one	10 (5 on each of the top two levels)
	Class I through IV	Open	CMSA	One	8
	Class I through IV and Group A plastics	Open	ESFR	One	8
	Class IV	Open	CMDA	More than one	10 (5 on each of the top two levels)
	Class IV and Group A plastics	Solid shelf	Any	One	8
				More than one	14 (7 on each of the top two levels)
		Open	CMDA	One	8
				More than one	14 (7 on each of the top two levels)
	Group A plastics	Open	CMSA	One	8
	Rubber tires	Open	CMDA	One	12



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Table 25.12.3.1 In-Rack Sprinkler System Design: Minimum Required Flow/Pressure from In-Rack Sprinklers

Type of Storage	Commodity Class	Rack Type	Ceiling Sprinkler Type	Storage Height		Minimum Design Flow/Pressure for In-Rack Sprinklers
				ft	m	
Miscellaneous	Class I through IV, Group A plastics, and rubber tires	Any	Any	Any	Any	15 psi (1.0 bar)
Storage not meeting the definition of miscellaneous	Class I through IV	Open	CMDA	Up to 25	Up to 7.6	15 psi (1.0 bar)
			CMSA	Any	Any	15 psi (1.0 bar)
	Class I through IV and Group A plastics	Open	CMDA	Over 25	Over 7.6	30 gpm (115 L/min)
			ESFR	Any	Any	60 gpm (230 L/min)
	Group A plastics	Solid shelves	Any	Any	Any	30 gpm (115 L/min)
			CMDA	Up to 25	Up to 7.6	15 psi (1.0 bar)
			CMSA	Up to 25	Up to 7.6	15 psi (1.0 bar)
	Rubber tires	Open	CMDA	Any	Any	30 psi (2.1 bar)

In rack sprinkler water demand requirement

10 sprinkler (5 from each two top level)

Discharge per sprinkler = 30 GPM

Total In Rack Sprinkler Demand = 10 x 30 = 300 GPM