231C

NFPA 231C Standard for Rack Storage of Materials 1998 Edition

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Errata

NFPA 231C

Standard for Rack Storage of Materials

1998 Edition

Reference: Tables 6-11, 6-13.1, 6-13.2, 7-8.1, 9-1.1, and B-8-2.1
Errata No.: 231C-98-1

The Committee on Rack Storage notes the following errors in the 1998 edition of NFPA 231C, *Standard for Rack Storage of Materials.*

1. Revise Table 6-11 to read as shown following on pages 2 and 3 (also note that the second part of this table was missing from the CD Rom only).

2. Revise Table 6-13.1 to read as shown on page 4.

3. Revise Table 6-13.2 to read as shown on page 5.

4. Revise Table 7-8.1 to read as shown on pages 6 and 7.

5. Revise Table 9-1.1 to read as shown on page 8.

6. Revise Table B-8-2.1 to read as shown on page 9.

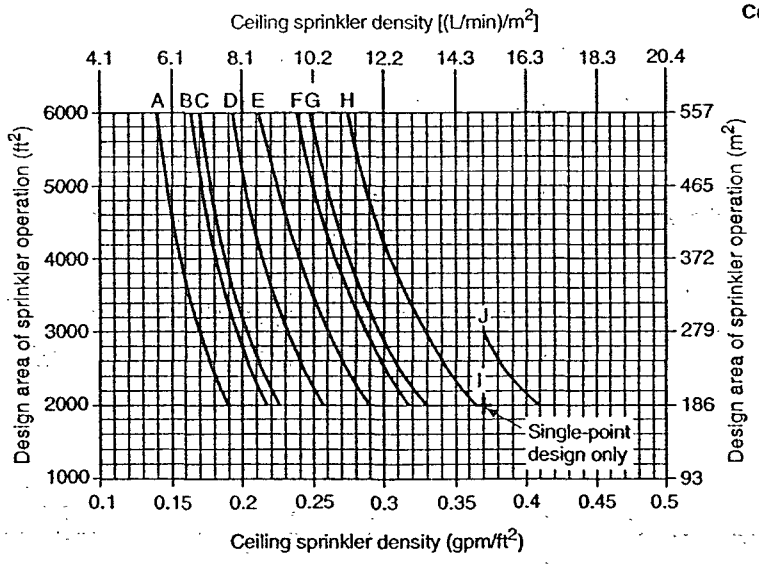
Issue Date: March 5, 1999

Table 6-11 Single-Row or Double-Row Racks — Storage Height up to and Including 25 ft (7.6 m) without Solid Shelves

Height	Commodity Class	Encapsulated	Aisles (4-4.1) (B-6-11.2) ft	Aisles (4-4.1) (B-6-11.2) m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers — Figure	With In-Rack Sprinklers — Curves	With In-Rack Sprinklers — Apply Figure 6-9.2	Without In-Rack Sprinklers — Figure	Without In-Rack Sprinklers — Curves	Without In-Rack Sprinklers — Apply Figure 6-9.2
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B	Yes	6-11(a)	F&H E&G	Yes
		Yes	4 8	1.2 2.4	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	III	No	4 8	1.2 2.4	No	6-11(c)	C&D A&B		6-11(c)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(f)	C&D A&B		NA	NA	NA
	IV	No	4 8	1.2 2.4	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(g)	C&D A&B		NA	NA	NA
Over 20 ft (6.1 m) up to and including 22 ft (6.7 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B	No	6-11(a)	F&H E&G	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B		NA	NA	NA
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B		NA	NA	NA
	III	No	4 8	1.2 2.4	No	6-11(c)	C&D A&B		6-11(c)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(f)	C&D A&B		NA	NA	NA
	IV	No	4 8	1.2 2.4	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(g)	C&D A&B		NA	NA	NA
Over 22 ft (6.7 m), up to and including 25 ft (7.6 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B	No	6-11(a)	F&H E&G	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B		NA	NA	NA
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B		NA	NA	NA

Table 6-11 Single-Row or Double-Row Racks — Storage Height up to and Including 25 ft (7.6 m) without Solid Shelves, *Continued*

Height	Commodity Class	Encapsulated	Aisles (4-4.1) (B-6-11.2) ft	Aisles (4-4.1) (B-6-11.2) m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers — Figure	With In-Rack Sprinklers — Curves	With In-Rack Sprinklers — Apply Figure 6-9.2	Without In-Rack Sprinklers — Figure	Without In-Rack Sprinklers — Curves	Without In-Rack Sprinklers — Apply Figure 6-9.2
Over 22 ft (6.7 m), up to and including 25 ft (7.6 m)	III	No	4	1.2	No	6-11(c)	C&D	No	6-11(c)	G&H	Yes
			8	2.4			A&B			E&F	
		Yes	4	1.2	One level	6-11(f)	C&D				
			8	2.4			A&B		NA	NA	NA
	IV	No	4	1.2	One level	6-11(d)	C&D				
			8	2.4			A&B		NA	NA	NA[3]
		Yes	4	1.2		6-11(g)	C&D				
			8	2.4			A&B		NA	NA	NA



Curve	Legend
A	Single- or double-row racks with 8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	Single- or double-row racks with 8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	Single- or double-row racks with 8-ft (2.4-m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 4-ft (1.2-m) aisles and high-temperature ceiling sprinklers
G	Single- or double-row racks with 8-ft (2.4-m) aisles and ordinary-temperature ceiling sprinklers
H	Single- or double-row racks with 4-ft (1.2-m) aisles and ordinary-temperature ceiling sprinklers
I	Multiple-row racks with 8-ft (2.4-m) or wider aisles and high-temperature ceiling sprinklers
J	Multiple-row racks with 8-ft (2.4-m) or wider aisles and ordinary-temperature ceiling sprinklers

Figure 6-11(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.

Table 6-13.1 Multiple-Row Racks — Rack Depth up to and Including 16 ft (4.9 m), Aisles 8 ft (2.4 m) or Wider Storage Height up to 25 ft (7.6 m)

				Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density
Over 12 ft (3.7 m) up to and including 15 ft (4.6 m)	I	No	No	6-11(a)	C&D	Yes	No	6-11(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No		6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No	No	6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes	NA	NA	NA	NA
	IV	No	No	6-11(d)			No	6-11(d)	C&D	No	No
		Yes	One level	6-11(d)	A&B		1.50 × density	NA	NA	NA	NA
Over 15 ft (4.6 m) up to and including 20 ft (6.1 m)	I	No	No	6-11(a)	C&D	Yes	No	6.12(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No		6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No	No	6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes	NA	NA	NA	NA
	IV	No	One level	6-11(d)			No	NA	NA	NA	NA
		Yes		6-11(d)	A&B		1.50 × density	NA	NA	NA	NA
Over 20 ft (6.1 m) up to and including 25 ft (7.6 m)	I	No	No	6-11(a)	C&D	No	No	6-11(a)	I&J	Yes	No
		Yes	One level	6-11(a)			Yes	NA	NA	NA	NA
	II	No	One level	6-11(b)			No	NA	NA	NA	NA
		Yes		6-11(b)			Yes	NA	NA	NA	NA
	III	No		6-11(c)			No	NA	NA	NA	NA
		Yes		6-11(c)			Yes	NA	NA	NA	NA
	IV	No	Two levels	6-11(d)			No	NA	NA	NA	NA
		Yes		6-11(d)	A&B		1.50 × density	NA	NA	NA	NA

Table 6-13.2 Multiple-Row Racks — Rack Depth over 16 ft (4.9 m) or Aisles Narrower than 8 ft (2.4 m) — Storage Height up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density
Over 12 ft (3.7 m) up to and including 15 ft (4.6 m)	I	No	No	6-11(a)	C&D	Yes	No	6-11(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No		6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No		6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes	NA	NA	NA	NA
	IV	No	No	6-11(d)			No	6-11(d)	C&D	No	No
		Yes	One level	6-11(d)			1.50 × density	NA	NA	NA	NA
Over 15 ft (4.6 m) up to and including 20 ft (6.1 m)	I	No	One level	6-11(a)	C&D	Yes	No	NA	NA	NA	NA
		Yes		6-11(a)			Yes				
	II	No		6-11(b)			No				
		Yes		6-11(b)			Yes				
	III	No		6-11(c)			No				
		Yes		6-11(c)			Yes				
	IV	No		6-11(d)			No				
		Yes		6-11(d)			1.50 × density				
Over 20 ft (6.1 m) up to and including 25 ft (7.6 m)	I	No	One level	6-11(a)	C&D	No	No	NA	NA	NA	NA
		Yes		6-11(a)			Yes				
	II	No		6-11(b)			No				
		Yes		6-11(b)			Yes				
	III	No		6-11(c)			No				
		Yes		6-11(c)			Yes				
	IV	No	Two levels	6-11(d)			No				
		Yes		6-11(d)			1.50 × density				

Table 7-8.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft^2	m^2	gpm/ft^2	L/min^2	gpm/ft^2	L/min^2
I	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m) under horizontal barriers	None	7-8.1(a)	30 ft (9.1 m)	No	2000	186	0.25	10.2	0.35	14.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-8.1(b)	Higher than 25 ft (7.6 m)	Yes			0.25	10.2	0.35	14.3
I, II, III	Vertical 10 ft (3.1 m) or at 15 and 25 Horizontal 10 ft (3.1 m)	None	7-8.1(c)	30 ft (9.1 m)	Yes			0.3	12.2	0.4	16.3
	Vertical 10 ft (3.1 m) Horizontal 10 ft (3.1 m)	Vertical 30 ft (9.1 m) Horizontal 10 ft (3.1 m)	7-8.1(d)		Yes			0.3	12.2	0.4	16.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-8.1(e)		Yes			0.3	12.2	0.4	16.3
	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	7-8.1(f)	Higher than 25 ft (7.6 m)	No			0.3	12.2	0.4	16.3

Table 7-8.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider, *Continued*

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft^2	m^2	gpm/ft^2	L/min^2	gpm/ft^2	L/min^2
I, II, III, IV	Horizontal barriers at 20 ft (6.1 m) Vertical intervals — 2 lines of sprinklers under barriers — maximum horizontal spacing 10 ft (3.1 m) staggered		7-8.1(g)	Higher than 25 ft (7.6 m)	Yes	2000	186	0.3	12.2	0.4	16.3
	Vertical 15 ft (4.6 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-8.1(h)		Yes			0.35	14.3	0.45	18.3
	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-8.1(i)		No			0.35	14.3	0.45	18.3
	Horizontal barriers at 15 ft (4.6 m) Vertical intervals — 2 lines of sprinkler under barriers — maximum horizontal spacing 10 ft (3.1 m) staggered		7-8.1(j)		Yes			0.35	14.3	0.45	18.3

[1]Minimum in-rack sprinkler discharge, 30 gpm (114 L/min) *(see Section 7-6)*.
[2]Water shields required *(see Sections 6-4 and 7-4)*.
[3]All in-rack sprinkler spacing dimensions start from the floor.
[4]For encapsulated commodity, increase density 25 percent *(see 7-10.2)*.
[5]Clearance is distance between top of storage and ceiling.
[6]See A-7-8.3, A-7-9, and A-7-10.1 for protection recommendations where clearance is greater than 10 ft (3.1 m).
[7]Install Sprinklers at least 3 in. (76.2 mm) from uprights *(see Section 7-5)*.
[8]Face sprinklers shall not be required for a Class I commodity consisting of noncombustible products on wood pallets (without combustible containers), except for arrays shown in Figures 7-8.1(g) and (j).
[9]In Figures 7-8.1(a) through (j), each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. (0.45 m) to 10 ft (3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Table 9-1.1 Large-Drop Sprinkler Design Criteria for Single-Row, Double-Row, and Multiple-Row Racks

Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/ Roof Height ft	Maximum Ceiling/ Roof Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure [psi (bar)]) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gal/min	Hose Stream Demand L/min	Water Supply Duration (hr)
I, II	25	7.6	30	9.1	Wet	20	20	20	500	1900	1 1/2
					Dry	30	30	30			
I, II	30	9.1	35	10.7	Wet	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500	1900	1 1/2
					Dry	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	500	1900	1 1/2
I, II, III	20	6.1	30	9.1	Wet	15	15	15	500	1900	1 1/2
					Dry	25	25	25			
I, II, III	25	7.6	35	10.7	Wet	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	1 1/2
					Dry	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	500	1900	1 1/2
IV	20	6.1	30	9.1	Wet	NA	20	15	500	1900	2
					Dry	NA	NA	NA			
IV	25	7.6	35	10.7	Wet	NA	20 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	20	6.1	30	9.1	Wet	NA	30	20	500	1900	2
					Dry	NA	NA	NA			
IV	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	25	7.6	35	10.7	Wet	NA	30 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500	1900	2
IV	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
	25	7.6	30	9.1	Dry	NA	NA	NA			

Note: NA — Not allowed

Table B-8-2.1 Summary of Test Results for Plastic Commodities Using $^5/_8$-in. (15.9-mm) Orifice Sprinklers

Test Parameters	Date of Test						
	8/20/93	8/25/93	9/2/93	10/7/93	2/17/94	2/25/94	4/27/94
Type of Shelving	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Slatted wood	Wire mesh
Other conditions/inclusions	—	—	—	—	Draft curtains	Draft curtains	—
Storage height (ft-in.)	19-11	19-11	15-4	15-4	19-11	19-11	13-11
Number of tiers	6[1]	6[1]	5[2]	5[2]	6[1]	6[2]	3
Clearance to ceiling/sprinklers (ft-in.)	6-10/6-3	6-10/6-3	11-5/10-10	11-5/10-10	6-10/6-3	6-10/6-3	8-4/7-9
Longitudinal/transverse flues (in.)	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/6 to $7^1/_2$	6/3[3]
Aisle width (ft)	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$	$7^1/_2$
Ignition centered below (number of sprinklers)	2	2	1	1	2	2	1
Sprinkler orifice size (in.)	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Sprinkler temperature rating (°F)	165	286	286	165	165	286	286
Sprinkler RTI (ft-sec)$^1/_2$	300	300	300	300	300	300	300
Sprinkler spacing (ft × ft)	8 × 10	8 × 10	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10
Sprinkler identification	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231	ELO-231
Constant water pressure (psi)	19	19	19	19	19	19	15.5
Minimum density (gpm/ft^2)	0.6	0.6	0.6	0.6	0.6	0.6	0.45
Test Results							
First sprinkler operation (min:sec)	2:03	2:25	1:12	0:44	1:25	0:52	0:49
Last sprinkler operation (min:sec)	2:12	15:19	6:34	7:34	15:54	14:08	10:58
Total sprinklers opened	4	9	7	13	35	18	12
Total sprinkler discharge (gpm)	205	450	363	613	1651	945	600
Average discharge per sprinkler (gpm)	51	50	52	47	47	52	50
Peak/max. 1-min average gas temperature (°F)	1107/566	1412/868	965/308	662/184	1575/883	1162/767	1464/895
Peak/max. 1-min average steel temperature (°F)	185/172	197/196	233/232	146/145	226/225	255/254	502/500
Peak/max. 1-min average plume velocity (ft/sec)	27/15	25/18	18/15[4]	14/10[4]	26/23	20/18[4]	33/20
Peak/max. 1-min heat flux (Btu/ft^2/sec)	0.6/0.5	2.0/1.9	2.8/2.5	1.1/0.8	1.0/0.9	4.8/3.0	1.6/1.4
Aisle jump, east/west target ignition (min:sec)	None	8:24/None	5:35/10:10	None	None	[5]/8:18	[5]/None
Equivalent number of pallet loads consumed	3	9	6	5	12	13	12
Test duration (min)	30	30	30	30	30	30	30
Results acceptable	Yes	Yes	Yes	Yes	No[6]	No[7]	Yes

Note: For SI units, 1 ft = 0.305 m; 1 in. = 25.4 mm; °F = (1.8 × °C) +32; °C = (°F − 32)/1.8; 1 psi = 0.069 bar; 1 gpm = 3.8 L/min; 1 ft/sec = 0.31 m/sec; 1 gpm/ft^2 = 40.8 (L/min)/m^2

[1]Main (ignition) racks divided into 5 or 6 tiers; bottom tiers each approximately 2 ft (0.6 m) high and upper tiers each about 5 ft (1.5 m) high; wood shelving below commodity at second through fifth tiers.

[2]Main (ignition) racks divided into 5 or 6 tiers; bottom tiers each approximately 2 ft (0.6 m) high and upper tiers each about 5 ft (1.5 m) high; wood shelving below commodity at second through fifth tiers; wire mesh shelving below commodity at sixth tier or below fifth (top) tier commodity.

[3]Transverse flues spaced 8 ft (2.4 m) apart [versus $3^1/_2$ ft (1.1 m) apart in all other tests].

[4]Instrumentation located 5 ft (1.5 m) north of ignition.

[5]Minor surface damage to cartons.

[6]High water demand.

[7]Excessive fire spread; marginally high water demand.

NFPA 231C

Standard for

Rack Storage of Materials

1998 Edition

This edition of NFPA 231C, *Standard for Rack Storage of Materials*, was prepared by the Technical Committee on Rack Storage and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 18–21, 1998, in Cincinnati, OH. It was issued by the Standards Council on July 16, 1998, with an effective date of August 5, 1998, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 231C was approved as an American National Standard on August 6, 1998.

Origin and Development of NFPA 231C

In August 1967, representatives for rack manufacturers, fire protection equipment manufacturers, the insurance community, and industrial users met and organized the Rack Storage Fire Protection Committee. The committee developed and financially sponsored a program of full-scale fire tests for the storage of combustible materials in racks.

In 1968, the NFPA Committee on Rack Storage of Materials was organized. All data developed by the Rack Storage Fire Protection Committee was subsequently turned over to the NFPA Committee on Rack Storage of Materials. Thus, the NFPA Committee was able to develop a standard that was supported entirely by actual fire test data. NFPA 231C was first adopted at the NFPA Annual Meeting in May 1971.

In 1972, revisions to NFPA 231C included changing certain recommendations to requirements, and new material was added to Appendix A. In 1973, further revisions were made to include storage for heights above 25 ft (7.6 m) and to relocate advisory material to Appendix A. In 1974, the entire format of the document was revised, editorial changes were made, and new material was added.

In 1975, new test data resulted in the introduction of additional material. The 1980 edition was a partial revision that included changes to the tables and figures in Chapter 6. Revisions made in 1986 included expanded protection criteria for plastic commodities.

The 1991 edition incorporated a variety of changes that included editorial improvements as well as numerous substantive changes. Technically important changes in the 1991 edition included permission to use intermediate-temperature and high-temperature sprinklers for plastic commodities. In addition, a series of figures was included that illustrated the relative positions of in-rack sprinklers for rack storage of Group A plastics. The previously issued TIA on ESFR sprinklers was incorporated as a new chapter.

The 1995 edition incorporated criteria for miscellaneous storage, extra-large orifice sprinklers, quick-response and large-orifice sprinklers for in-rack applications, and new large-drop and ESFR sprinkler applications. New definitions were also introduced, and some chapters were reworded to improve the user friendliness of the document.

The 1998 edition includes expanded descriptions and examples of storage commodities. Protection criteria have been added for mixed commodity storage, storage on plastic pallets, and storage of idle pallets in racks. More information has been provided on flue spaces and the placement of in-rack sprinklers. Other changes include expanded applications for ESFR and large-drop sprinklers, the application of new types of sprinklers, revised protection criteria for storage up to 12 ft in height and new limitations on dry pipe and preaction systems. Additionally criteria has been added for plastic storage on multiple-row racks and the storage of commodities on slatted shelves.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of this document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire prevention and fire protection considerations for the rack storage of materials, including automatic systems. This Committee also shall have primary responsibility for emergency operations, including fire-fighting operations in facilities used for the rack storage of materials.

Contents

NFPA 231C

Standard for

Rack Storage of Materials

1998 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

A dagger (†) following the number or letter designating a paragraph or section in the text indicates explanatory test data and procedures with regard to that paragraph or section can be found in Appendix B.

Information on referenced publications can be found in Chapter 13 and Appendix C.

Chapter 1 Introduction

1-1† Application and Scope. This standard shall apply to the storage of materials that represent the broad range of commodities stored in racks.

Exception: Miscellaneous storage shall be permitted to be protected in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

1-1.1 This standard shall not apply to storage on plastic shelves.

1-1.2* This standard shall not apply to the storage of high hazard materials such as tires, roll paper stored on end, and flammable liquids, which is outside the scope of this standard. Storage of such commodities shall be protected in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code;* NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film;* NFPA 58, *Liquefied Petroleum Gas Code;* NFPA 231, *Standard for General Storage;* NFPA 231D, *Standard for Storage of Rubber Tires;* NFPA 231F, *Standard for the Storage of Roll Paper;* NFPA 232, *Standard for the Protection of Records;* and NFPA 490, *Code for the Storage of Ammonium Nitrate,* as applicable.

1-1.3 This standard shall not apply to bin storage and shelf storage.

1-1.4 Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not reduced.

1-2 Retroactivity Clause. The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire. The provisions reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, the provisions of this document shall not be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

Exception: This standard shall apply in cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property.

1-3 Definitions. Unless specifically stated elsewhere, for the purpose of this standard, the terms in this section shall be defined as follows:

Aisle Width. The horizontal dimension between the face of the loads in racks under consideration. *[See Figure 1-3(a).]*

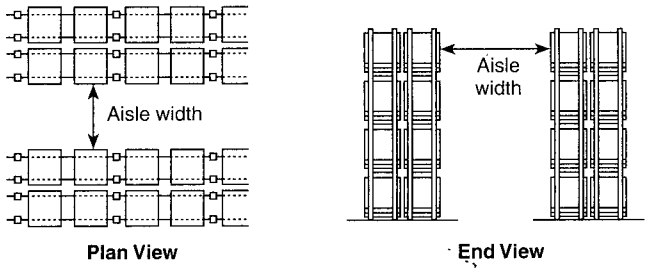


Figure 1-3(a) Illustration of aisle width.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Bulkhead. A vertical barrier across the rack.

Cartoned. A method of storage that consists of corrugated cardboard or paperboard containers that fully enclose the commodity.

Ceiling Height. The distance between the floor and the underside of the ceiling above, or roof deck within, a storage area.

Commodity. The combinations of products, their packing materials, and their containers.

Conventional Pallet. A material-handling aid designed to support a unit load with openings to provide access for material-handling devices. *[See Figure 1-3(b).]*

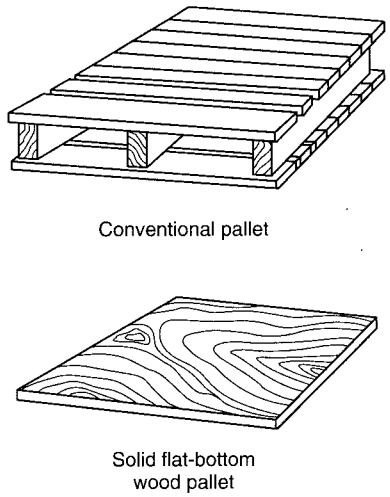


Figure 1-3(b) Typical pallets.

Early Suppression Fast Response (ESFR) Sprinkler.* A type of fast-response sprinkler that meets the criteria of 1-4.5.1(a) of NFPA 13, *Standard for the Installation of Sprinkler Systems,* and is listed for its capability to provide fire suppression of specific high challenge fire hazards.

Encapsulated. A method of packaging that consists of a plastic sheet that completely encloses the sides and top of a pallet load that contains a combustible commodity or a combustible package or a group of combustible commodities or combustible packages; combustible commodities that are individually wrapped in plastic sheeting and stored exposed in a pallet load.

Totally noncombustible commodities on wood pallets that are enclosed only by a plastic sheet as described are not covered under this definition. Banding (i.e., stretch-wrapping around only the sides of a pallet load) is not considered to be encapsulation. Where there are holes or voids in the plastic or waterproof cover on the top of the carton that exceed more than half the area of the cover, the term *encapsulated* shall not apply. The term encapsulated does not apply to plastic-enclosed products or packages inside a large, nonplastic, enclosed container.

Face Sprinkler. A standard sprinkler that is located in a transverse flue space along the aisle or in the rack, within 18 in. (0.46 m) of the aisle face of storage, and that is used to oppose the vertical development of fire on the external face of storage.

Free-Flowing Plastic Material. Plastic that falls out of its container during a fire, fills flue spaces, and creates a smothering effect on the fire. Some examples include powder, pellets, flakes, or random-packed small objects [e.g., razor blade dispensers, 1-oz to 2-oz (29.6-ml to 59.1-ml) bottles].

Horizontal Barrier. A solid barrier in the horizontal position that covers the entire rack, including all flue spaces at certain height increments, to prevent vertical fire spread.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Longitudinal Flue Space. The space between rows of storage perpendicular to the direction of loading. *[See Figure 1-3(c).]*

Miscellaneous Storage. Storage that does not exceed 12 ft (3.7 m) in height and is incidental to another occupancy-use group as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems.* Such storage shall not constitute more than 10 percent of the building area or 4000 ft^2 (372 m^2) of the sprinklered area, whichever is greater. Such storage shall not exceed 1000 ft^2 (93 m^2) in one pile or area, and each such pile or area shall be separated from other storage areas by at least 25 ft (7.6 m).

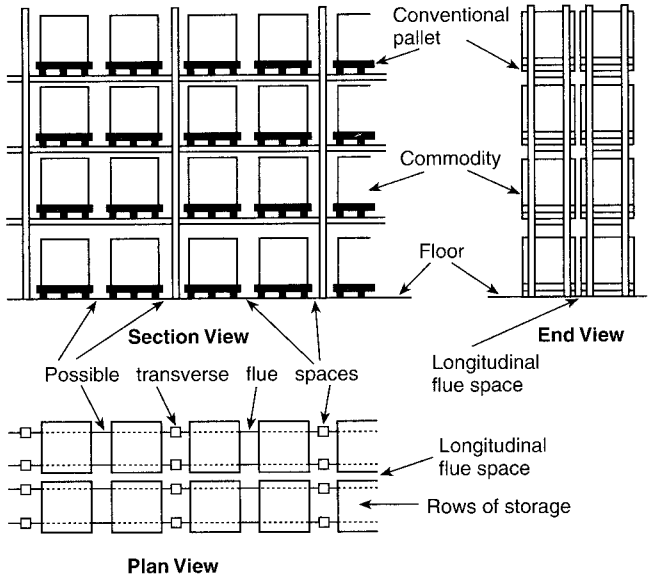


Figure 1-3(c) Typical double-row (back-to-back) rack arrangement.

Rack. Any combination of vertical, horizontal, and diagonal members that supports stored materials. Some rack structures use solid shelves. Racks shall be permitted to be fixed, portable, or movable *[see Figures A-4-1(a) through (k)]*. Loading shall be permitted to be either manual — using lift trucks, stacker cranes, or hand placement — or automatic — using machine-controlled storage and retrieval systems.

Double-Row Rack. Two single-row racks placed back-to-back that have a combined width of up to 12 ft (3.7 m), with aisles of at least 3.5 ft (1.1 m) on each side.

Movable Rack. A rack on fixed rails or guides that can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks.

Multiple-Row Rack. A rack that is wider than 12 ft (3.7 m) or a single-row or a double-row rack that is separated by aisles less than 3.5 ft (1.1 m) wide and that has an overall width greater than 12 ft (3.7 m).

Portable Rack. A rack that is not fixed in place and that can be arranged in any number of configurations.

Single-Row Rack. A rack that has no longitudinal flue space and that has a width of up to 6 ft (1.8 m), with aisles at least 3.5 ft (1.1 m) from other storage.

Roof Height. The distance between the floor and the underside of the roof deck within a storage area.

Shall. Indicates a mandatory requirement.

Shelf Storage. Storage on structures less than 30 in. (7.62 cm) deep with shelves usually 2 ft (0.6 m) apart vertically and separated by approximately 30-in. (76.2-cm) aisles.

Should. Indicates a recommendation or that which is advised but not required.

Slave Pallet. A special pallet that is captive to a material-handling system. *[See Figure 1-3(b).]*

Solid Shelving. Solid, slatted, and other types of shelving that are located within racks that obstruct sprinkler water that penetrates down through the racks.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Transverse Flue Space. The space between rows of storage that is parallel to the direction of loading. *[See Figure 1-3(c).]*

Chapter 2 Classification of Storage

2-1*† Commodity Classifications.

2-1.1 General.

2-1.1.1* Commodity classification and the corresponding protection requirements shall be determined based on the makeup of individual storage units (i.e., unit load, pallet load).

2-1.1.2 Mixed Commodities. Protection requirements for mixed commodities shall not be based on the overall commodity mix in a fire area. Mixed commodity storage shall be protected by the requirements for the highest commodity and storage arrangement classification.

Exception No. 1: Up to 10 pallet loads of a higher hazard commodity, within the scope of this standard, shall be permitted to be present in an area that does not exceed 40,000 ft² (3716 m²). The higher hazard commodity shall be randomly dispersed with no adjacent loads in any direction (including the diagonal direction). If the ceiling protection is based on Class I or Class II commodities, the permitted number of pallet loads for Class IV or Group A plastics shall be reduced to five.

Exception No. 2: Where the higher hazard materials are confined to a designated area and properly protected for that area.

2-1.2 Pallet Types. Where loads are palletized, the use of wooden or metal pallets shall be assumed in the classification of commodities. Where plastic pallets are used, the classification of the commodity unit shall be increased by one class (e.g., Class III becomes Class IV, and Class IV becomes Group A plastics). No increase shall be required for a Group A plastic commodity.

Exception: Where specific test data are available, the results of the data shall take precedence in determining the classification of commodities.

2-1.3* Commodity Classes.

2-1.3.1* A Class I commodity shall be defined as a noncombustible product that is arranged in one of the following configurations:

(a) It is placed directly on wooden pallets.
(b) It is placed in single-layer corrugated cartons, with or without single-thickness cardboard dividers, with or without pallets.
(c) It is shrink wrapped or paper wrapped as a unit load with or without pallets.

2-1.3.2* A Class II commodity shall be defined as a noncombustible product that is placed in slatted wooden crates, solid wood boxes, multiple-layer corrugated cartons, or equivalent combustible packaging material, with or without pallets.

2-1.3.3* A Class III commodity shall be defined as a product fashioned from wood, paper, natural fibers, or Group C plastics, with or without cartons, boxes, or crates and with or without pallets. Such products shall be permitted to contain a limited amount (5 percent by weight or volume) of Group A or B plastic.

2-1.3.4* A Class IV commodity shall be defined as a product, with or without pallets, that meets one of the following criteria:

(a) It is constructed partially or totally of Group B plastic.
(b) It consists of free-flowing Group A plastic materials.
(c) It contains, within itself or its packaging, an appreciable amount (5 percent to 15 percent by weight or 5 percent to 25 percent by volume) of Group A plastic: The remaining materials shall be permitted to be any of the following:
    1. Metal
    2. Wood
    3. Paper
    4. Natural or synthetic fibers
    5. Group B or Group C plastics

2-1.4 Classification of Plastics, Elastomers, and Rubber. Plastics, elastomers, and rubber shall be classified as Group A, Group B, or Group C.

Groups A, B, and C classifications are based on unmodified plastic materials. The use of fire-retarding or flame-retarding modifiers or the physical form of the material can change the standard classification.

2-1.4.1* Group A.

ABS (acrylonitrile-butadiene-styrene copolymer)
Acetal (polyformaldehyde)
Acrylic (polymethyl methacrylate)
Butyl rubber
EPDM (ethylene-propylene rubber)
FRP (fiberglass-reinforced polyester)
Natural rubber (if expanded)
Nitrile rubber (acrylonitrile-butadiene rubber)
PET (thermoplastic polyester)
Polybutadiene
Polycarbonate
Polyester elastomer
Polyethylene
Polypropylene
Polystyrene
Polyurethane
PVC (polyvinyl chloride — highly plasticized, with plasticizer content greater than 20 percent) (rarely found)
SAN (styrene acrylonitrile)
SBR (styrene-butadiene rubber)

2-1.4.2 Group B.

Cellulosics (cellulose acetate, cellulose acetate butyrate, ethyl cellulose)
Chloroprene rubber
Fluoroplastics (ECTFE — ethylene-chlorotrifluoroethylene copolymer; ETFE — ethylene-tetrafluoroethylene

copolymer; FEP — fluorinated ethylene-propylene copolymer)
Natural Rubber (not expanded)
Nylon (Nylon 6, Nylon 6/6)
Silicone rubber

2-1.4.3 Group C.

Fluoroplastics (PCTFE — polychlorotrifluoroethylene; PTFE — polytetrafluoroethylene)
Melamine (melamine formaldehyde)
Phenolic
PVC (polyvinyl chloride — flexible — PVCs with plasticizer content up to 20 percent)
PVDC (polyvinylidene chloride)
PVDF (polyvinylidene fluoride)
PVF (polyvinyl fluoride)
Urea (urea formaldehyde)

Chapter 3 Building Construction

3-1 Construction. Buildings used for the rack storage of materials that are protected in accordance with this standard shall be of any of the types described in NFPA 220, *Standard on Types of Building Construction.*

3-2 Fire Protection of Steel.

3-2.1† Fire protection of roof steel shall not be required where sprinkler systems are installed in accordance with Chapters 6 through 10.

3-2.2† Fire protection of steel building columns shall not be required where ceiling sprinklers and sprinklers in racks are installed in accordance with Chapters 5 through 8.

3-2.3† Where storage height exceeds 15 ft (4.6 m) and only ceiling sprinklers are installed, fire protection shall be required for all types of steel building columns that are located within the racks or for vertical rack members that support the building. Such protection shall use one of the following methods:

(a) Provision of one-hour fire proofing
(b) Provision of sidewall sprinklers at the 15-ft (4.6-m) elevation that are pointed toward one side of the steel column. Flow from such sprinklers shall not be required to be included in the hydraulic calculations for sprinkler system demand.
(c) Provision of ceiling sprinkler density for a minimum of 2000 ft^2 (185.9 m^2) with ordinary-temperature-rated or high-temperature-rated sprinklers as specified in Table 3-2.3(c) for storage heights above 15 ft (4.6 m), up to and including 20 ft (6.1 m)
(d) Provision of large-drop or early suppression fast response (ESFR) ceiling sprinkler protection in accordance with Chapters 9 and 10, respectively

3-3† Vents and Draft Curtains. Sprinkler protection criteria shall be determined based on the assumption that roof vents and draft curtains are not being used.

Chapter 4 Storage Arrangement

4-1* Rack Structure. Rack configurations shall be of a generally accepted arrangement.

4-2* Rack Loading. Racks shall not be loaded beyond their design capacity.

4-3 Flue Space.

4-3.1† Storage up to and Including 25 ft (7.6 m). In double-row and multiple-row racks without solid shelves, a longitudinal (back-to-back clearance between loads) flue space shall not be required. Nominal 6-in. (142.4-mm) transverse flue spaces between loads and at rack uprights shall be maintained in single-row, double-row, and multiple-row racks. Random variations in the width of flue spaces or in their vertical alignment shall be permitted. *(See Figure 4-3.1.)*

4-3.2 Storage Height Over 25 ft (7.6 m). Nominal 6-in. (142.4-mm) transverse flue spaces between loads and at rack uprights shall be maintained in single-row, double-row, and multiple-row racks. Nominal 6-in. (152.4-mm) longitudinal flue spaces shall be provided in double-row racks. Random variations in the width of flue spaces or in their vertical alignment shall be permitted.

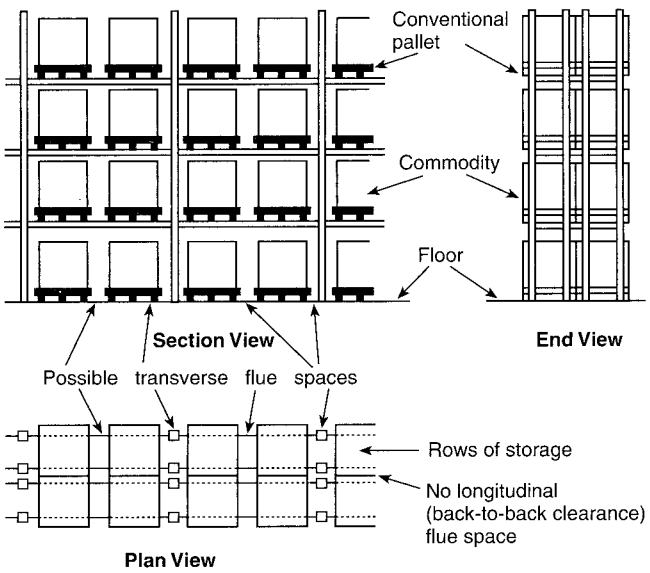
4-4* Aisle Width.

4-4.1 The aisle width and the depth of racks are determined by material-handling methods. The widths of aisles shall be considered in the design of the protection system. *(See Chapters 5 through 7.)*

Table 3-2.3(c) Ceiling Sprinkler Densities for Protection of Steel Building Columns

	Aisle Width			
	4 ft (1.2 m)		8 ft (2.4 m)	
Commodity Class	gpm/ft^2	(L/min)/m^2	gpm/ft^2	(L/min)/m^2
I	0.37	15.1	0.33	13.5
II	0.44	17.9	0.37	15.1
III	0.49	20.0	0.42	17.1
IV and plastics	0.68	27.7	0.57	23.2

Note: For aisle widths of 4 ft to 8 ft (1.2 m to 2.4 m), a direct linear interpolation between densities shall be permitted to be made.
For SI units, 1 gpm/ft^2 = (40.746 L/min)/m^2.



Note: No longitudinal flue space is necessary.

Figure 4-3.1 Typical double-row rack with back-to-back loads.

4-4.2 Aisle widths shall be maintained either by fixed-rack structures or controlled by the careful location of portable racks. Any decrease in aisle width shall require a review of the adequacy of the protective system.

4-5*† Storage Heights. The distance from the top of the storage to the ceiling sprinkler deflectors shall be not less than 18 in. (0.46 m).

Exception: Where large-drop or ESFR sprinkler protection is used, the distance from the top of the storage to the ceiling sprinkler deflectors shall be not less than 36 in. (91 cm).

4-6 Commodity Clearances.

4-6.1* Commodity clearances shall be maintained in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials.*

4-6.2* Incandescent Light Fixtures.

4-7† Storage of Idle Pallets.

4-7.1 Idle wood or plastic pallets stored on the floor shall be protected in accordance with NFPA 231, *Standard for General Storage.*

4-7.2 Idle wood or plastic pallets shall not be stored in racks.

Exception No. 1: Idle wood pallets shall be permitted to be stored in racks where protected in accordance with the applicable provisions of Chapter 10.

Exception No. 2: Idle plastic pallets shall be permitted to be stored in racks where protected in accordance with the applicable provisions of Chapter 10.

Chapter 5 Fire Protection — General

5-1 Protective Systems.

5-1.1* Sprinkler systems shall be wet-pipe systems.

Exception: In areas that are subject to freezing or where special conditions exist, dry-pipe systems and preaction systems shall be permitted.

5-1.2 Where dry-pipe systems are used, the ceiling sprinkler areas of operation shall be increased 30 percent over the areas specified by Chapters 6, 7, and 8. Densities and areas shall be selected so that the final area of operation after the 30 percent increase is not greater than 6000 ft^2 (557.4 m^2).

5-1.3 Where preaction systems are used, preaction systems shall be treated as dry-pipe systems.

Exception: This requirement shall not apply where it can be demonstrated that the detection system that activates the preaction system causes water to be discharged from sprinklers as quickly as the discharge from a wet-pipe system.

5-1.4 Detectors for preaction systems shall be installed in accordance with 5-9.3.

5-2 Ceiling Sprinklers.

5-2.1 Where automatic sprinkler systems are installed, they shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Exception: Where modified by this standard.

5-2.2* Standard response $^1/_2$-in. (12.7-mm) orifice or 17/32-in. (13.5-mm) orifice spray sprinklers shall be used where applying the figure curves and tables in Chapters 6, 7, and 8. *(See Chapters 9 and 10 for large-drop and ESFR sprinklers.)*

Exception: The use of $^5/_8$-in. (15.9-mm) or larger orifice spray sprinklers shall be permitted where listed for such use.

5-2.3* The minimum temperature rating of ceiling sprinklers shall be 150°F (66°C).

5-2.4 In buildings that are used in part for rack storage of commodities, the design of the ceiling sprinkler system that is within 15 ft (4.6 m) of the racks shall be the same as that provided for the rack storage area.

Exception: Where separated by a barrier partition that is capable of preventing heat from a fire in the rack storage area from fusing sprinklers in the nonrack storage area.

5-2.5 Where nonstorage spaces in buildings have lower ceilings than storage spaces, the space above the drop ceiling shall be sprinklered. Where the area above a drop ceiling is sprinklered, the sprinkler system shall be in accordance with 5-2.2 or the exception to 5-2.2.

Exception: Spaces above drop ceilings shall not be required to be sprinklered where they comply with NFPA 13, Standard for the Installation of Sprinkler Systems, for allowable unsprinklered concealed spaces.

5-3† Ceiling Sprinkler Spacing. For the purpose of selecting sprinkler spacing in hydraulically designed sprinkler systems using $^1/_2$-in. (12.7-mm) orifice sprinklers or $^{17}/_{32}$-in. (13.5-mm) orifice sprinklers to achieve a stipulated density, 60 psi (413.7 kPa) shall be the maximum discharge pressure used at the calculation starting point.

5-4 In-Rack Sprinklers.

5-4.1 In-Rack Sprinkler System Size. The area protected by a single system of sprinklers in racks (in-rack sprinklers) shall not exceed 40,000 ft^2 (3716 m^2) of floor area occupied by the

racks, including aisles, regardless of the number of intermediate sprinkler levels.

5-4.2* In-Rack Sprinkler System Control Valves. Where sprinklers are installed in racks, separate indicating control valves and drains shall be provided and arranged so that ceiling and in-rack sprinklers can be controlled independently.

Exception No. 1: Independent control shall not be required for the installation of 20 or fewer in-rack sprinklers that are supplied by any one ceiling sprinkler system.

Exception No. 2: The separate indicating valves shall be permitted to be arranged as sectional control valves where the racks occupy only a portion of the area protected by the ceiling sprinklers. (See 5-2.3.)

5-4.3 In-Rack Sprinkler Water Demand. The water demand for sprinklers that are stored in racks shall be added to the ceiling sprinkler water demand at the point of connection. The demand shall be balanced to the higher of the two corresponding pressures.

5-4.4 Obstructions to In-Rack Sprinkler Discharge. The obstruction criteria and requirements for clearance from storage of NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall not apply to in-rack sprinklers.

5-5*† Sprinkler Waterflow Alarm.

5-6† Hose Connections. For first-aid fire fighting and for mop-up operations, small [$1^1/_2$-in. (38-mm)] hose lines shall be available to cover all areas of rack structures. The hose connections shall not be subject to the requirements of Class II hose systems as specified in NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. Hose connections shall be supplied from one of the following:

(a) Outside hydrants
(b) Separate piping system for small hose stations
(c) Valved hose connections on sprinkler risers where such connections are made upstream of all sprinkler control valves
(d) Adjacent sprinkler systems
(e) Ceiling sprinkler system in the same area (as long as in-rack sprinklers are provided in the same area and are separately controlled)

Exception: Hose connections shall not be required for the protection of Classes I, II, III, and IV commodities that are stored at heights of 12 ft (3.7 m) and less.

5-7 Hose Demand.

5-7.1 Where inside (small) hose streams are required, an allowance of at least 100 gpm (379 L/min) shall be added to the sprinkler water demand for all commodities.

5-7.2 For combined inside (small) and outside (large) hose streams, an allowance of at least 500 gpm (1893 L/min) shall be added to the sprinkler water demand for all commodities.

Exception: For Classes I, II, and III commodities that are stored up to 12 ft (3.7 m) and Class IV commodities that are stored up to 10 ft (3.1 m), the hose stream allowance shall be permitted to be reduced to 250 gpm (946 L/min).

5-8† Duration of Water Supplies. For single-row and double-row racks, the water supply duration shall be at least $1^1/_2$ hours for Classes I, II, and III commodities and at least 2 hours for Class IV and Group A plastic commodities. For multiple-row racks, the water supply duration shall be at least 2 hours for all classifications of commodities.

Exception: For Class IV commodities that are stored at heights of 12 ft (3.7 m) or less, the water supply duration shall be permitted to be $1^1/_2$ hours.

5-9 High-Expansion Foam.

5-9.1* Where high-expansion foam systems are installed, they shall be in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, and they shall be automatic in operation.

Exception: Where modified by this standard.

5-9.2 In-rack sprinklers shall not be required where high-expansion foam systems are used in combination with ceiling sprinklers.

5-9.3 Detectors for High-Expansion Foam Systems. Detectors shall be listed and shall be installed in one of the following configurations:

(a) At the ceiling only where installed at one-half the listed linear spacing [e.g., 15 ft × 15 ft (4.6 m × 4.6 m) rather than at 30 ft × 30 ft (9.1 m × 9.1 m)]

Exception: Ceiling detectors alone shall not be used where the ceiling/roof clearance from the top of the storage exceeds 10 ft (3.1 m) or the height of the storage exceeds 25 ft (7.6 m).

(b) At the ceiling at the listed spacing and in racks at alternate levels
(c) Where listed for rack storage installation and installed in accordance with the listing to provide response within 1 minute after ignition using an ignition source that is equivalent to that used in a rack storage testing program

5-9.4 High-Expansion Foam Submergence.

5-9.4.1 Storage of Classes I, II, III, and IV Commodities up to and Including 25 ft (7.6 m) in Height.

5-9.4.1.1* Where high-expansion foam systems are used without sprinklers, the maximum submergence time shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

5-9.4.1.2 Where high-expansion foam systems are used in combination with ceiling sprinklers, the maximum submergence time shall be 7 minutes for Class I, II, or III commodities and 5 minutes for Class IV commodities.

5-9.4.1.3 High-Expansion Foam Ceiling Sprinkler Density. Where high-expansion foam systems are used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.2 L/min)/m^2] for Class I, II, or III commodities or 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (186-m^2) operating area.

5-9.4.2 Storage of Classes I, II, III, and IV Commodities Over 25 ft (7.6 m) in Height.

5-9.4.2.1 Where high-expansion foam systems are used for storage over 25 ft (7.6 m) high up to and including 35 ft (10.7 m) high, they shall be used in combination with ceiling sprinklers. The maximum submergence time for the high-expansion foam shall be 5 minutes for Class I, II, or III commodities and 4 minutes for Class IV commodities.

5-9.4.2.2 Where high-expansion foam is used in combination with ceiling sprinklers, the minimum ceiling sprinkler design density shall be 0.2 gpm/ft^2 [(8.2 L/min)/m^2] for Class I, II, or III commodities and 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class IV commodities for the most hydraulically remote 2000-ft^2 (186-m^2) operating area.

5-10 Solid and Slatted Shelves.

5-10.1*† Slatted shelves shall be considered equivalent to solid shelves.

Exception: A wet-pipe sprinkler system that is designed to provide a minimum of 0.6 gpm/ft^2 density [(24 L/min)/m^2] over a minimum design area of 2000 ft^2 (186 m^2) shall be permitted to protect single-row and double-row slatted-shelf racks where all of the following conditions are met:

(a) Sprinklers shall be $^5/_8$-in. (15.9-mm) orifice spray sprinklers with a temperature rating of ordinary, intermediate, or high and shall be listed for protection of storage occupancies.

(b) The protected commodities shall be limited to Class I, IV, Group B plastics, Group C plastics, cartoned (expanded and unexpanded) group A plastics, and exposed (unexpanded) Group A plastics.

(c) Shelves shall be slatted using a minimum nominal 2-in. (50-mm) thick by maximum nominal 6-in. (150-mm) wide slat held in place by spacers that maintain a minimum 2-in. (50-mm) opening between each slat.

(d) There shall be no slatted shelf levels in the rack above 12 ft (3.7 m). Wire mesh (greater than 50 percent opening) shall be permitted for shelf levels above 12 ft (3.7 m).

(e) Transverse flue spaces at least 3 in. (75 mm) wide shall be provided at least every 10 ft (3.1 m) horizontally.

(f) Longitudinal flue spaces at least 6 in. (150 mm) wide shall be provided for double-row racks.

(g) The aisle widths shall be at least 7.5 ft (2.3 m).

(h) The maximum roof height shall be 27 ft (8.23 m).

(i) The maximum storage height shall be 20 ft (6.1 m).

(j) Solid plywood or similar materials shall not be placed on the slatted shelves so that they block the 2-in. (50.8-mm) spaces between slats, nor shall they be placed on the wire mesh shelves.

5-10.2† Sprinklers shall be installed at the ceiling and beneath each shelf in single-row, double-row, or multiple-row racks with solid shelves that obstruct both longitudinal and transverse flue spaces. Design criteria for combined ceiling and in-rack sprinklers shall be used with such storage configuration.

5-11† Open-Top Combustible Containers.

5-12 Movable Racks. Storage in movable racks shall be protected in the same manner as multiple-row racks.

Chapter 6 Spray Sprinkler Protection for Classes I, II, III, and IV Commodities for Storage up to and Including 25 ft (7.6 m) in Height

Part A General

(See also Chapter 5.)

6-1 General. For Class I through Class IV commodities that are stored at heights of 12 ft (3.7 m) or less, the sprinkler design criteria shall be in accordance with Table 6-1.

Table 6-1 Protection of Class I through Class IV Commodities Stored 12 ft (3.7 m) or Less in Height

Commodity Class	Design Curve
I	OH-1
II up to 8 ft (2.4 m)	OH-1
III over 8 ft (2.4 m) up to 12 ft (3.7 m)	OH-2
III	OH-2
IV up to 10 ft (3.1 m)	OH-2
IV over 10 ft (3.1 m) to 12 ft (3.7 m)	EH-1

6-2 In-Rack Sprinkler Type. Sprinklers in racks shall be ordinary temperature standard response with nominal $^1/_2$-in. (12.7-mm) orifice size, pendent or upright. Sprinklers with intermediate-temperature and high-temperature ratings shall be used near heat sources as required in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

6-3 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of in-rack sprinklers shall be restricted only by hydraulic calculations and not by any piping schedule.

6-4† In-Rack Sprinkler Water Shields. Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers that are equipped with water shields shall be provided where there is more than one level if the in-rack sprinklers are not shielded by horizontal barriers.

6-5 In-Rack Sprinkler Location.

6-5.1*† The elevation of in-rack sprinkler deflectors with respect to storage shall not be a consideration in single-row or double-row rack storage up to and including 20 ft (6.1 m) in height.

6-5.2* In single-row or double-row racks without solid shelves with storage over 20 ft (6.1 m) high, in multiple-row racks, and in single-row or double-row racks with solid shelves and storage height up to and including 25 ft (7.6 m), a minimum 6-in. (152.4-mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Sprinkler discharge shall not be obstructed by horizontal rack members.

6-5.3 In-rack sprinklers at one level only for storage up to and including 25 ft (7.6 m) in height shall be located at the first tier level at or above one-half of the storage height.

6-5.4 In-rack sprinklers at two levels only for storage up to and including 25 ft (7.6 m) in height shall be located at the first tier level at or above one-third and two-thirds of the storage height.

6-6 In-Rack Sprinkler Spacing.

6-6.1* The maximum horizontal spacing of sprinklers in single-row or double-row racks with nonencapsulated storage up to and including 25 ft (7.6 m) in height shall be in accordance with Table 6-6.1.

For encapsulated storage, the maximum horizontal spacing shall be 8 ft (2.4 m).

Table 6-6.1 In-Rack Sprinkler Spacing

Aisle Widths		Commodity Class					
		I and II		III		IV	
ft	m	ft	m	ft	m	ft	m
8	2.4	12	3.7	12	3.7	8	2.4
4	1.2	12	3.7	8	2.4	8	2.4

6-6.2† Sprinklers that are installed in racks shall be spaced without regard to rack uprights.

6-7† In-Rack Sprinkler Discharge Pressure. Sprinklers in racks shall discharge at not less than 15 psi (103.4 kPa) for all classes of commodities.

6-8† In-Rack Sprinkler Water Demand. The water demand for sprinklers that are installed in racks shall be based on the simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, Class II, or Class III commodities
(b) Eight sprinklers where only one level is installed in racks with Class IV commodities
(c) Ten sprinklers (five on each of the two top levels) where more than one level is installed in racks with Class I, Class II, or Class III commodities
(d) Fourteen sprinklers (seven on each of the two top levels) where more than one level is installed in racks with Class IV commodities

Exception: Where a storage rack, due to its length, requires less than the number of in-rack sprinklers specified, only the in-rack sprinklers in a single rack shall be required to be included in the calculation.

6-9*† Ceiling Sprinkler Water Demand. The design curves shown in Figures 6-11(a) through (g) shall apply to nominal 20-ft (6.1-m) storage heights.

6-9.1 The design curves shown in Figures 6-11(a) through (g) indicate water demands for ordinary-temperature-rated and nominal high-temperature-rated sprinklers at the ceiling. The ordinary-temperature design curves that correspond to ordinary-temperature-rated sprinklers shall be used for sprinklers with ordinary- and intermediate-temperature classification. The high-temperature design curves that correspond to high-temperature-rated sprinklers shall be used for sprinklers that have a high-temperature rating.

6-9.2 For storage height up to and including 25 ft (7.6 m) that is protected with ceiling sprinklers only, and for storage height up to and including 20 ft (6.1 m) that is protected with ceiling sprinklers and minimum required in-rack sprinklers, the densities that are obtained from the design curves shown in Figures 6-11(a) through (g) shall be adjusted in accordance with Figure 6-9.2. *(See Table 6-9.2.)*

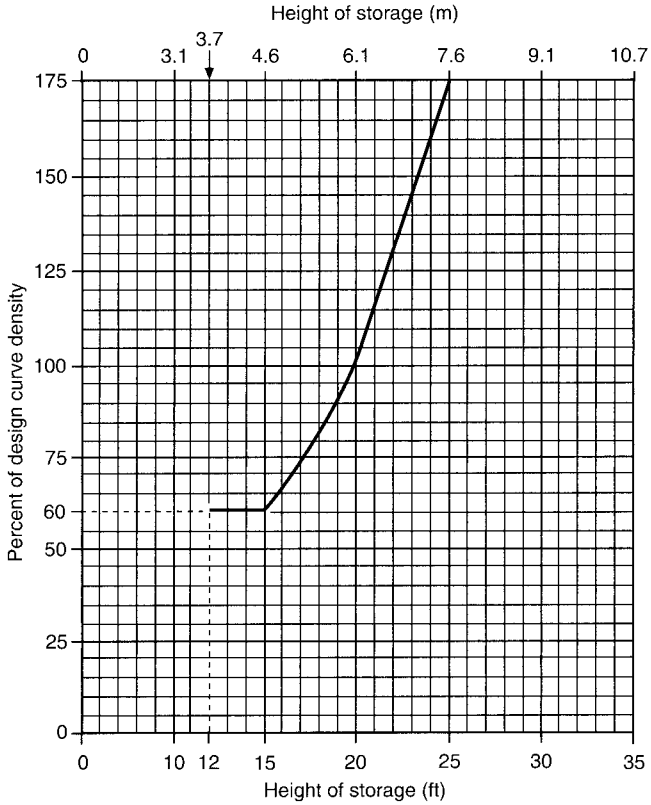


Figure 6-9.2 Ceiling sprinkler density versus storage height.

Table 6-9.2 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

Storage Height	In-Rack Sprinklers	Apply Fig. 6-9.2	Permitted Ceiling Sprinkler Density Adjustments
Over 12 ft (3.7 m) up to and including 25 ft (7.6 m)	None	Yes	None
	Minimum required	Yes	None
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	More than minimum but not in every tier	Yes	Reduce density 20 percent from that of minimum in-rack sprinklers
	In every tier	Yes	Reduce density 40 percent from that of minimum in-rack sprinklers

Table 6-9.2 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers, *Continued*

Storage Height	In-Rack Sprinklers	Apply Fig. 6-9.2	Permitted Ceiling Sprinkler Density Adjustments
Over 20 ft (6.1 m) up to and including 25 ft (7.6 m)	Minimum required	No	None
	More than minimum but not in every tier	No	Reduce density 20 percent from that of minimum in-rack sprinklers
	In every tier	No	Reduce density 40 percent from that of minimum in-rack sprinklers

6-9.3 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) that is protected with ceiling sprinklers and minimum required in-rack sprinklers, the densities that are obtained from the design curves shown in Figures 6-11(a) through (g) shall be used. Densities shall not be adjusted in accordance with Figure 6-9.2. *(See Table 6-9.2.)*

6-9.4 For storage height up to and including 20 ft (6.1 m) that is protected with ceiling sprinklers and with more than one level of in-rack sprinklers, but that is not protected in every tier, the densities that are obtained from the design curves shown in Figures 6-11(a) through (g) and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 20 percent. *(See Table 6-9.2.)*

6-9.5 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) that is protected with ceiling sprinklers and with more than the minimum required level of in-rack sprinklers, but that is not protected in every tier, the densities obtained from the design curves shown in Figures 6-11(a) through (g) shall be permitted to be reduced 20 percent. Densities shall not be adjusted in accordance with Figure 6-9.2. *(See Table 6-9.2.)*

6-9.6 For storage height up to and including 20 ft (6.1 m) that is protected with ceiling sprinklers and in-rack sprinklers at each tier, the densities that are obtained from the design curves shown in Figures 6-11(a) through (g) and adjusted in accordance with Figure 6-9.2 shall be permitted to be reduced an additional 40 percent. *(See Table 6-9.2.)*

6-9.7 For storage height over 20 ft (6.1 m) up to and including 25 ft (7.6 m) that is protected with ceiling sprinklers and in-rack sprinklers at each tier, the densities that are obtained from the design curves in Figures 6-11(a) through (g) shall be permitted to be reduced 40 percent. Densities shall not be adjusted in accordance with Figure 6-9.2. *(See Table 6-9.2.)*

6-9.8† Where clearance from the ceiling to the top of the storage is less than $4^1/_2$ ft (1.37 m) *(see Section 4-5)*, the sprinkler-operating area that is indicated in curves E, F, G, and H in Figures 6-11(a) through (e) shall be permitted to be reduced as indicated in Figure 6-9.8 but shall not be permitted to be reduced to not less than 2000 ft^2 (186 m^2). *(See 6-9.9.)*

6-9.9 Where clearance from the ceiling to the top of Class I or Class II encapsulated storage is $1^1/_2$ ft to 3 ft (0.46 m to 0.91 m), the sprinkler-operating area that is indicated in curve F only of Figure 6-11(e) shall be permitted to be reduced by 50 percent but shall not be permitted to be reduced to less than 2000 ft^2 (186 m^2).

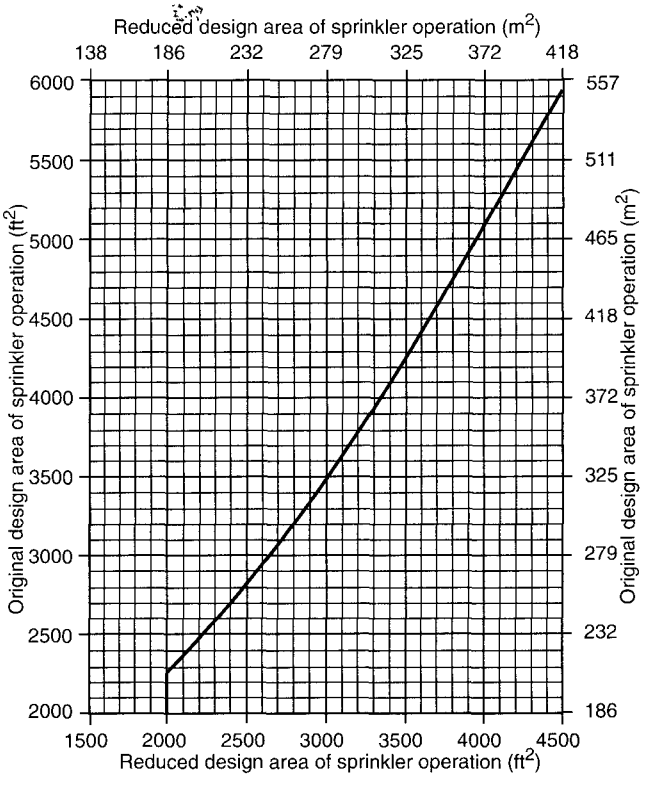


Figure 6-9.8 Adjustment of design area of sprinkler operation for clearance from top of storage to ceiling.

6-9.10 Where solid, flat-bottom, combustible pallets are used with storage height up to and including 25 ft (7.6 m), the densities that are indicated in the design curves shown in Figures 6-11(a) through (g), based on conventional pallets, shall be increased 20 percent for the given area. The percentage shall be applied to the density determined in accordance with Figure 6-9.2. The increase in density shall not apply where in-rack sprinklers are installed.

6-10* Ceiling Sprinkler Discharge Criteria for Plastics Storage. The protection criteria specified in Chapter 8 for Group A plastics shall be permitted to be used to protect the corresponding storage heights and configurations of Classes I, II, III, and IV commodities.

Part B Double- and Single-Row Racks

(See also Chapter 5.)

6-11* Ceiling Sprinkler Water Demand.

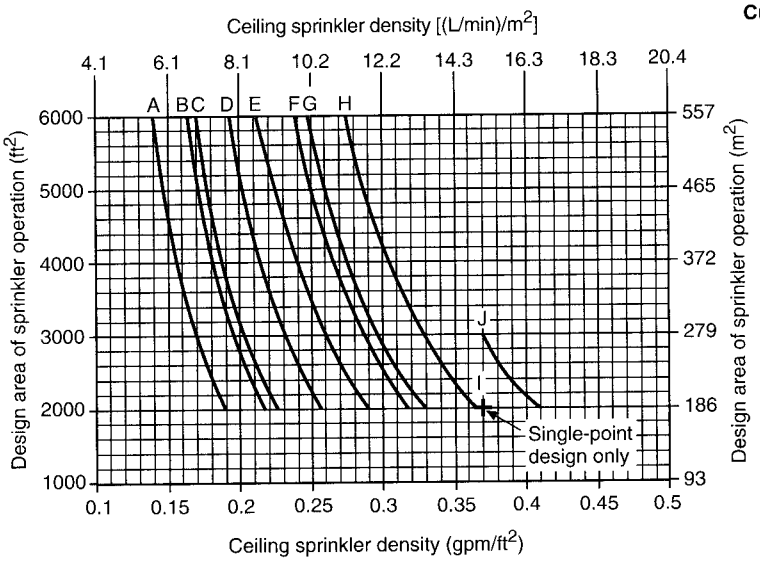
6-11.1 For Class I, Class II, Class III, or Class IV commodities that are encapsulated or nonencapsulated in single-row or double-row racks, ceiling sprinkler water demand in terms of density, in gpm/ft^2 [(L/min)/m^2], and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves shown in Figures 6-11(a) through (g) as specified by Table 6-11. The curves shown in Figures 6-11(a) through (g) also shall apply to portable racks that are arranged in the same manner as single-row, double-row, or multiple-row racks. The design shall be sufficient to satisfy a single point on the curve that corresponds to the storage configuration and commodity class. The design shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust the density for storage height. For SI units, 1 ft = 0.3048 m.

Table 6-11 Single-Row or Double-Row Racks — Storage Height up to and Including 25 ft (7.6 m) without Solid Shelves

			Aisles (4-4.1) (B-6-11.2)			Ceiling Sprinkler Water Demand					
						With In-Rack Sprinklers			Without In-Rack Sprinklers		
Height	Commodity Class	Encapsulated	ft	m	Sprinklers Mandatory In-Rack	Figure	Curves	Apply Figure 6-9.2	Figure	Curves	Apply Figure 6-9.2
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B	Yes	6-11(a)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	III	No	4 8	1.2 2.4	No	6-11(c)	C&D A&B		6-11(c)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(f)	C&D A&B				
	IV	No	4 8	1.2 2.4	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(g)	C&D A&B				
Over 20 ft (6.1 m) up to and including 22 ft (6.7 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B	No	6-11(a)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B				
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B				
	III	No	4 8	1.2 2.4	No	6-11(c)	C&D A&B		6-11(c)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(f)	C&D A&B				
	IV	No	4 8	1.2 2.4	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(g)	C&D A&B				
Over 22 ft (6.7 m), up to and including 25 ft (7.6 m)	I	No	4 8	1.2 2.4	No	6-11(a)	C&D A&B		6-11(a)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B				
	II	No	4 8	1.2 2.4	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4 8	1.2 2.4	One level	6-11(e)	C&D A&B				-

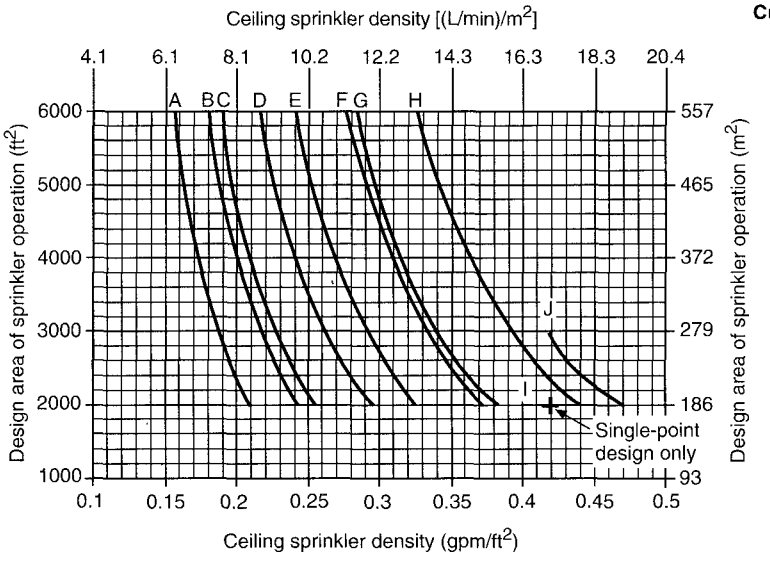
Table 6-11 Single-Row or Double-Row Racks — Storage Height up to and Including 25 ft (7.6 m) without Solid Shelves, *Continued*

Height	Commodity Class	Encapsulated	Aisles (4-4.1) (B-6-11.2) ft	Aisles (4-4.1) (B-6-11.2) m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers Figure	With In-Rack Sprinklers Curves	With In-Rack Sprinklers Apply Figure 6-9.2	Without In-Rack Sprinklers Figure	Without In-Rack Sprinklers Curves	Without In-Rack Sprinklers Apply Figure 6-9.2
	III	No	4	1.2	No	6-11(c)	C&D		6-11(c)	G&H	Yes
			8	2.4			A&B			E&F	
		Yes	4	1.2	One level	6-11(f)	C&D				
			8	2.4			A&B				
	IV	No	4	1.2		6-11(d)	C&D	No			
			8	2.4	One level		A&B				
		Yes	4	1.2		6-11(g)	C&D				
			8	2.4			A&B				



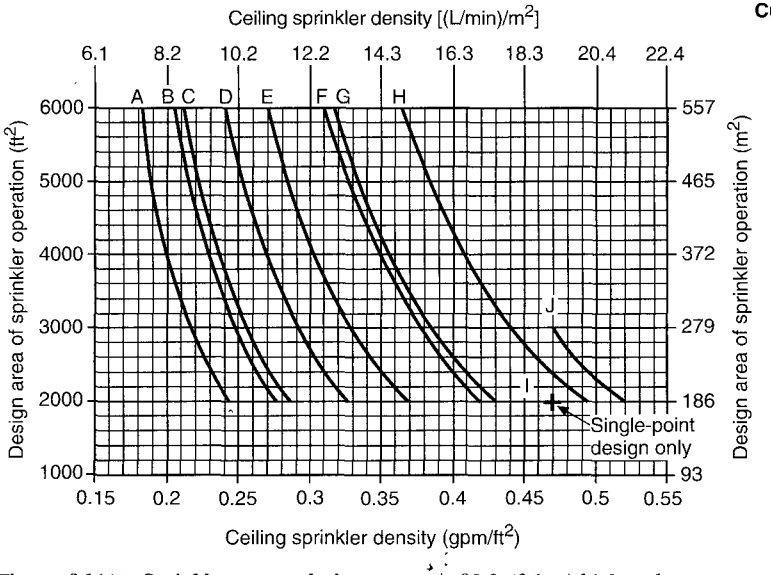
Curve	Legend
A	Single- or double-row racks with 8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	Single- or double-row racks with 8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	Single- or double-row racks with 8-ft (2.4-m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 4-ft (1.2-m) aisles and high-temperature ceiling sprinklers
G	Single- or double-row racks with 8-ft (2.4-m) aisles and ordinary-temperature ceiling sprinklers
H	Single- or double-row racks with 4-ft (1.2-m) aisles and ordinary-temperature ceiling sprinklers
I	Multiple-row racks with 8-ft (2.4-m) or wider aisles and high-temperature ceiling sprinklers
J	Multiple-row racks with 8-ft (2.4-m) or wider aisles and ordinary-temperature ceiling sprinklers

Figure 6-11(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.



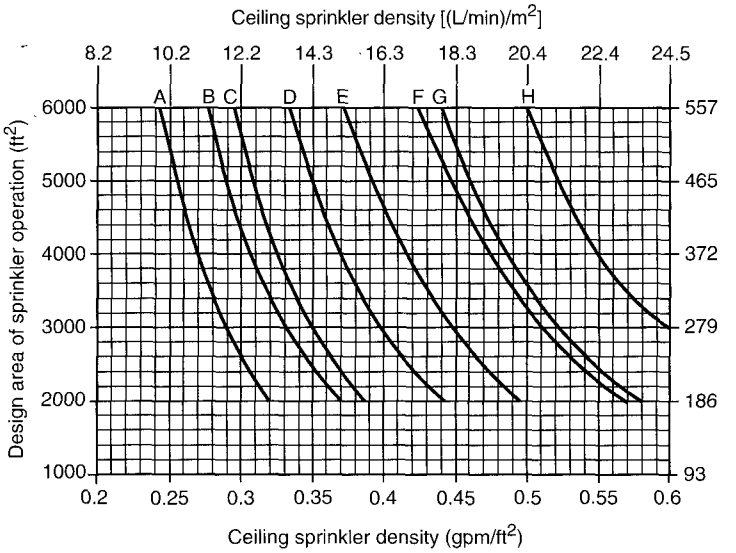
Curve	Legend	Curve	Legend
A	Single- or double-row racks with 8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	E	Single- or double-row racks with 8-ft (2.4-m) aisles and high-temperature ceiling sprinklers
B	Single- or double-row racks with 8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	F	Single- or double-row racks with 8-ft (2.4-m) aisles and ordinary-temperature ceiling sprinklers
C	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	G	Single- or double-row racks with 4-ft (1.2-m) aisles and high-temperature ceiling sprinklers
D	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	H	Single- or double-row racks with 4-ft (1.2-m) aisles and ordinary-temperature ceiling sprinklers
		I	Multiple-row racks with 8-ft (2.4-m) or wider aisles and high-temperature ceiling sprinklers
		J	Multiple-row racks with 8-ft (2.4-m) or wider aisles and ordinary-temperature ceiling sprinklers

Figure 6-11(b) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class II nonencapsulated commodities — conventional pallets.



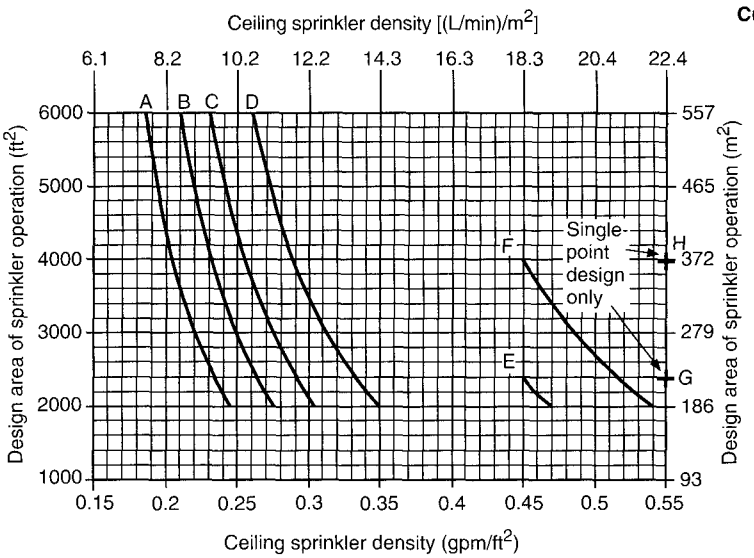
Curve	Legend	Curve	Legend
A	Single- or double-row racks with 8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	E	Single- or double-row racks with 8-ft (2.4-m) aisles and high-temperature ceiling sprinklers
B	Single- or double-row racks with 8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	F	Single- or double-row racks with 8-ft (2.4-m) aisles and ordinary-temperature ceiling sprinklers
C	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	G	Single- or double-row racks with 4-ft (1.2-m) aisles and high-temperature ceiling sprinklers
D	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers	H	Single- or double-row racks with 4-ft (1.2-m) aisles and ordinary-temperature ceiling sprinklers
		I	Multiple-row racks with 8-ft (2.4-m) or wider aisles and high-temperature ceiling sprinklers
		J	Multiple-row racks with 8-ft (2.4-m) or wider aisles and ordinary-temperature ceiling sprinklers

Figure 6-11(c) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class III nonencapsulated commodities — conventional pallets.



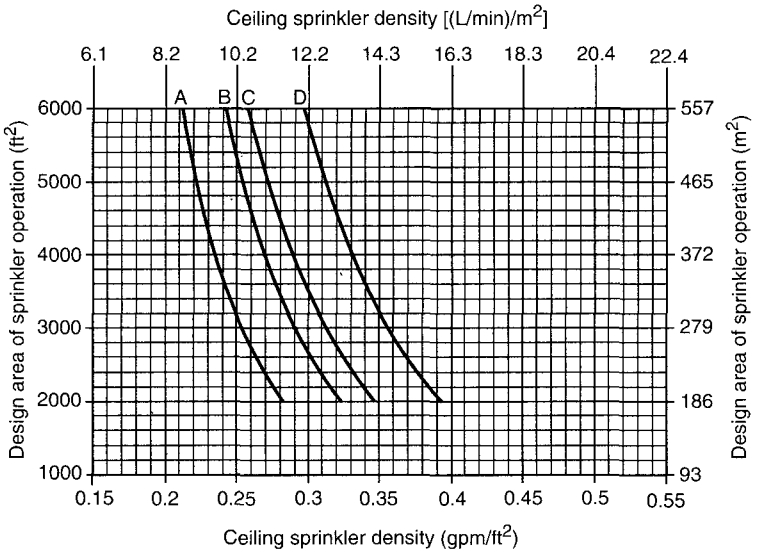
Curve	Legend
A	Single- or double-row racks with 8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	Single- or double-row racks with 8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	Single- or double-row racks with 4-ft (1.2-m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	Single- or double-row racks with 8-ft (2.4-m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 8-ft (2.4-m) aisles and ordinary-temperature ceiling sprinklers
G	Single- or double-row racks with 4-ft (1.2-m) aisles and high-temperature ceiling sprinklers
H	Single- or double-row racks with 4-ft (1.2-m) aisles and ordinary-temperature ceiling sprinklers

Figure 6-11(d) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.



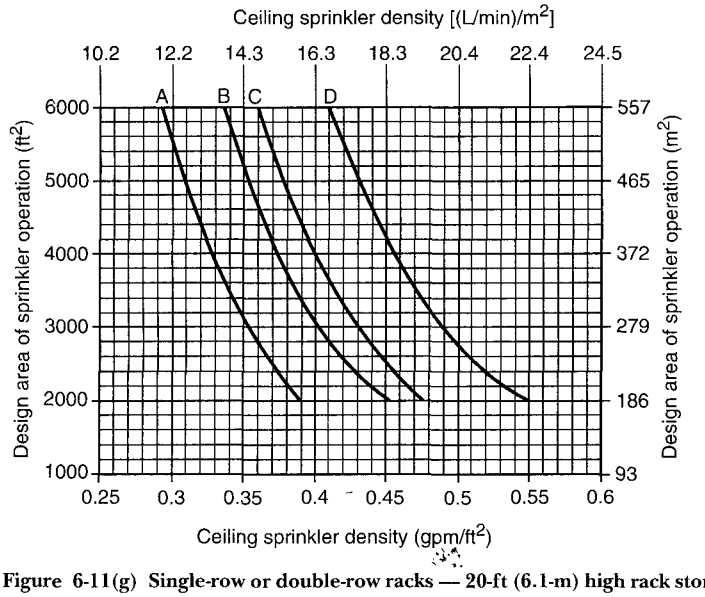
Curve	Legend
A	8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	4-ft (1.2-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	4-ft (1.2-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	8-ft (2.4-m) aisles with high-temperature ceiling sprinklers
F	8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers
G	4-ft (1.2-m) aisles with high-temperature ceiling sprinklers
H	4-ft (1.2-m) aisles with ordinary-temperature ceiling sprinklers

Figure 6-11(e) Single-row or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Classes I and II encapsulated commodities — conventional pallets.



Curve	Legend
A	8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	4-ft (1.2-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	4-ft (1.2-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

Figure 6-11(f) Single-row or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class III encapsulated commodities — conventional pallets.



Curve	Legend
A	8-ft (2.4-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	8-ft (2.4-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	4-ft (1.2-m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	4-ft (1.2-m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers

Figure 6-11(g) Single-row or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class IV encapsulated commodities — conventional pallets.

6-11.2† Design curves for single-row and double-row racks shall be selected to correspond to aisle width. For aisle widths between 4 ft and 8 ft (1.2 m and 2.4 m), a direct linear interpolation between curves shall be made. The density given for 8-ft (2.4-m) wide aisles shall be applied to aisles wider than 8 ft (2.4 m). The density given for 4-ft (1.2-m) wide aisles shall be applied to aisles that are narrower than 4 ft (1.2 m) down to $3^1/_2$ ft (1.1 m). Where aisles are narrower than $3^1/_2$ ft (1.1 m), racks shall be considered to be multiple-row racks.

6-12 In-Rack Sprinkler Location. In single-row or double-row racks without solid shelves, in-rack sprinklers shall be installed in accordance with Table 6-11.

Part C Multiple-Row Racks

(See also Chapter 5.)

6-13† In-Rack Sprinkler Location.

6-13.1 For encapsulated or nonencapsulated storage in multiple-row racks that are no deeper than 16 ft (4.9 m) with aisles 8 ft (2.4 m) or wider, in-rack sprinklers shall be installed in accordance with Table 6-13.1.

6-13.2 For encapsulated or nonencapsulated storage in multiple-row racks that are deeper than 16 ft (4.9 m), or with aisles less than 8 ft (2.4 m) wide, in-rack sprinklers shall be installed in accordance with Table 6-13.2

Table 6-13.1 Multiple-Row Racks — Rack Depth up to and Including 16 ft (4.9 m), Aisles 8 ft (2.4 m) or Wider Storage Height up to 25 ft (7.6 m)

				Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density
Over 12 ft (3.7 m) up to and including 15 ft (4.6 m)	I	No	No	6-11(a)	C&D	Yes	No	6-11(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No		6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No	No	6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes				
	IV	No	No	6-11(d)			No	6-11(d)	C&D	No	No
		Yes	One level	6-11(d)	A&B		1.50 × density				
Over 15 ft (4.6 m) up to and including 20 ft (6.1 m)	I	No	No	6-11(a)	C&D	Yes	No	6.12(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No		6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No	No	6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes				
	IV	No	One level	6-11(d)			No				
		Yes		6-11(d)	A&B		1.50 × density				
Over 20 ft (6.1 m) up to and including 25 ft (7.6 m)	I	No	No	6-11(a)		No	No	6-11(a)	I&J	Yes	No
		Yes	One level	6-11(a)			Yes				
	II	No		6-11(b)			No				
		Yes	One level	6-11(b)	C&D		Yes				
	III	No		6-11(c)			No				
		Yes		6-11(c)			Yes				
	IV	No	Two levels	6-11(d)			No				
		Yes		6-11(d)	A&B		1.50 × density				

Table 6-13.2 Multiple-Row Racks — Rack Depth over 16 ft (4.9 m) or Aisles Narrower than 8 ft (2.4 m) — Storage Height up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Sprinklers Mandatory In-Racks	Ceiling Sprinkler Water Demand							
				With In-Rack Sprinklers				Without In-Rack Sprinklers			
				Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density	Figure No.	Curves	Apply Figure 6-9.2	1.25 × Density
Over 12 ft (3.7 m) up to and including 15 ft (4.6 m)	I	No		6-11(a)	C&D	Yes	No	6-11(a)	I&J	Yes	No
		Yes		6-11(a)			Yes	6-11(a)	I&J		Yes
	II	No	No	6-11(b)			No	6-11(b)	I&J	Yes	No
		Yes		6-11(b)			Yes	6-11(b)	I&J		Yes
	III	No		6-11(c)			No	6-11(c)	I&J	Yes	No
		Yes	One level	6-11(c)			Yes				
	IV	No	No	6-11(d)			No	6-11(d)	C&D	No	No
		Yes	One level	6-11(d)			1.50 × density				
Over 15 ft (4.6 m) up to and including 20 ft (6.1 m)	I	No		6-11(a)	C&D	Yes	No				
		Yes		6-11(a)			Yes				
	II	No		6-11(b)			No				
		Yes	One level	6-11(b)			Yes				
	III	No		6-11(c)			No				
		Yes		6-11(c)			Yes				
	IV	No		6-11(d)			No				
		Yes		6-11(d)			1.50 × density				
Over 20 ft (6.1 m) up to and including 25 ft (7.6 m)	I	No		6-11(a)	C&D	No	No				
		Yes		6-11(a)			Yes				
	II	No	One level	6-11(b)			No				
		Yes		6-11(b)			Yes				
	III	No		6-11(c)			No				
		Yes		6-11(c)			Yes				
	IV	No	Two levels	6-11(d)			No				
		Yes		6-11(d)			1.50 × density				

6-13.3* The maximum horizontal spacing of sprinklers on branch lines, in multiple-row racks with encapsulated or nonencapsulated storage up to and including 25 ft (7.6 m) in height, shall not exceed 12 ft (3.7 m) for Class I, Class II, or Class III commodities and 8 ft (2.4 m) for Class IV commodities. Area limitations shall be 100 ft^2 (9.29 m^2) per sprinkler for Class I, Class II, or Class III commodities and 80 ft^2 (7.43 m^2) per sprinkler for Class IV commodities. The rack plan view shall be considered in determining the area covered by each sprinkler. The aisles shall not be included in area calculations.

6-13.4 A minimum of 6 in. (152.4 mm) shall be maintained between the sprinkler deflector and the top of a tier of storage.

6-14 Ceiling Sprinkler Water Demand.

6-14.1 For nonencapsulated Class I, Class II, Class III, or Class IV commodities, ceiling sprinkler water demand in terms of density, in gpm/ft^2 [(L/min)/m^2], and area of sprinkler operation [ft^2 (m^2) of ceiling or roof] shall be selected from the curves shown in Figures 6-11(a) through (d). The curves shown in Figures 6-11(a) through (d) also shall apply to portable racks that are arranged in the same manner as single-row, double-row, or multiple-row racks. The design shall be sufficient to satisfy a single point on the curve that corresponds to the storage configuration and commodity class. The design shall not be required to meet all points on the selected curve. Figure 6-9.2 shall be used to adjust the density for storage height unless otherwise specified. *(See A-6-6.1 and A-6-11.)*

6-14.2 For encapsulated Class I, Class II, or Class III commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated commodities on multiple-row racks.

6-14.3 For encapsulated Class IV commodities with storage height up to and including 25 ft (7.6 m) on multiple-row racks, ceiling sprinkler density shall be 50 percent greater than for nonencapsulated commodities on double-row racks.

Chapter 7 Spray Sprinkler Protection for Classes I, II, III, and IV Commodities for Storage over 25 ft (7.6 m) in Height

Part A General

7-1 In-Rack Sprinkler Type. Sprinklers in racks shall be ordinary temperature standard response classification with nominal $^{1}/_{2}$-in. or $^{17}/_{32}$-in. (12.7-mm or 13.5-mm) orifice size, pendent or upright. Sprinklers with intermediate-temperature and high-temperature ratings shall be used near heat sources as required in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Exception: Quick-response sprinklers shall be permitted to be installed in racks.

7-2 In-Rack Sprinkler Spacing. In-rack sprinklers shall be staggered horizontally and vertically where installed in accordance with Table 7-8.1, Figures 7-8.1(a) through (j), and Figures 7-8.3(a) through (e).

7-3 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of in-rack sprinklers shall be restricted only by hydraulic calculations and not by any piping schedule.

7-4 In-Rack Sprinkler Water Shields. Water shields shall be provided directly above in-rack sprinklers, or listed sprinklers that are equipped with water shields shall be provided where there is more than one level if the sprinklers are not shielded by horizontal barriers. *(See B-6-4.)*

7-5 In-Rack Sprinkler Location. In single-row, double-row, or multiple-row racks, a minimum 6-in. (152.4-mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage. Face sprinklers in such racks shall be located a minimum of 3 in. (76.2 mm) from rack uprights and no more than 18 in. (460 mm) from the aisle face of storage. Longitudinal flue in-rack sprinklers shall be located at the intersection of the longitudinal and transverse flue spaces and with the deflector located above or below adjacent horizontal rack members. Such in-rack sprinklers shall be located a minimum of 3 in. (76.2 mm) from rack uprights and at least 50 percent of the sprinkler shall be located within the plan view area of the transverse or longitudinal flue space, as appropriate.

7-6 In-Rack Sprinkler Discharge. Sprinklers in racks shall discharge at a rate not less than 30 gpm (113.6 L/min) for all classes of commodities. *(See B-6-8.)*

7-7 In-Rack Sprinkler Water Demand.

7-7.1 The water demand for sprinklers that are installed in racks shall be based on the simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Six sprinklers where only one level is installed in racks with Class I, Class II, or Class III commodities

(b) Eight sprinklers where only one level is installed in racks with Class IV commodities

(c) Ten sprinklers (five on each of the two top levels) where more than one level is installed in racks with Class I, Class II, or Class III commodities

(d) Fourteen sprinklers (seven on each of the two top levels) where more than one level is installed in racks with Class IV commodities

Part B Double-Row and Single-Row Racks

7-8 In-Rack Sprinkler Location.

7-8.1* In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of the storage and the ceiling, in-rack sprinklers shall be installed in accordance with Table 7-8.1 and Figures 7-8.1(a) through (j). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of the storage. *(See Section 7-9.)*

Where a single-row rack is mixed with double-row racks, Table 7-8.1 and Figures 7-8.1(a) through (j) shall be used.

Exception: Figures 7-8.3(a) through (c) shall be permitted to be used for the protection of the single-row racks.

7-8.2 In-rack sprinklers for storage that is higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and shall be located in the horizontal space that is nearest to the vertical intervals that are specified in Table 7-8.1 and Figures 7-8.1(a) through (j).

7-8.3* In single-row racks without solid shelves, with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of the storage and the ceiling, sprinklers shall be installed in accordance with Figures 7-8.3(a) through (e).

In single-row racks, where Figures 7-8.3(a) through (e) show in-rack sprinklers in transverse flue spaces that are centered between the rack faces, the in-rack sprinklers shall be permitted to be positioned in the transverse flue at any point between the load faces.

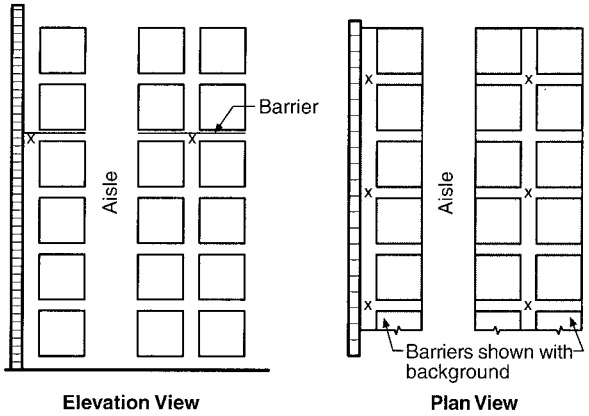
Table 7-8.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider

Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft^2	m^2	gpm/ft^2	L/min^2	gpm/ft^2	L/min^2
I	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m) under horizontal barriers	None	7-8.1(a)	30 ft (9.1 m)	No	2000	186	0.25	10.2	0.35	14.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-8.1(b)	Higher than 25 ft (7.6 m)	Yes			0.25	10.2	0.35	14.3
I, II, III	Vertical 10 ft (3.1 m) or at 15 and 25 Horizontal 10 ft (3.1 m)	None	7-8.1(c)	30 ft (9.1 m)	Yes			0.3	12.2	0.4	16.3
	Vertical 10 ft (3.1 m) Horizontal 10 ft (3.1 m)	Vertical 30 ft (9.1 m) Horizontal 10 ft (3.1 m)	7-8.1(d)		Yes			0.3	12.2	0.4	16.3
	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-8.1(e)		Yes			0.3	12.2	0.4	16.3
	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	Vertical 25 ft (7.6 m) Horizontal 5 ft (1.5 m)	7-8.1(f)	Higher than 25 ft (7.6 m)	No			0.3	12.2	0.4	16.3

Table 7-8.1 Double-Row Racks without Solid Shelves — Storage Higher than 25 ft (7.6 m), Aisles 4 ft (1.2 m) or Wider, *Continued*

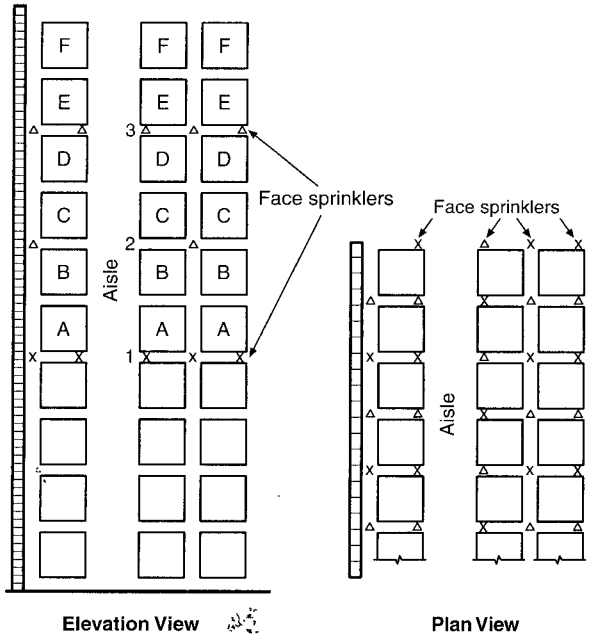
Commodity Class	In-Rack Sprinklers — Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[1,2,3]		Figure No.	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance up to 10 ft[4,5,6]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[7]	Face[8,9]				ft²	m²	gpm/ft²	L/min²	gpm/ft²	L/min²
I, II, III, IV	Horizontal barriers at 20 ft (6.1 m) Vertical intervals — 2 lines of sprinklers under barriers — maximum horizontal spacing 10 ft (3.1 m) staggered		7-8.1(g)	Higher than 25 ft (7.6 m)	Yes	2000	186	0.3	12.2	0.4	16.3
	Vertical 15 ft (4.6 m) Horizontal 10 ft (3.1 m)	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m)	7-8.1(h)		Yes			0.35	14.3	0.45	18.3
	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)	7-8.1(i)		No			0.35	14.3	0.45	18.3
	Horizontal barriers at 15 ft (4.6 m) Vertical intervals — 2 lines of sprinkler under barriers — maximum horizontal spacing 10 ft (3.1 m) staggered		7-8.1(j)		Yes			0.35	14.3	0.45	18.3

[1]Minimum in-rack sprinkler discharge, 30 gpm (114 L/min) *(see Section 7-6).*
[2]Water shields required *(see Sections 6-4 and 7-4).*
[3]All in-rack sprinkler spacing dimensions start from the floor.
[4]For encapsulated commodity, increase density 25 percent *(see 7-10.2).*
[5]Clearance is distance between top of storage and ceiling.
[6]See A-7-8.3, A-7-9, and A-7-10.1 for protection recommendations where clearance is greater than 10 ft (3.1 m).
[7]Install Sprinklers at least 3 in. (76.2 mm) from uprights *(see Section 7-5).*
[8]Face sprinklers shall not be required for a Class I commodity consisting of noncombustible products on wood pallets (without combustible containers), except for arrays shown in Figures 7-8.1(g) and (j).
[9]In Figures 7-8.1(a) through (j), each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. (0.45 m) to 10 ft (3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.



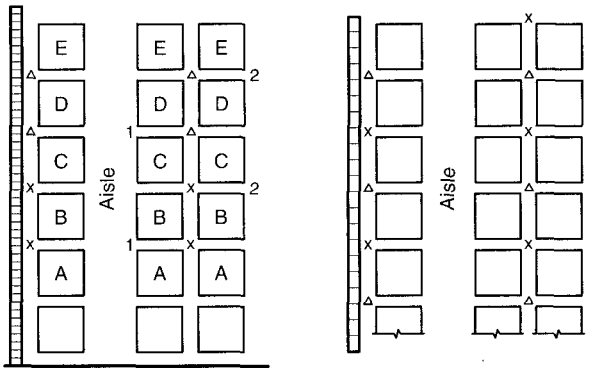
Note: X represents in-rack sprinklers.

Figure 7-8.1(a) In-rack sprinkler arrangement, Class I commodities, storage height 25 ft to maximum 30 ft (7.6 m to maximum 9.1 m).



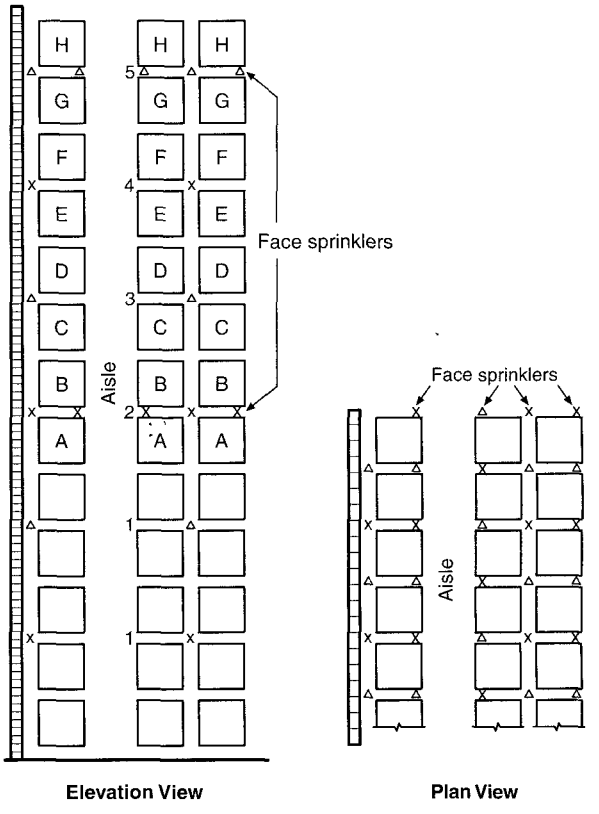
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than that represented by loads labeled F, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated, with stagger as indicated.
5. Δ and X represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(b) In-rack sprinkler arrangement, Class I commodities, storage height over 25 ft (7.6 m).



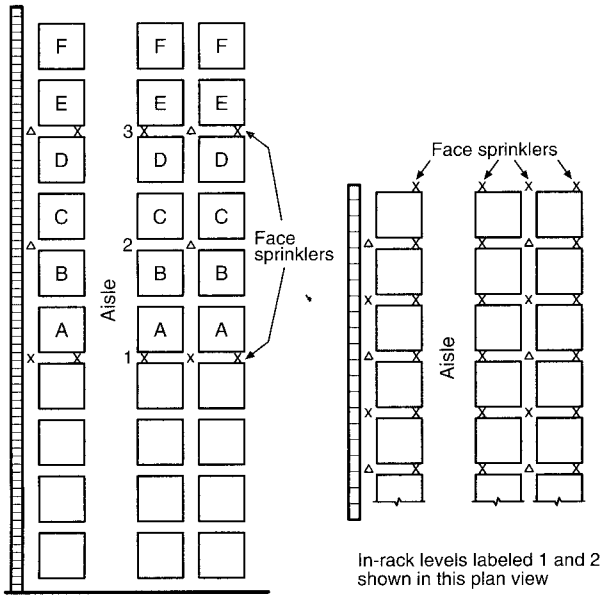
Notes:
1. Alternate location of in-rack sprinklers: sprinklers labeled 1 shall be permitted to be installed above loads A and C or sprinklers labeled 2 above loads B and D.
2. Δ and X represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(c) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height 25 ft to maximum 30 ft (7.6 m to maximum 9.1 m).



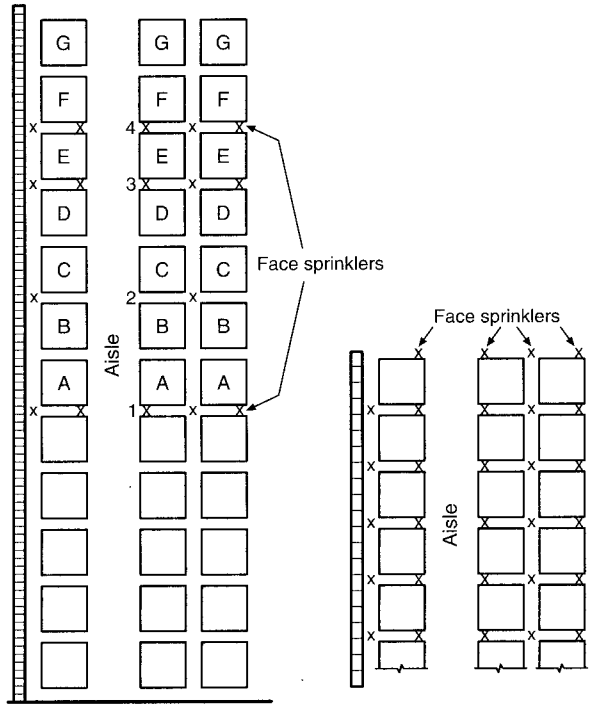
Notes:
1. Sprinklers labeled 1 shall be required where loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled B or C represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled D or E represent top of storage.
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 that represented by loads labeled H, the pattern for locating in-rack sprinklers as specified by Notes 3, 4, and 5 shall be repeated, with stagger as indicated.
7. Face sprinklers shall be permitted to be omitted where the commodit consists of unwrapped or unpackaged metal parts on wood pallets.
8. Δ and X represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(d) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



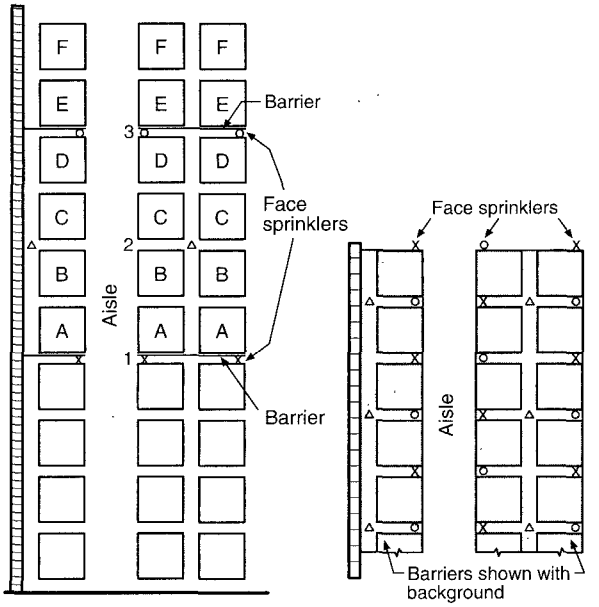
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than that represented by loads labeled F, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated, with stagger as indicated.
5. Δ and X represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(e) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



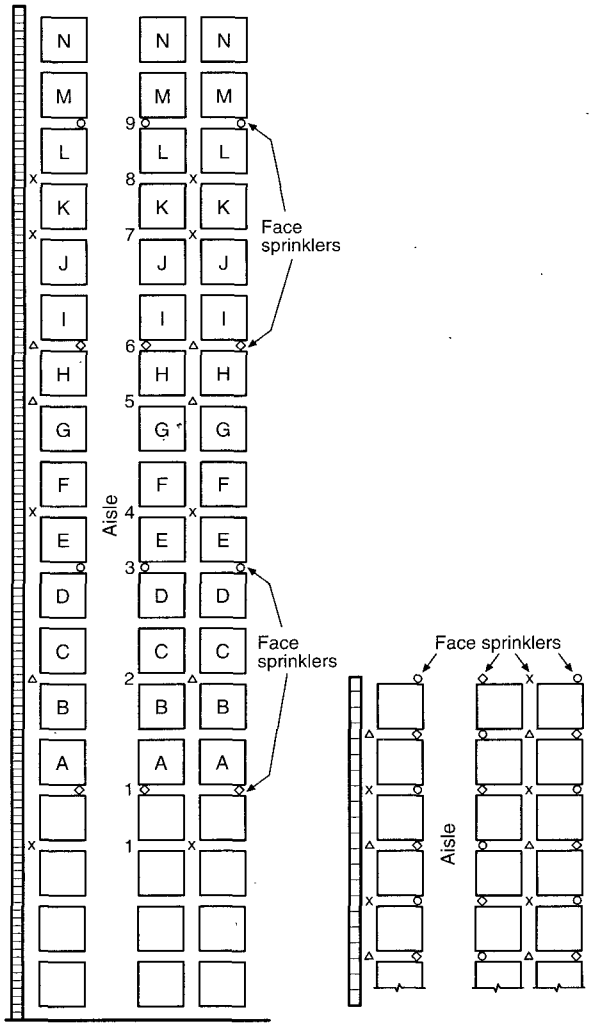
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E represent top of storage.
4. Sprinklers labeled 1 and 4 shall be required where loads labeled F or G represent top of storage.
5. For storage higher than that represented by loads labeled G, the pattern for locating in-rack sprinklers as specified by Notes 2, 3, and 4 shall be repeated.
6. X represents face and in-rack sprinklers.

Figure 7-8.1(f) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



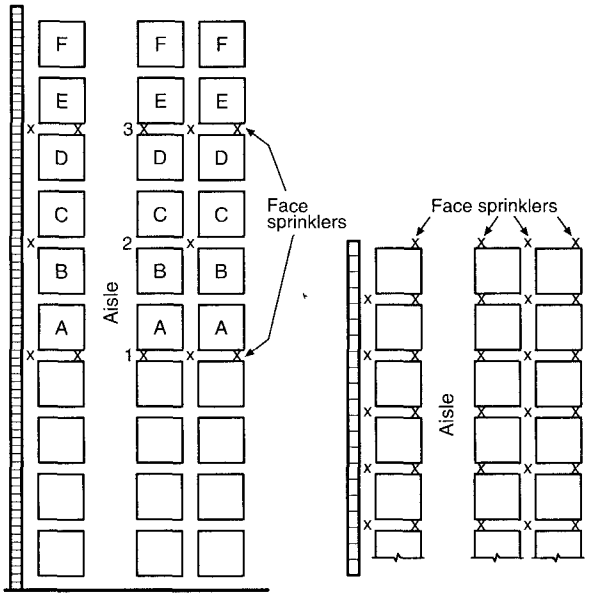
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than that represented by loads labeled F, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated.
5. O, Δ, and X represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(g) In-rack sprinkler arrangement, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



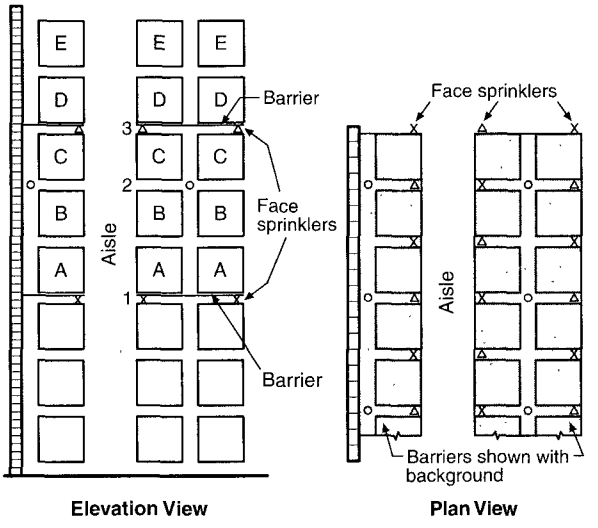
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled E or F represent top of storage.
4. Sprinklers labeled 1, 2, 3, and 4 shall be required where loads labeled 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. Sprinklers labeled 1, 2, 3, 4, and 6 (not 5) shall be required where loads labeled I or J represent top of storage.
7. Sprinklers labeled 1, 2, 3, 4, 6, and 7 shall be required where loads labeled K represent top of storage.
8. Sprinklers labeled 1, 2, 3, 4, 6, and 8 shall be required where loads labeled L represent top of storage.
9. Sprinklers labeled 1, 2, 3, 4, 6, 8, and 9 shall be required where loads labeled M or N represent top of storage.
10. For storage higher than that represented by loads labeled N, the pattern for locating in-rack sprinklers as specified by Notes 1 through 9 shall be repeated, with stagger as indicated. In the pattern, loads labeled M are equivalent to loads labeled A.
11. O, X, and Δ represent sprinklers on vertical or horizontal stagger.

Figure 7-8.1(h) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).



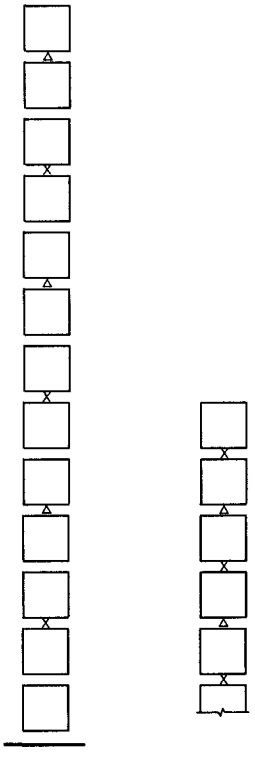
Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C or D represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled E or F represent top of storage.
4. For storage higher than that represented by loads labeled F, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated.
5. X represents face and in-rack sprinklers.

Figure 7-8.1(i) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).



Notes:
1. Sprinklers labeled 1 (the selected array from Table 7-8.1) shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barrier labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than that represented by loads labeled E, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated.
5. Δ and X represent sprinklers on vertical or horizontal stagger.
6. O represents longitudinal flue space sprinklers.

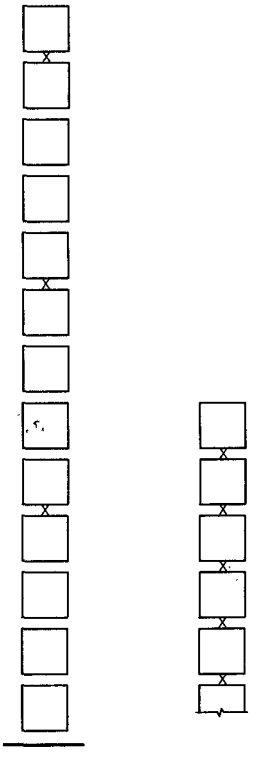
Figure 7-8.1(j) In-rack sprinkler arrangement, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).



Elevation View Plan View

Notes:
1. For all storage heights, sprinklers shall be installed in every other tier and staggered as indicated.
2. Δ and X indicate sprinklers on vertical or horizontal stagger.
3. Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

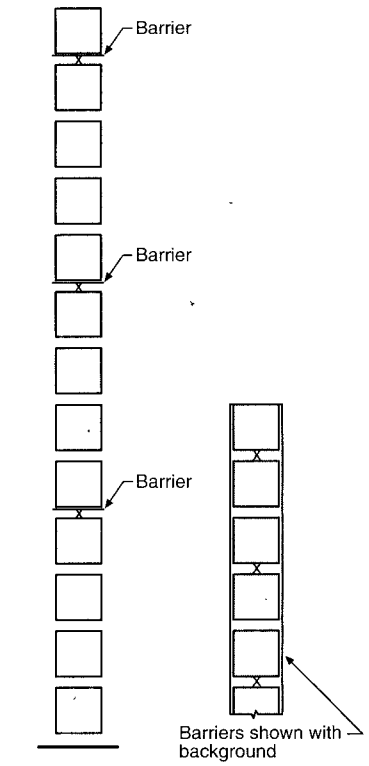
Figure 7-8.3(a) In-rack sprinkler arrangement, single-row racks, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m)



Elevation View Plan View

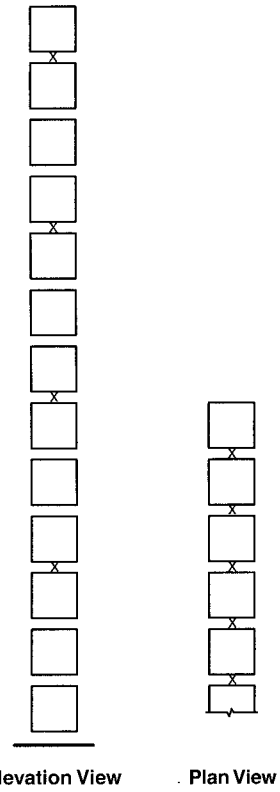
Note: Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-8.3(b) In-rack sprinkler arrangement, single-row racks, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



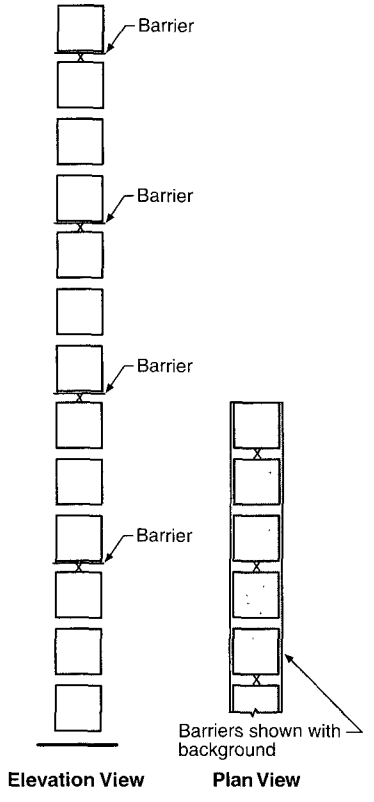
Note: Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-8.3(c) In-rack sprinkler arrangement, single-row racks, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



Note: Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-8.3(d) In-rack sprinkler arrangement, single-row racks, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).



Note: Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-8.3(e) In-rack sprinkler arrangement, single-row racks, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).

7-9* Horizontal Barriers and In-Rack Sprinklers. Horizontal barriers that are used in conjunction with in-rack sprinklers to impede vertical fire development shall be constructed of sheet metal, wood, or similar material and shall extend the full length and width of the rack. Barriers shall be fitted within 2 in. (50.8 mm) horizontally around rack uprights. *[See Table 7-8.1, Figures 7-8.1(a), (g), and (j), and Figures 7-8.3(c) and (e).]*

7-10 Ceiling Sprinkler Water Demand.

7-10.1*† The ceiling sprinkler water demand for nonencapsulated storage on racks without solid shelves that are separated by aisles at least 4 ft (1.2 m) wide, with not more than 10 ft (3.1 m) between the top of the storage and the sprinklers, shall be based on a 2000-ft^2 (186-m^2) sprinkler-operating area. Sprinklers shall discharge a minimum of 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class I commodities; 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Classes II and III commodities; and 0.35 gpm/ft^2 [(14.3 L/min)/m^2] for Class IV commodities for ordinary-temperature-rated sprinklers. Discharge shall be a minimum of 0.35 gpm/ft^2 [(14.3 L/min)/m^2] for Class I commodities; 0.40 gpm/ft^2 [(16.3 L/min)/m^2] for Classes II and III commodities; and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities for high-temperature-rated sprinklers. *(See Table 7-8.1.)*

7-10.2 Where storage as described in 7-10.1 is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.

Part C Multiple-Row Racks

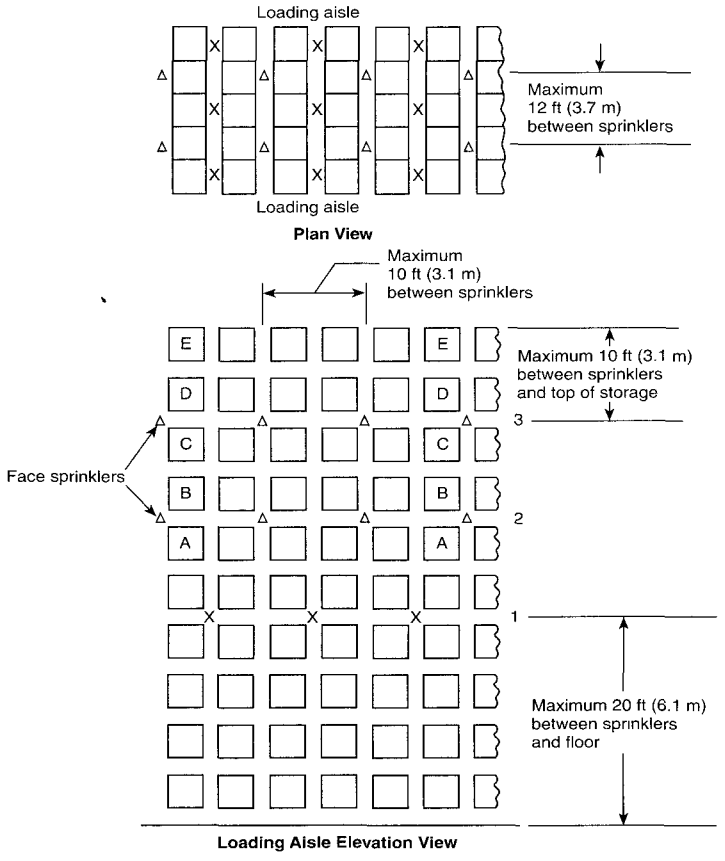
7-11* In-Rack Sprinkler Location. In multiple-row racks with a maximum of 10 ft (3.1 m) between the top of the storage and the ceiling, in-rack sprinklers shall be installed as specified in Figures 7-11(a), (b), and (c). The highest level of in-rack sprinklers shall not be more than 10 ft (3.1 m) below the maximum storage height for Class I, Class II, or Class III commodities and shall not be more than 5 ft (1.5 m) below the top of storage for Class IV commodities. *(See Table 7-11.)*

7-12 In-Rack Sprinkler Spacing. The maximum horizontal spacing of sprinklers in multiple-row racks with storage higher than 25 ft (7.6 m) shall be in accordance with Figures 7-11(a), (b), and (c).

7-13 Ceiling Sprinkler Water Demand.

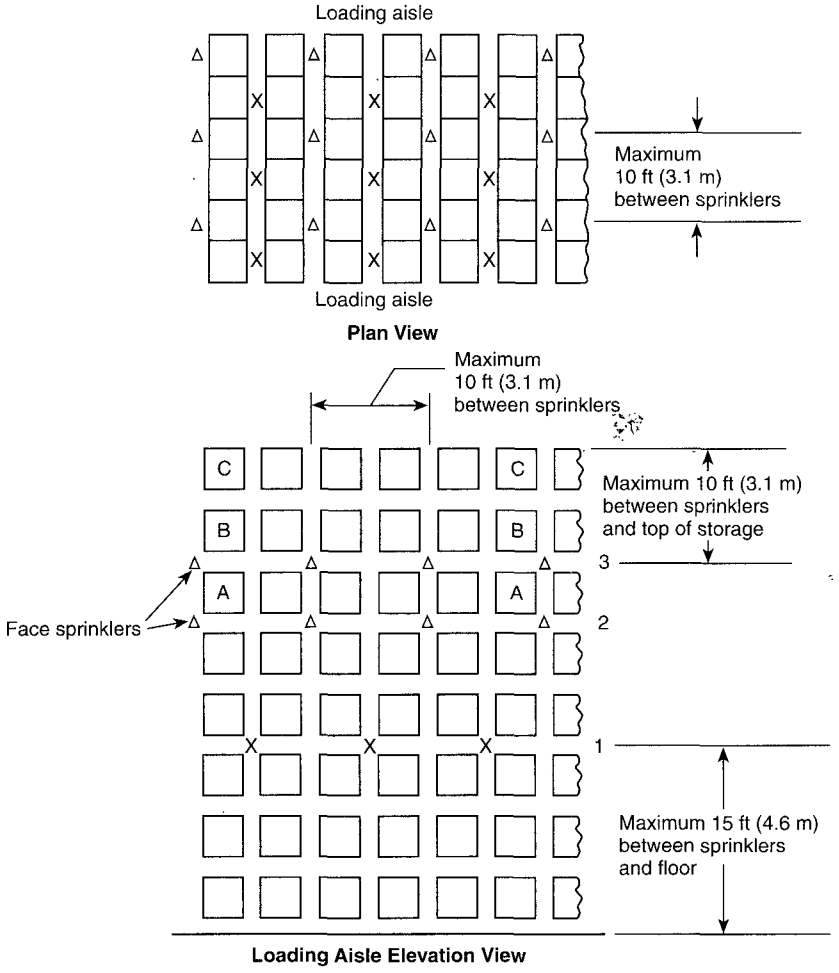
7-13.1 The ceiling sprinkler water demand for nonencapsulated storage on racks without solid shelves that are separated by aisles at least 4 ft (1.2 m) wide, with not more than 10 ft (3.1 m) between the top of the storage and the sprinklers, shall be based on a 2000-ft^2 (186-m^2) sprinkler-operating area for multiple-row racks. Sprinklers shall discharge a minimum of 0.25 gpm/ft^2 [(10.2 L/min)/m^2] for Class I commodities; 0.3 gpm/ft^2 [(12.2 L/min)/m^2] for Classes II and III commodities; and 0.35 gpm/ft^2 [(14.3 L/min)/m^2] for Class IV commodities for ordinary-temperature-rated sprinklers. Discharge shall be a minimum of 0.35 gpm/ft^2 [(14.3 L/min)/m^2] for Class I commodities; 0.40 gpm/ft^2 [(16.3 L/min)/m^2] for Classes II and III commodities; and 0.45 gpm/ft^2 [(18.3 L/min)/m^2] for Class IV commodities for high-temperature-rated sprinklers. *(See Table 7-11.)*

7-13.2 Where storage is encapsulated, ceiling sprinkler density shall be 25 percent greater than for nonencapsulated storage.



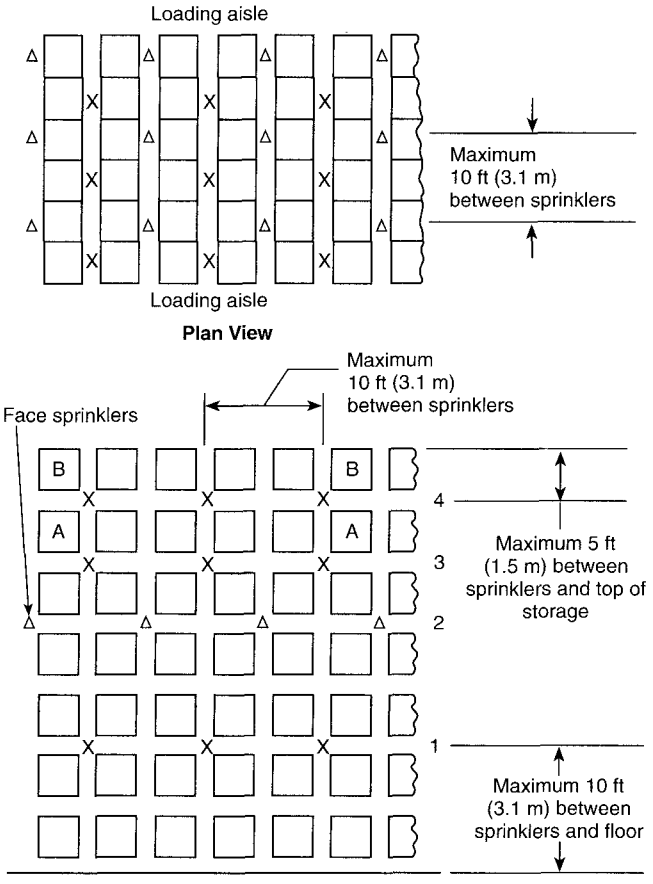
Notes:
1. Sprinklers labeled 1 shall be required where loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled B or C represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than that represented by loads labeled E, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated, with stagger as indicated.
5. Δ and X represent sprinklers on vertical or horizontal stagger.
6. Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-11(a) In-rack sprinkler arrangement, multiple-row racks, Class I commodities, storage height over 25 ft (7.6 m).



Notes:
1. Sprinklers labeled 1 and 2 shall be required where loads labeled A represent top of storage.
2. Sprinklers labeled 1 and 3 shall be required where loads labeled B or C represent top of storage.
3. For storage higher than that represented by loads labeled C, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated, with stagger as indicated.
4. Δ and X represent sprinklers on vertical or horizontal stagger.
5. Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-11(b) In-rack sprinkler arrangement, multiple-row racks, Class I, Class II, or Class III commodities, storage height over 25 ft (7.6 m).



Notes:
1. Sprinklers labeled 1, 2, and 3 shall be required where loads labeled A represent top of storage.
2. Sprinklers labeled 1, 2, and 4 shall be required where loads labeled B and 4 represent top of storage.
3. For storage higher than that represented by loads labeled B, the pattern for locating in-rack sprinklers as specified by Notes 1 and 2 shall be repeated, with stagger as indicated.
4. Δ and X represent sprinklers on vertical or horizontal stagger.
5. Each square in the figure represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side.

Figure 7-11(c) In-rack sprinkler arrangement, multiple-row racks, Class I, Class II, Class III, or Class IV commodities, storage height over 25 ft (7.6 m).

Table 7-11 Multiple-Row Racks — Storage Heights over 25 ft (7.6 m)

Commodity Class	Encapsulated	In-Rack Sprinklers[1,2]						Height Limit	Stagger	Figure No.	Maximum Spacing from Top of Storage to Highest In-Rack Sprinklers		Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density			
		Approximate Vertical Spacing		Maximum Horizontal Spacing in a Flue		Maximum Horizontal Spacing across Flue									Ordinary Temperature		High Temperature	
		ft	m	ft	m	ft	m				ft	m	ft	m	gpm/ft	(L/min) /m²	gpm/ft	(L/min) /m²
I	No	20	6.1	12	3.7	10	3.1	None	Between adjacent flues	7.11(a)	10	3.1			0.25	10.2	0.35	14.3
	Yes														0.31	12.6	0.44	17.9
I, II, III	No	15	4.6	10	3.1	10	3.1			7-11(b)	10	3.1	2000	186	0.3	12.2	0.4	16.3
	Yes														0.37	15.1	0.5	20.4
I, II, III, IV	No	10	3.1	10	3.1	10	3.1			7.11(c)	5	1.5			0.35	14.2	0.45	18.3
	Yes														0.44	17.9	0.56	22.8

[1]All four rack faces shall be protected by sprinklers located within 18 in. (0.46 m) of the faces, as indicated in Figures 7-11(a), (b), and (c). It shall not be required that each sprinkler level protect all faces (*see A-7-11*).

[2]All in-rack sprinkler spacing dimensions start from the floor.

Chapter 8 Spray Sprinkler Protection for Plastic Commodities

8-1* General. For Group A plastics that are stored at heights of 5 ft (1.5 m) or less, the sprinkler design criteria for miscellaneous storage specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be used.

8-1.1† Plastics in corrugated cartons shall be protected in accordance with Figure 8-1.1. Figure 8-1.1 also shall be used to determine protection for commodities that do not entirely consist of Group A plastics but that contain such quantities and arrangements of Group A plastics that they are deemed more hazardous than Class IV commodities.

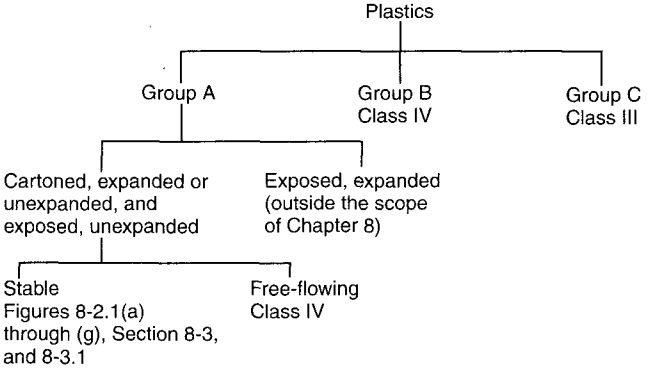


Figure 8-1.1 Decision tree.

8-1.2 Group B plastics and free-flowing Group A plastics shall be protected in the same manner as Class IV commodities.

8-1.3 Group C plastics shall be protected in the same manner as Class III commodities.

8-1.4† Ceiling sprinklers shall have an orifice size larger than $^1/_2$ in. (12.7 mm) and shall be ordinary, intermediate, or high temperature rated.

Exception No. 1: For densities of 0.30 gpm/ft² [(12.2 L/min)/m²] or less, $^1/_2$-in. (12.7-mm) orifice sprinklers shall be permitted.

Exception No. 2: High-temperature sprinklers shall be used where required by NFPA 13, Standard for the Installation of Sprinkler Systems.

8-1.5 In-Rack Sprinklers.

8-1.5.1 In-Rack Sprinkler Classification. Sprinklers in racks shall be ordinary temperature standard response.

Exception No. 1: High-temperature sprinklers shall be used as specified in NFPA 13, Standard for the Installation of Sprinkler Systems.

Exception No. 2: Quick-response sprinklers shall be permitted to be installed in racks.

8-1.5.2 In-Rack Sprinkler Pipe Size. The number of sprinklers and the pipe sizing on a line of in-rack sprinklers shall be restricted only by the hydraulic calculations and not by any piping schedule.

8-1.5.3 In-Rack Sprinkler Water Shields. Where in-rack sprinklers are not shielded by horizontal barriers, water shields shall be provided above the sprinklers, or listed sprinklers that are equipped with water shields shall be provided.

8-1.5.4 In-Rack Sprinkler Clearance. A minimum 6-in. (152.4-mm) vertical clear space shall be maintained between the sprinkler deflectors and the top of a tier of storage.

8-1.5.5 In-Rack Sprinkler Water Demand. The water demand for sprinklers that are installed in racks shall be based on the simultaneous operation of the most hydraulically remote sprinklers as follows:

(a) Eight sprinklers where only one level is installed in racks

(b) Fourteen sprinklers (seven on each of the top two levels) where more than one level is installed in racks

8-1.5.6 Chapters 1 through 5 apply to the storage of plastics.

8-2 Single-Row, Double-Row, and Multiple-Row Racks — Storage Height up to and Including 25 ft (7.6 m) — Clearances up to and Including 10 ft (3.1 m).

8-2.1 Ceiling Sprinkler Water Demand. For Group A plastic commodities in cartons, encapsulated or nonencapsulated in single-row, double-row, and multiple-row racks, ceiling sprinkler water demand in terms of density in gpm/ft² [(L/min)/m²] and area of sprinkler operation [ft² (m²) in ceiling or roof] shall be selected from Figures 8-2.1 (a) through (g). Linear interpolation of design densities and areas of application shall be permitted between storage heights with the same clearances. No interpolation between clearances shall be permitted.

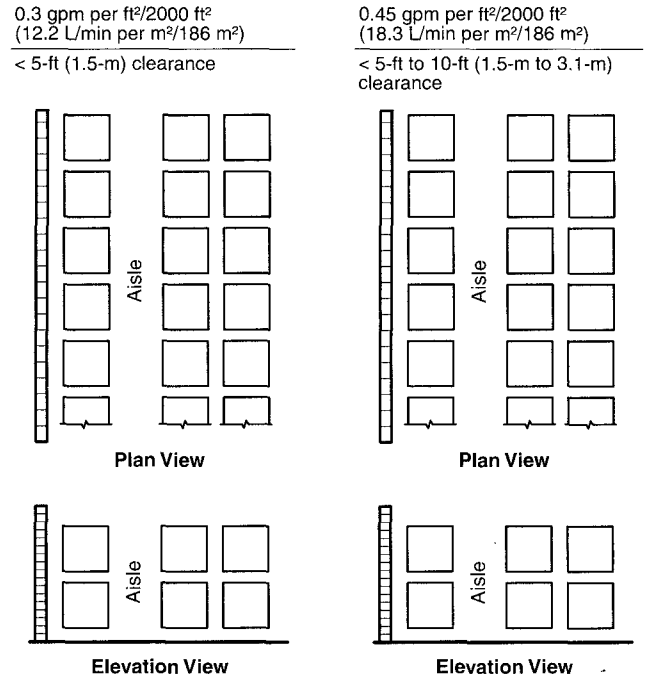


Figure 8-2.1(a) 5-ft to 10-ft (1.5-m to 3.1-m) storage.

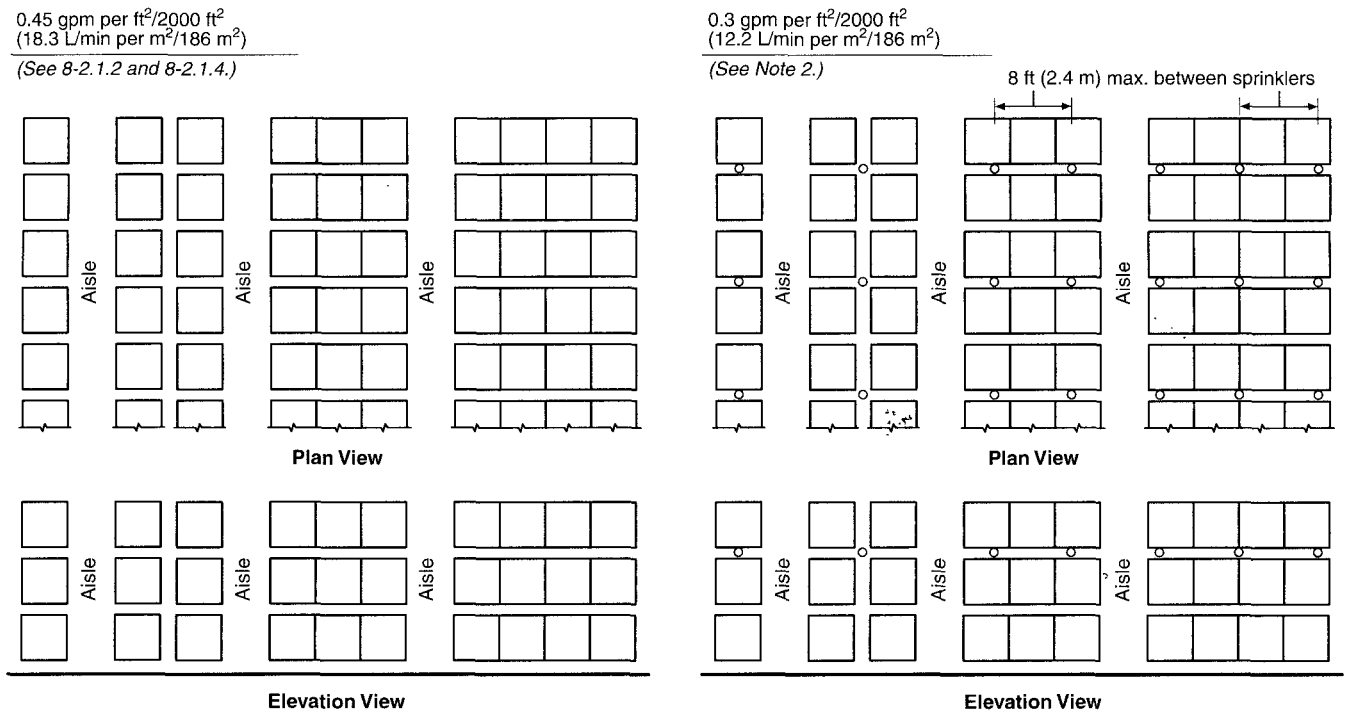


Figure 8-2.1(b) 15-ft (4.6-m) storage; < 5-ft (1.5-m) clearance.

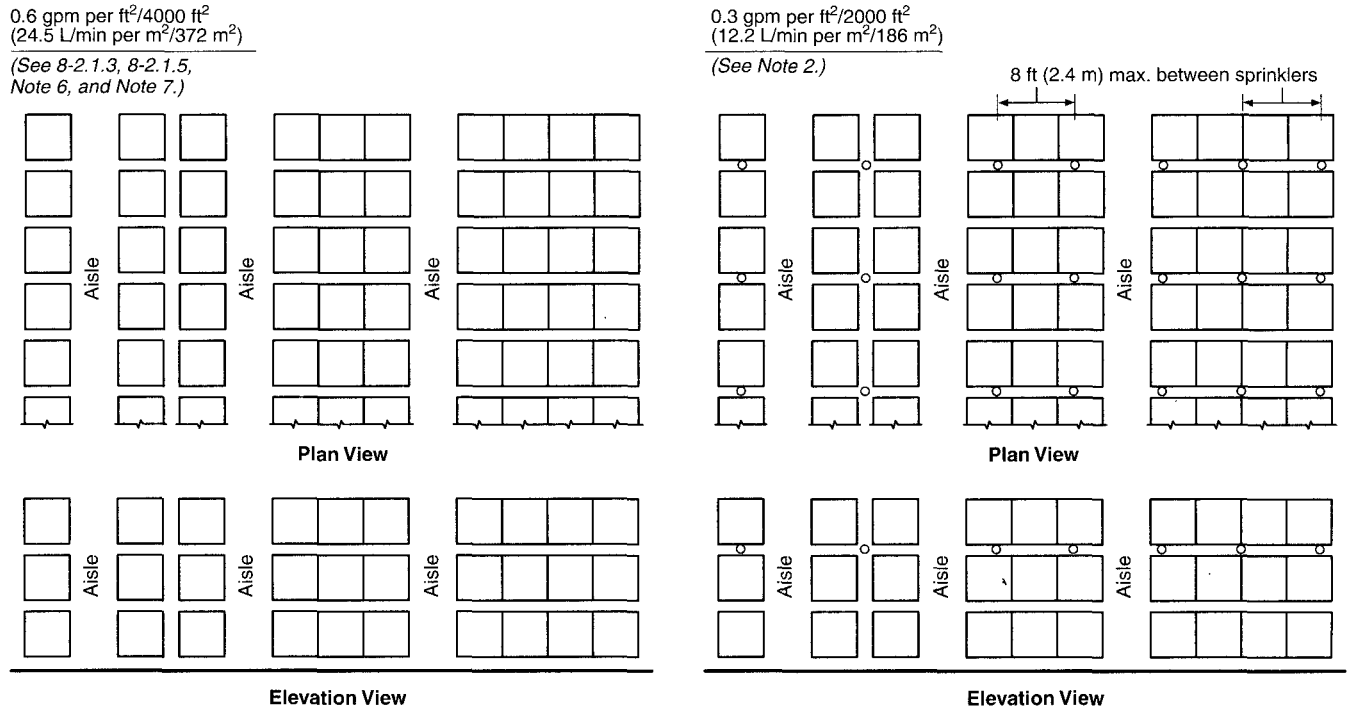


Figure 8-2.1(c) 15-ft (4.6-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance.

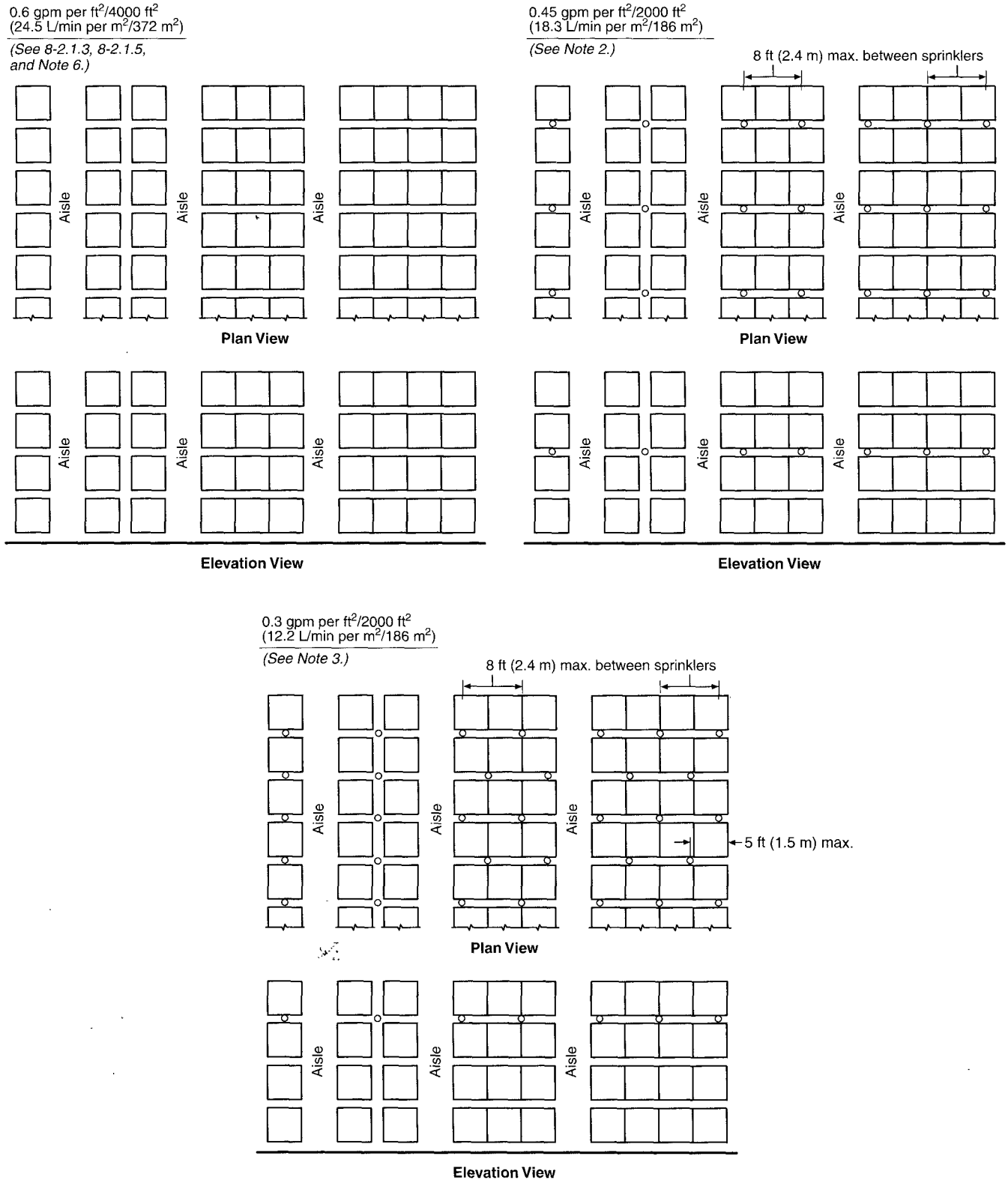


Figure 8-2.1(d) 20-ft (6.1-m) storage; < 5-ft (1.5-m) ceiling clearance.

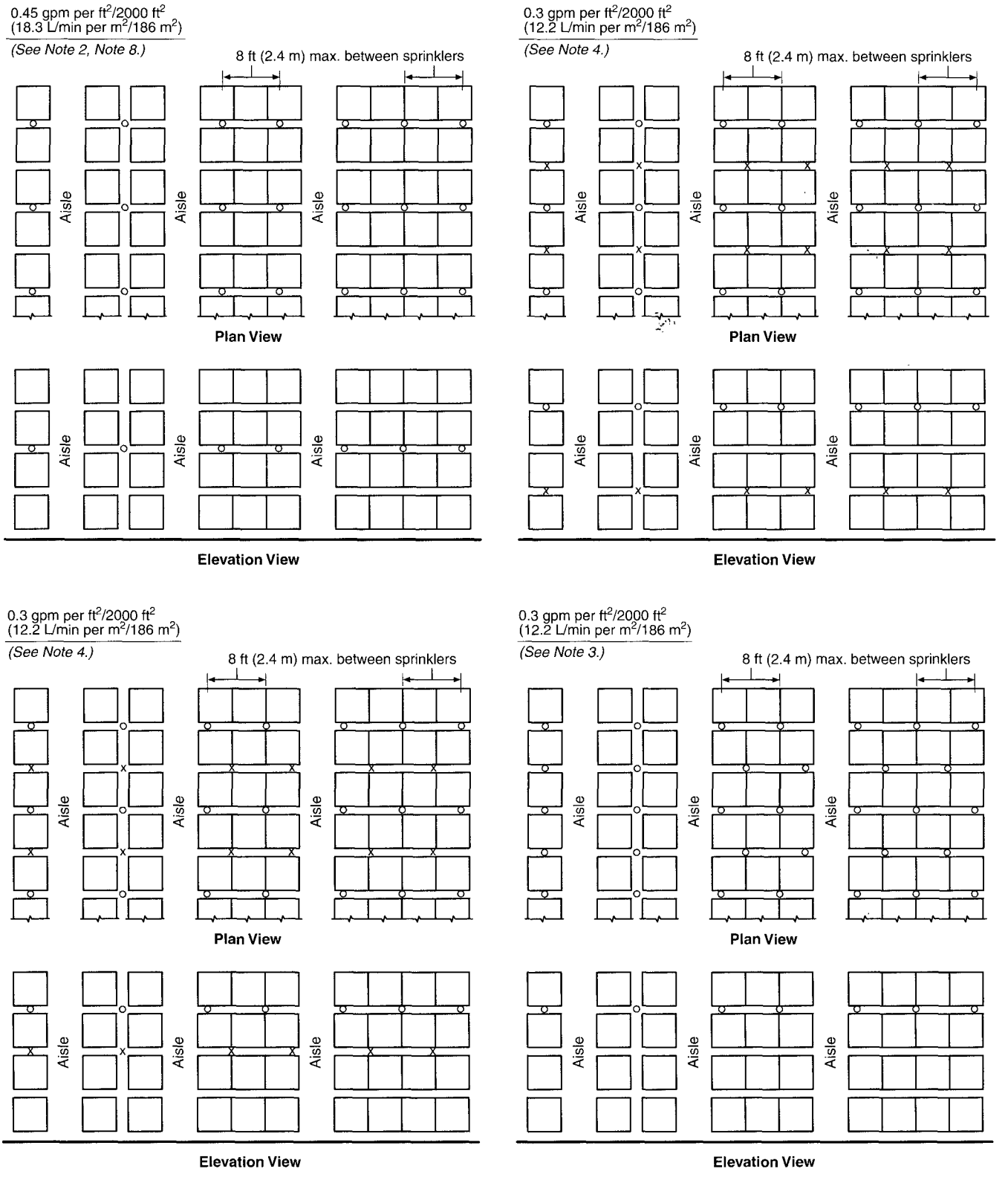


Figure 8-2.1(e) 20-ft (6.1-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance.

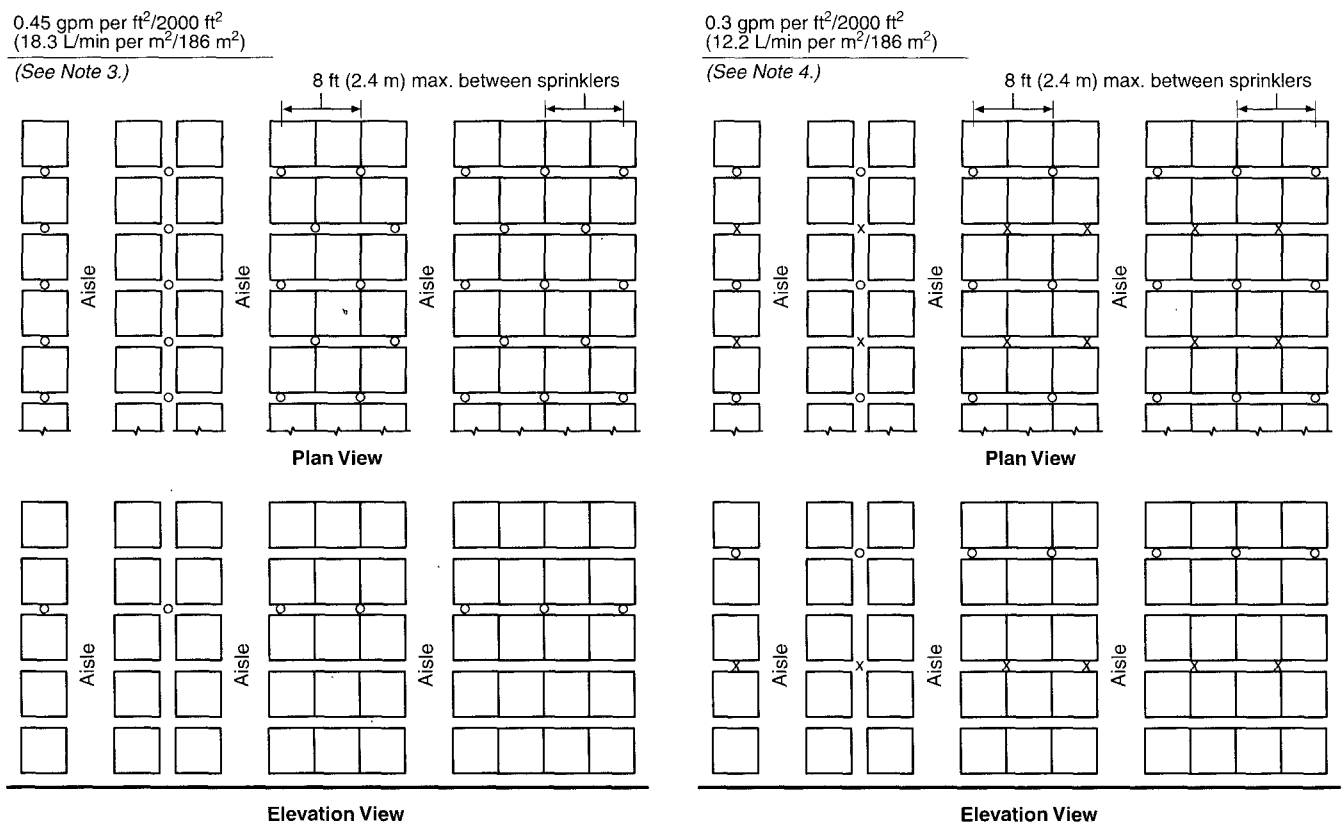
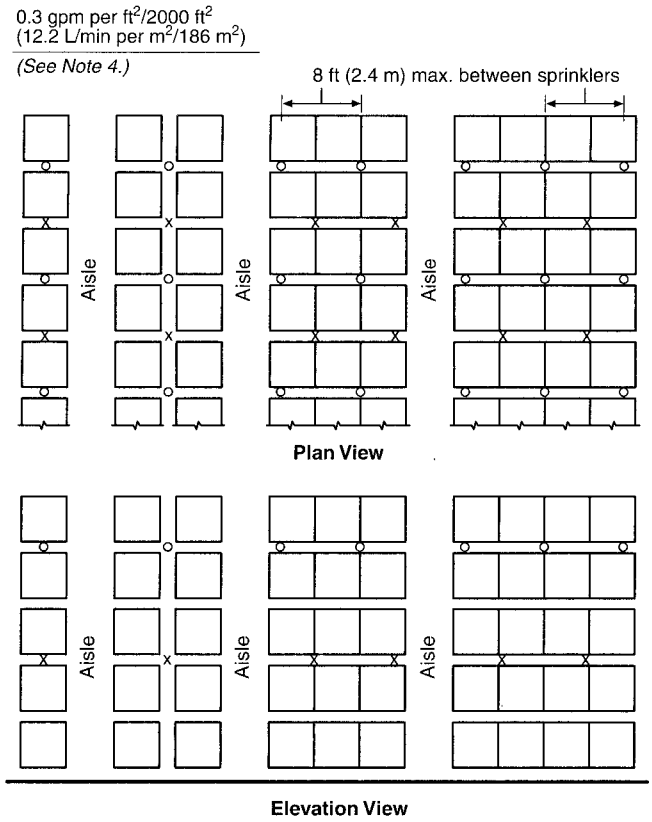


Figure 8-2.1(f) 25-ft (7.6-m) storage; < 5-ft (1.5-m) ceiling clearance. *(See Note 5.)*



Notes to Figures 8-2.1(a) through (g):

1. Each square represents a cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads that are spaced 10 ft (3.1 m) apart vertically between in-rack sprinklers.
2. Single level of in-rack sprinklers [½ in. or 17/32 in. (12.7 mm or 13.5 mm) operating at 15 psi (1.0 bar) minimum] installed on 8 ft to 10 ft (2.4 m to 3.1 m) spacings located, as indicated, in the transverse flue spaces.
3. Single level of in-rack sprinklers [17/32 in. (13.5 mm) operating at 15 psi (1.0 bar) minimum or ½ in. (12.7 mm) operating at 30 psi (2.1 bar) minimum] installed on 4-ft to 5-ft (1.2-m to 1.5-m) spacings located, as indicated, in the longitudinal flue space at the intersection of every transverse flue space.
4. Two levels of in-rack sprinklers [½ in. or 17/32 in. (12.7 mm or 13.5 mm) operating at 15 psi (1.0 bar) minimum] installed on 8-ft to 10-ft (2.4-m to 3.1-m) spacings located as indicated and staggered in the transverse flue space.
5. Ceiling-only protection shall not be permitted for this type of storage configuration.
6.† Where 5/8-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling only, the ceiling sprinkler discharge criteria shall be permitted to be reduced to 0.6 gpm per ft²/2000 ft² (24.5 L/min per m²/186 m²).
7.† Where 5/8-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling only and the ceiling height in the protected area does not exceed 22 ft (6.7 m), the ceiling sprinkler discharge criteria shall be permitted to be reduced to 0.45 gpm per ft²/2000 ft² (18.3 L/min per m²/186 m²).
8.† Where 5/8-in. (15.9-mm) orifice sprinklers listed for storage use are installed at the ceiling, the in-rack sprinklers shall not be required, provided the ceiling sprinkler discharge criteria is increased to 0.6 gpm per ft²/2000 ft² (24 L/min per m²/186 m²) and the ceiling height in the protected area does not exceed 27 ft (8.2 m).

Figure 8-2.1(g) 25-ft (7.6-m) storage; 5-ft to 10-ft (1.5-m to 3.1-m) ceiling clearance. *(See Note 5.)*

8-2.1.1 Single-Row, Double-Row, and Multiple-Row Racks — 5-ft to 10-ft (1.5-m to 3.1-m) Storage with $1^1/_2$-ft to 10-ft (0.5-m to 3.1-m) Clearance. The protection strategies that use only ceiling sprinklers, as shown in Figure 8-2.1(a), shall be permitted for single-row and double-row rack storage with 4-ft (1.2-m) or wider aisles and for multiple-row storage.

8-2.1.2 Single-Row and Double-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.5-m) Clearance. The protection strategy that uses only ceiling sprinklers, as shown in Figure 8-2.1(b), shall be permitted only for single-row and double-row rack storage with 8-ft (2.4-m) aisles. For $3^1/_2$-ft (1.1-m) aisles, a density of 0.60 gpm/ft² [(24.5 L/min)/m²] and an area of application of 1500 ft² (139.5 m²) shall be used. For aisle widths of $3^1/_2$ ft to 8 ft (1.1 m to 2.4 m), a direct linear interpolation shall be permitted between densities and areas of application.

8-2.1.3 Single-Row and Double-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6.1-m) Storage with Less than 5-ft (1.5-m) Clearance. The protection strategies that use only ceiling sprinklers, as shown in Figures 8-2.1(c) and (d), shall be permitted only for single-row and double-row rack storage with 8-ft (2.4-m) aisles. In-rack sprinkler protection shall be required for aisles less than 8 ft (2.4 m) in width.

8-2.1.4 Multiple-Row Racks — 15-ft (4.6-m) Storage with Less than 5-ft (1.5-m) Clearance. The protection strategy that uses only ceiling sprinklers, as shown in Figure 8-2.1(b), shall not be permitted for multiple-row rack storage. The density to be used shall be 0.60 gpm/ft² [(24.5 L/min)/m²] over 2000 ft² (186 m²). The combination of ceiling and in-rack sprinklers specified in Figure 8-2.1(b) shall be permitted as an alternative.

8-2.1.5 Multiple-Row Racks — 15-ft (4.6-m) Storage with 10-ft (3.1-m) Clearance; 20-ft (6.1-m) Storage with Less than 5-ft (1.5-m) Clearance. The protection strategies that use only ceiling sprinklers, as shown in Figures 8-2.1(c) and (d), shall not be permitted for multiple-row rack storage. Only the specified combinations of ceiling and in-rack sprinklers shall be used.

8-2.2 In-Rack Sprinklers. In-rack sprinklers shall be installed in accordance with Figures 8-2.1(b) through (g).

8-3 Single-Row, Double-Row, and Multiple-Row Racks — Storage over 25 ft (7.6 m) in Height.

8-3.1 Ceiling Sprinkler Water Demand.

8-3.1.1 For Group A plastic commodities in cartons, encapsulated or nonencapsulated, ceiling sprinkler water demand in terms of density, in gpm/ft² [(L/min)/m²], and area of operation [ft² (m²)] shall be selected from Table 8-3.1.

8-3.1.2 Where a single-row rack is mixed with double-row racks, Figures 8-2.1(a) through (g) or Figures 8-3.2.1(a) and (b) shall be used in accordance with the corresponding storage height.

Exception: Figures 8-3.2.3(a) through 8-3.2.3(c) shall be permitted to be used for the protection of the single-row racks.

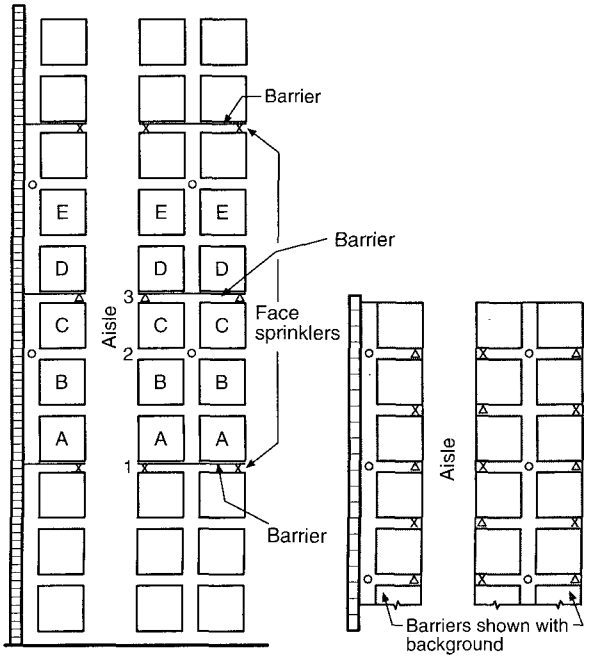
8-3.2 In-Rack Sprinkler Location.

8-3.2.1 In double-row racks without solid shelves and with a maximum of 10 ft (3.1 m) between the top of the storage and the ceiling, in-rack sprinklers shall be installed in accordance with Figures 8-3.2.1(a) or (b). The highest level of in-rack sprinklers shall be not more than 10 ft (3.1 m) below the top of storage.

Table 8-3.1 Ceiling Sprinkler Discharge Criteria for Single-Row, Double-Row, and Multiple-Row Racks with Storage over 25 ft (7.6 m) in Height

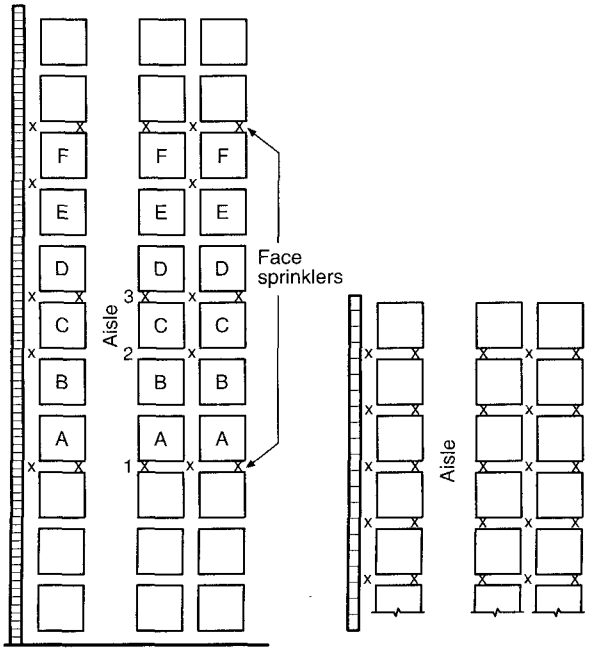
Storage Height above Top Level In-Rack Sprinklers	Ceiling Sprinkler Discharge Criteria/Area of Application (ft^2)
5 ft (1.5 m) or less	0.3 gpm/2000 ft^2 [(12.2 L/min)/m^2/186 m^2]
Over 5 ft (1.5 m) up to 10 ft (3.1 m)	0.45/2000 ft^2 [(18.3 L/min)/(m^2/186 m^2)]

Note: Provide in-rack sprinkler protection per Figures 8-3.2.1(a) and (b) and Figures 8-3.2.3(a) through (c).



Notes:
1. Sprinklers and barriers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 and barriers labeled 1 shall be required where loads labeled C represent top of storage.
3. Sprinklers and barriers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than that represented by loads labeled E, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated.
5. Δ and X represent face sprinklers on vertical or horizontal stagger.
6. O represents longitudinal flue space sprinklers.
7. Each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 8-3.2.1(a) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).

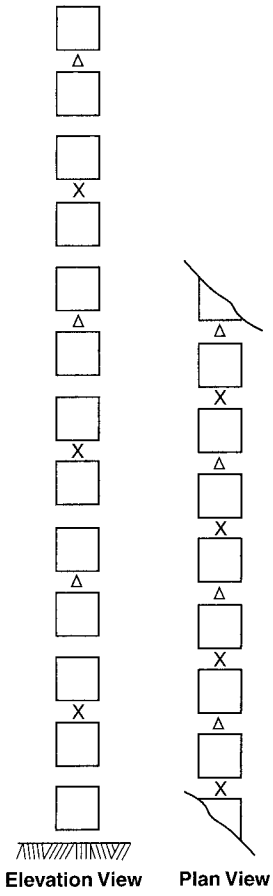


Notes:
1. Sprinklers labeled 1 shall be required where loads labeled A or B represent top of storage.
2. Sprinklers labeled 1 and 2 shall be required where loads labeled C represent top of storage.
3. Sprinklers labeled 1 and 3 shall be required where loads labeled D or E represent top of storage.
4. For storage higher than loads labeled F, the pattern for locating in-rack sprinklers as specified by Notes 2 and 3 shall be repeated.
5. X represents face and in-rack sprinklers.
6. Each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 8-3.2.1(b) In-rack sprinkler arrangement, Group A plastic commodities, storage height over 25 ft (7.6 m).

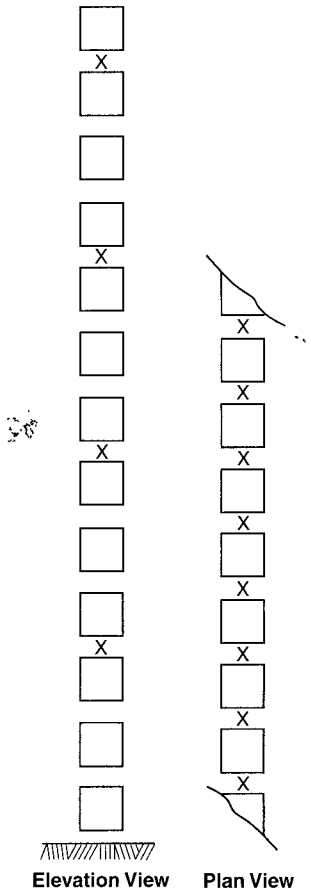
8-3.2.2 In-rack sprinklers for storage that is higher than 25 ft (7.6 m) in double-row racks shall be spaced horizontally and shall be located in the horizontal space that is nearest to the vertical intervals that are specified in Figures 8-3.2.1(a) or (b).

8-3.2.3 In single-row racks without solid shelves, with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of the storage and the ceiling, sprinklers shall be installed in accordance with Figures 8-3.2.3(a), (b), or (c).



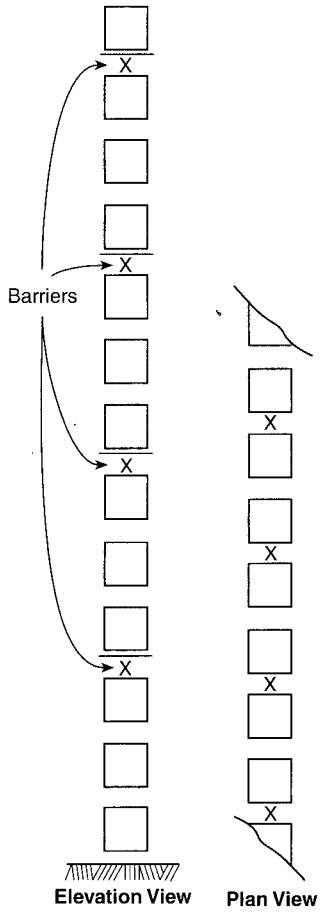
Note: Each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 8-3.2.3(a) In-rack sprinkler arrangement, single-row racks, Group A plastic commodities, storage height over 25 ft (7.6 m).



Note: Each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 8-3.2.3(b) In-rack sprinkler arrangement, single-row racks, Group A plastic commodities, storage height over 25 ft (7.6 m).



Note: Each square represents a storage cube that measures 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. to 10 ft (0.46 m to 3.1 m). Therefore, there can be one load to six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

Figure 8-3.2.3(c) In-rack sprinkler arrangement, single-row racks, Group A plastic commodities, storage height over 25 ft (7.6 m).

8-3.2.4 In multiple-row racks without solid shelves, with storage height over 25 ft (7.6 m) and a maximum of 10 ft (3.1 m) between the top of the storage and the roof/ceiling, in-rack sprinklers shall be installed in accordance with Figures 8-3.2.4(a) through (f).

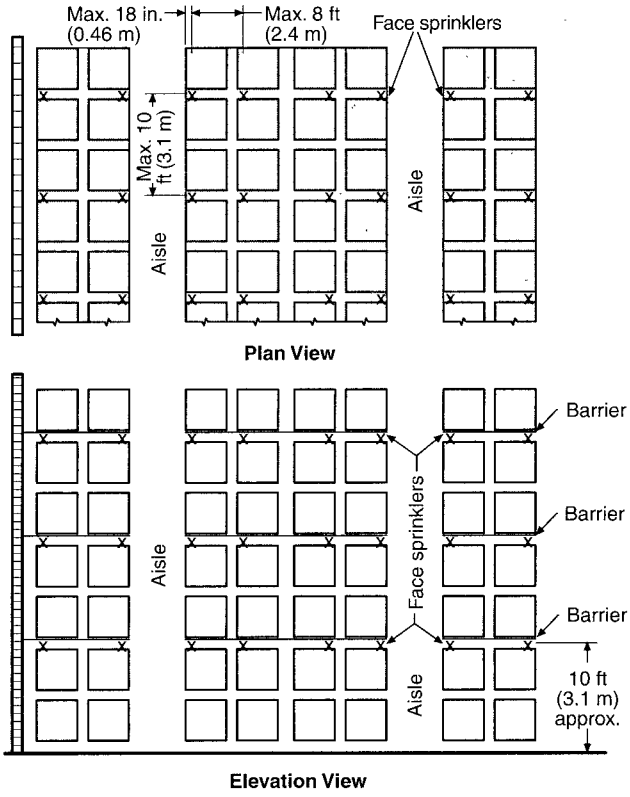


Figure 8-3.2.4(a)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

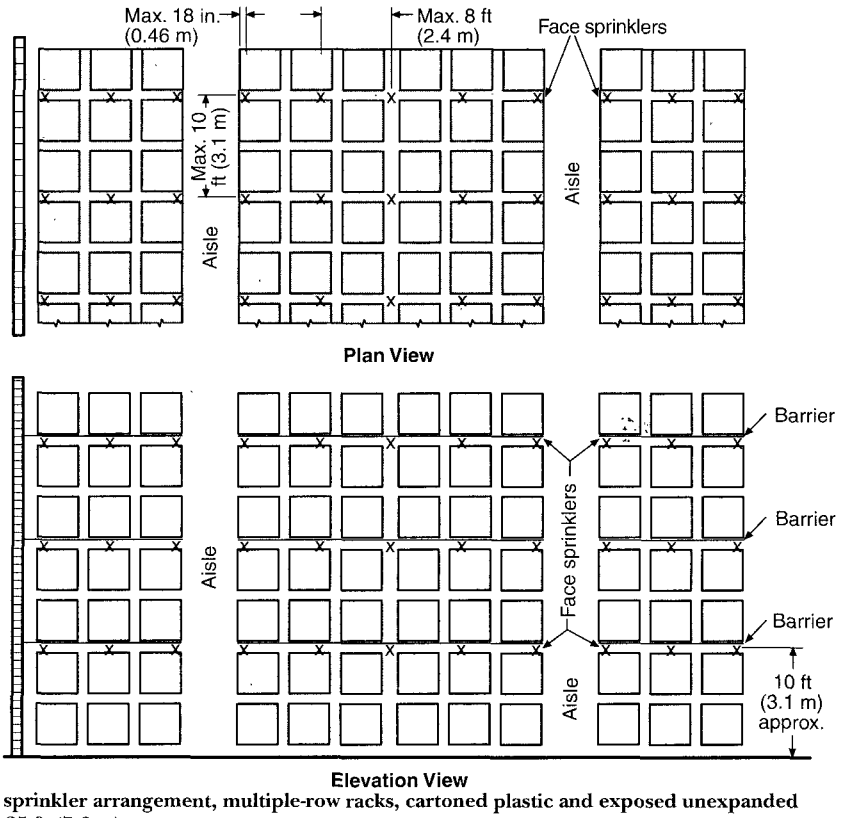


Figure 8-3.2.4(b)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

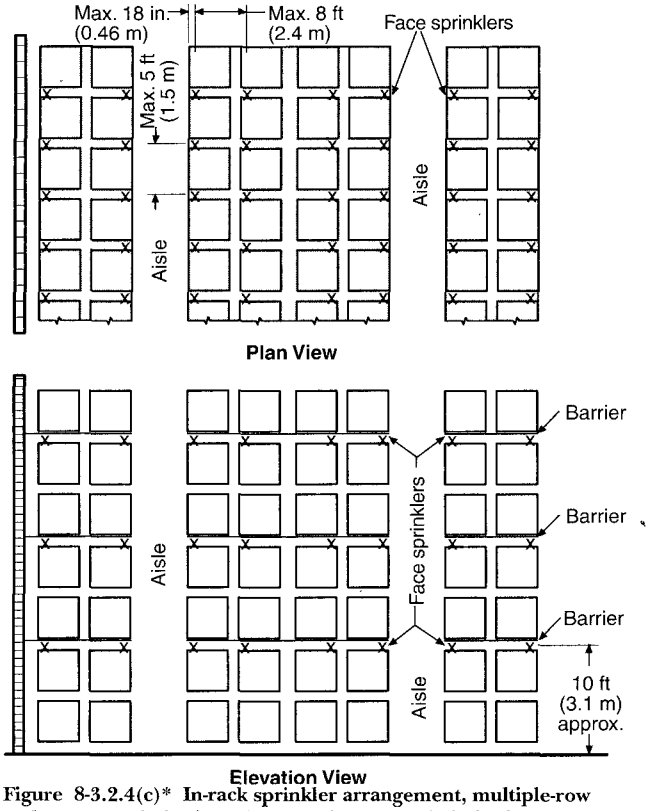


Figure 8-3.2.4(c)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

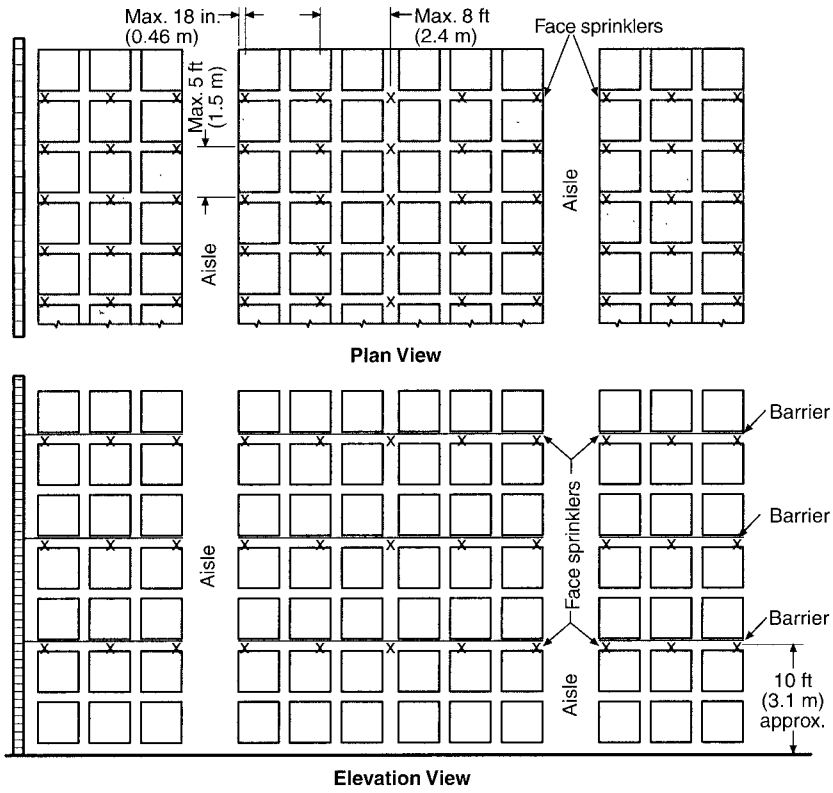


Figure 8-3.2.4(d)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

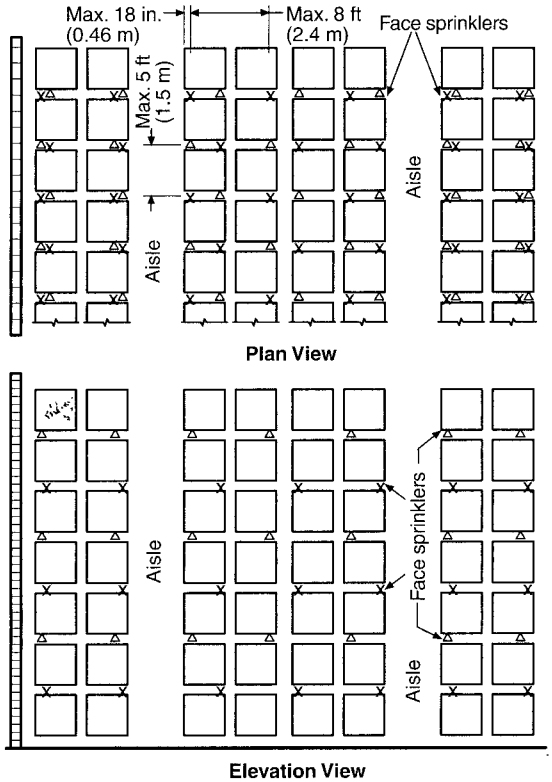


Figure 8-3.2.4(e)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

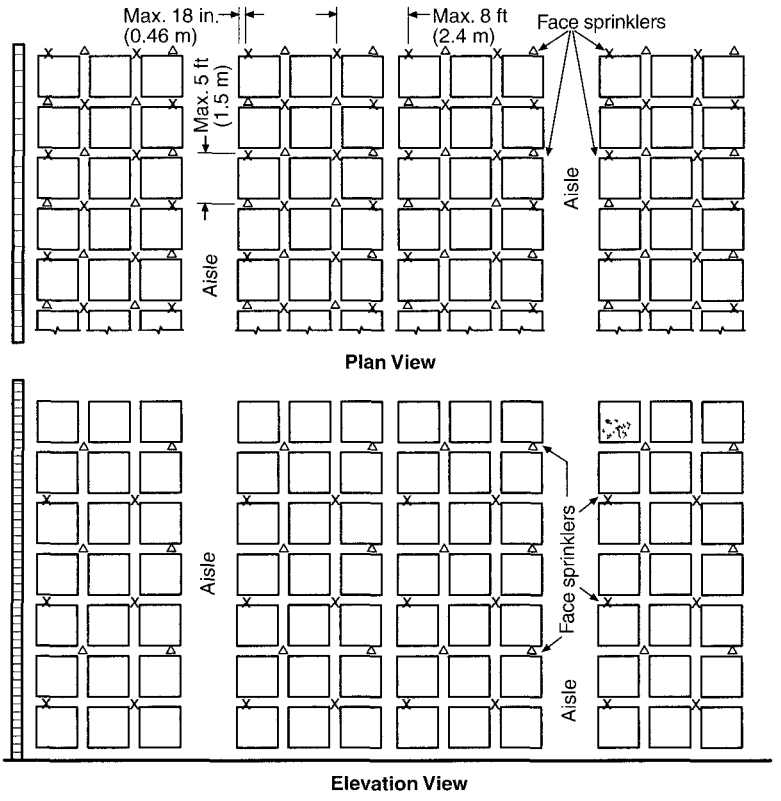


Figure 8-3.2.4(f)* In-rack sprinkler arrangement, multiple-row racks, cartoned plastic and exposed unexpanded plastic, storage height over 25 ft (7.6 m).

8-3.3 In-Rack Sprinkler Size. Sprinklers in racks shall be $^1/_2$-in. (12.7-mm) or 17/32-in. (13.5-mm) orifice size, pendent or upright.

8-3.4 In-Rack Sprinkler Discharge. Sprinklers in racks shall discharge at not less than 30 gpm (113.6 L/min).

8-3.5* Horizontal Barriers and In-Rack Sprinklers. Horizontal barriers that are used in conjunction with in-rack sprinklers to impede vertical fire development shall be constructed of sheet metal, wood, or similar material and shall extend the full length and width of the rack. Barriers shall be fitted within 2 in. (50.8 mm) horizontally around rack uprights. *[See Figure 8-3.2.1(a) and Figure 8-3.2.3(c).]*

Chapter 9 Large-Drop Sprinklers

9-1 General.

9-1.1 Large-drop sprinklers shall be permitted for the protection of the rack storage of materials where installed in accordance with the design criteria of Table 9-1.1.

9-1.2 For large-drop sprinklers that are installed under open wood-joist construction, the minimum operating pressure shall be 50 psi (3.5 bar).

Exception: Where each joist channel of open wood-joist construction is fully firestopped to its full depth at intervals not exceeding 20 ft (6.1 m), the lower pressures specified in Table 9-1.1 shall be permitted to be used.

9-1.3 Building steel shall not require special protection where Table 9-1.1 is applied.

9-1.4 Protection requirements are based on rack storage that have no solid shelves.

9-1.5 Minimum 6-in. (152.4-mm) longitudinal flue spaces shall be maintained in addition to transverse flue spaces.

9-1.6 For dry-pipe systems, high-temperature sprinklers shall be used; for wet-pipe systems, ordinary-temperature or high-temperature sprinklers shall be permitted.

9-1.7 For the purpose of Chapter 9 and the use of Table 9-1.1, preaction systems shall be treated as dry-pipe systems.

Exception: This requirement shall not apply where it can be demonstrated that the detection system that activates the preaction system causes water to be discharged from sprinklers as quickly as the discharge from a wet-pipe system.

9-1.8 Sprinkler spacing shall be not less than 80 ft^2 (7.4 m^2) or more than 100 ft^2 (9.3 m^2).

9-1.9 Where in-rack sprinklers are required by Table 9-1.1, in-rack sprinkler spacing, design pressure, and hydraulic calculation criteria shall be in accordance with the requirements of Chapter 6 or Chapter 8, as applicable for the commodity.

9-1.10 The requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems,* shall apply.

Exception: Where this standard modifies the requirements of NFPA 13.

9-2 Other Requirements. Where large-drop sprinklers are installed, storage height limitations in accordance with Section 4-5 shall apply.

Table 9-1.1 Large-Drop Sprinkler Design Criteria for Single-Row, Double-Row, and Multiple-Row Racks

Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/ Roof Height ft	Maximum Ceiling/ Roof Height m	Type of System	Number of Design Sprinklers by Minimum Operating Pressure [psi (bar)]) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gal/ min	Hose Stream Demand L/min	Water Supply Duration (hr)
I, II	25	7.6	30	9.1	Wet	20	20	20	500	1900	$1^1/_2$
					Dry	30	30	30			
I, II	30	9.1	35	10.7	Wet	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500	1900	$1^1/_2$
					Dry	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	30 plus one level of in-rack sprinklers	500	1900	$1^1/_2$
I, II, III	20	6.1	30	9.1	Wet	15	15	15	500	1900	$1^1/_2$
					Dry	25	25	25			
I, II, III	25	7.6	35	10.7	Wet	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	$1^1/_2$
					Dry	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	25 plus one level of in-rack sprinklers	500	1900	$1^1/_2$
IV	20	6.1	30	9.1	Wet	NA	20	15	500	1900	2
					Dry	NA	NA	NA			
IV	20	6.1	30	9.1	Wet	NA	20 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	20	6.1	30	9.1	Wet	NA	30	20	500	1900	2
					Dry	NA	NA	NA			
IV	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	25	7	35	10.7	Wet	NA	30 plus one level of in-rack sprinklers	20 plus one level of in-rack sprinklers	500	1900	2
IV	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
					Dry	NA	NA	NA			
Cartoned or exposed unexpanded plastics	20	6.1	25	7.6	Wet	NA	15	15	500	1900	2
					Dry	NA	NA	NA			

Table 9-1.1 Large-Drop Sprinkler Design Criteria for Single-Row, Double-Row, and Multiple-Row Racks, *Continued*

	Maximum Storage Height		Maximum Ceiling/ Roof Height			Number of Design Sprinklers by Minimum Operating Pressure [psi (bar)])			Hose Stream Demand		Water Supply Duration
Commodity Class	ft	m	ft	m	Type of System	25 (1.7)	50 (3.4)	75 (5.2)	gal/ min	L/min	(hr)
IV	25	7.6	30	9.1	Wet	NA	15 plus one level of in-rack sprinklers	15 plus one level of in-rack sprinklers	500	1900	2
Cartoned or exposed unexpanded plastics	25	7.6	30	9.1	Dry	NA	NA	NA			

Note: NA — Not allowed

Chapter 10 Early Suppression Fast Response (ESFR) Sprinklers

10-1* General.

10-1.1 Early suppression fast response (ESFR) sprinklers shall be permitted to be used for the protection of rack storage in accordance with Table 10-1.1 and shall be used only in buildings equal to, or less than, the height of the building for which they have been listed.

Exception: ESFR protection as specified shall not apply to the following:

(a) Rack storage that involves solid shelves

(b) Rack storage that involves combustible, open-top cartons or containers

10-1.2 Maximum building height shall be measured to the underside of the roof deck or ceiling.

10-2 Sprinkler System Design.

10-2.1* ESFR sprinkler systems shall be designed to provide the minimum operating pressure, in accordance with Table 10-1.1 for the commodity, storage height, and ceiling/roof height of the building involved, to the 12 most hydraulically remote sprinklers, as determined by operating four sprinklers on each of three branch lines.

10-2.2 The distance between branch lines and sprinklers on branch lines shall not be more than 10 ft (3.1 m) nor less than 8 ft (2.4 m) for buildings higher than 30 ft (9.1 m) up to 45 ft (13.7 m); and the distance shall not be more than 12 ft (3.7 m) nor less than 8 ft (2.4 m) for buildings up to 30 ft (9.1 m) high.

10-2.3 Wet-pipe systems only shall be permitted to be used with ESFR sprinklers.

10-2.4 The requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall apply.

Exception: Where this standard modifies the requirements of NFPA 13.

10-2.5 Where required by Table 10-1.1, one level of $^{17}/_{32}$-in. (13.5-mm) orifice, quick-response, ordinary-temperature in-rack sprinklers shall be installed at the tier level closest to but not exceeding one-half of the maximum storage height. In-rack sprinkler hydraulic design criteria shall be the most hydraulically remote eight heads at 50 psi (3.4 bar). In-rack sprinklers shall be located at the intersection of the longitudinal and transverse flue space. Horizontal spacing shall not be permitted to exceed 5-ft (1.5-m) intervals.

10-3 Water Demand.

10-3.1 A minimum of 250 gpm (946 L/min) shall be added to the sprinkler demand for combined large and small hose streams.

10-3.2 Water supply duration shall be at least 1 hour.

10-4 Other Requirements.

10-4.1 Where ESFR sprinklers are installed, the requirements of 4-3.1 for longitudinal flue spaces in double-row racks shall apply.

10-4.2 Where ESFR sprinklers are installed, storage height limitations in accordance with Section 4-5 shall apply.

Table 10-1.1 Early Suppression Fast Response (ESFR) Sprinkler Data

Type of Storage*	Commodity	Maximum Height of Storage ft	Maximum Height of Storage m	Maximum Ceiling/ Roof Height of Building ft	Maximum Ceiling/ Roof Height of Building m	Nominal *K*-Factor	Sprinkler Design Pressure psi	Sprinkler Design Pressure bar	In-Rack Sprinkler Requirements
Single-row rack storage, double-row rack storage, multiple-row rack storage	1. Cartoned unexpanded plastic 2. Cartoned expanded plastic 3. Exposed unexpanded plastic 4. Classes I, II, III, and IV commodities, encapsulated or unencapsulated 5. Idle wood and plastic pallets	25	7.6	30	9.1	13.5–14.5	50	3.4	No
	1. Cartoned or exposed unexpanded plastic 2. Classes I, II, III, and IV commodities, encapsulated or unencapsulated 3. Idle wood and plastic pallets	35	10.7	40	12.2	13.5–14.5	75	5.2	No
		20	6.1	25	7.6	11.0–11.5	50	3.4	No
	1. Cartoned or exposed unexpanded plastic	35	10.7	45	13.7	13.5–14.5	90	27.4	No
	2. Classes I, II, III, and IV commodities, encapsulated or unencapsulated	40	12.2	45	13.7	13.5–14.5	90	27.4	Yes

* No open-top containers or solid shelves.

Chapter 11 Equipment

11-1 Mechanical Handling Equipment — Industrial Trucks.

11-1.1 Power-operated industrial trucks shall comply with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation*, and their maintenance and operation shall be in accordance with Chapters 4 and 5 of that standard.

11-1.2† Industrial trucks that use LP-Gas or liquid fuel shall be refueled outside of the storage building at a location that is designated for such purpose.

Chapter 12 Building Maintenance and Operation

12-1* Building Operations Other than Storage. Welding, soldering, brazing, and cutting shall be permitted to be performed on rack or building components that cannot be removed, provided no storage is located below and within 25 ft (7.6 m) of the working area and provided flameproof tarpaulins enclose the working area. The sprinkler system shall be in service during any welding, soldering, brazing, and cutting operations. Water-type extinguishers with a capacity of $2^1/_2$ gal (9.45 L) and charged inside hose lines shall be located in the working area. A fire watch shall be maintained during welding, soldering, brazing, and cutting operations and for at least 30 additional minutes.

12-2* Waste Disposal. Approved containers for rubbish and other trash materials shall be provided.

12-3 Smoking. Smoking shall be strictly prohibited. Signs that read *no smoking* shall be posted in prohibited areas.

Exception: Smoking shall be permitted in locations that are prominently designated as smoking areas.

12-4* Maintenance. Fire walls, fire doors, and floors shall be maintained in good repair at all times.

12-5* Plant Emergency Organization. A fire watch shall be maintained when the sprinkler system is not in service.

12-6* General Fire Protection. The sprinkler system and the water supplies shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*

Chapter 13 Referenced Publications

13-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix C.

13-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1998 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1997 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 1998 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 231, *Standard for General Storage*, 1998 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1998 edition.

NFPA 231F, *Standard for the Storage of Roll Paper*, 1996 edition.

NFPA 232, *Standard for the Protection of Records*, 1995 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1998 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation*, 1996 edition.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1.2 See also NFPA 231E, *Recommended Practice for the Storage of Baled Cotton.*

A-1-3 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Early Suppression Fast Response (ESFR) Sprinkler. It is important to realize that the effectiveness of these highly tested and engineered sprinklers depends on the combination of fast response and the quality and uniformity of the sprinkler discharge. It should also be realized that ESFR sprinklers cannot be relied upon to provide fire control, let alone suppression, if they are used outside the guidelines specified in Chapter 10 and NFPA 13, *Standard for the Installation of Sprinkler Systems.*

A-1-3 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1 Specification of the type, amount and, arrangement of combustibles for any commodity classification is essentially an attempt to define the potential fire severity, based on its burning characteristics, so that the fire can be successfully controlled by the prescribed sprinkler protection for the commodity class. In actual storage situations, however, many storage arrays do not fit precisely into one of the fundamental classifications, therefore, the user needs to make judgments after comparing each classification to the existing storage conditions. Storage arrays consist of thousands of products, which make it impossible to specify all the acceptable variations for any class. As an alternative, the Technical Committee on General Storage has classified a variety of common products in this appendix based on judgment, loss experience, and fire test results.

Table A-2-1 provides examples of commodities that are outside the scope of this standard.

Table A-2-1.3 is an alphabetized list of commodities with corresponding classifications.

Tables A-2-1.3.1, A-2-1.3.2, A-2-1.3.3, A-2-1.3.4, and A-2-1.4.1 provide examples of commodities within a specific class.

Table A-2-1 Examples of Commodities Outside the Scope of NFPA 231C

Boxes, Crates
– Empty, wood, slatted*
Lighters (butane)
– Loose in large containers (Level 3 aerosol)

*Should be treated as idle pallets.

A-2-1.1.1 Commodity classification is governed by the types and amounts of materials (e.g., metal, paper, wood, plastics) that are part of a product and its primary packaging. However, in a storage or warehouse situation, classification is also affected by such factors as the primary storage or shipping container material, the amount of air space, and the location of the more hazardous materials within the container. For example, a Group A plastic product enclosed in a five-sided or six-sided metal container can be considered Class II; while a ceramic product heavily wrapped in tissue paper and placed in a corrugated carton can be considered Class III.

A-2-1.3 See Table A-2-1.3.

Table A-2-1.3 Alphabetized Listing of Commodity Classes

Commodity	Commodity Class
Aerosols	
Cartoned or uncartoned	
– Level 1	Class III
Alcoholic Beverages	
Cartoned or uncartoned	
– Up to 20 percent alcohol in metal, glass, or ceramic containers	Class I
– Up to 20 percent alcohol in wood containers	Class II
Ammunition	
Small arms, shotgun	
– Packaged, cartoned	Class IV
Appliances, Major (e.g., stoves, refrigerators)	
– Not packaged, no appreciable plastic exterior trim	Class I
– Corrugated, cartoned, (no appreciable plastic trim)	Class II
Baked Goods	
Cookies, cakes, pies	
– Frozen, packaged in cartons[1]	Class II
– Packaged in cartons	Class III
Batteries	
Dry cells (nonlithium or similar exotic metals)	
– Packaged in cartons	Class I
– Blister-packed in cartons	Class II
Automobile	
– Filled[2]	Class I
Truck or larger	
– Empty or filled[2]	Group A plastics
Beans	
Dried	
– Packaged, cartoned	Class III
Bottles, Jars	Class I
Empty, cartoned	Class IV
– Glass	
– Plastic PET (polyethylene terephthalate)	
Filled noncombustible powders	
– Plastic PET	Class II
– Glass, cartoned	Class I
– Plastic, cartoned [less than 1 gal (3.8 L)]	Class IV
– Plastic, uncartoned (other than PET), any size	Group A plastics
– Plastic, cartoned or exposed [greater than 1 gal (3.8 L)]	Group A plastics
– Plastic, solid plastic crates	Group A plastics
– Plastic, open plastic crates	Group A plastics
Filled noncombustible liquids	
– Glass, cartoned	Class I
– Plastic, cartoned [less than 5 gal (18.9 L)]	Class I
– Plastic, open or solid plastic crates[3]	Group A plastics
– Plastic, PET	
Boxes, Crates	
– Empty, wood, solid walls	Class II
– Empty, wood, slatted[4]	Outside of scope
Bread	
Wrapped, cartoned	Class III
Butter	
Whipped spread	Class III
Candles	
Packaged, cartoned	
– Treat as expanded plastic	Group A plastics
Candy	
Packaged, cartoned	Class III
Canned Foods	
In ordinary cartons	Class I
Cans	
Metal	
– Empty	Class I
Carpet Tiles	
Cartoned	Group A plastics
Cartons	
Corrugated	
– Unassembled (neat piles)	Class III
– Partially assembled	Class IV
Wax coated, single walled	Group A plastics
Cement	
Bagged	Class I
Cereals	
Packaged, cartoned	Class III
Charcoal	
Bagged	
– Standard	Class III
Cheese	
– Packaged, cartoned	Class III
– Wheels, cartoned	Class III
Chewing Gum	
Packaged, cartoned	Class III
Chocolate	
Packaged, cartoned	Class III
Cloth	
Cartoned and not cartoned	
– Natural fiber, viscose	Class III
– Synthetic[5]	Class IV
Cocoa Products	
Packaged, cartoned	Class III
Coffee	
– Canned, cartoned	Class I
– Packaged, cartoned	Class III
Coffee Beans	
Bagged	Class III

Table A-2-1.3 Alphabetized Listing of Commodity Classes, *Continued*

Commodity	Commodity Class
Cotton	
– Packaged, cartoned	Class III
Diapers	
– Cotton, linen	Class III
– Disposable with plastics and nonwoven fabric (in cartons)	Class IV
– Disposable with plastics and nonwoven fabric (uncartoned), plastic wrapped	Group A plastics
Dried Foods	
Packaged, cartoned	Class III
Fertilizers	
Bagged	
– Phosphates	Class I
– Nitrates	Class II
Fiberglass Insulation	
– Paper-backed rolls, bagged or unbagged	Class IV
File Cabinets	
Metal	
– Cardboard box or shroud	Class I
Fish or Fish Products	
Frozen	
– Nonwaxed, nonplastic packaging	Class I
– Waxed-paper containers, cartoned	Class II
– Boxed or barreled	Class II
– Plastic trays, cartoned	Class III
Canned	
– Cartoned	Class I
Frozen Foods	
Nonwaxed, nonplastic packaging	Class I
– Waxed-paper containers, cartoned	Class II
– Plastic trays	Class III
Fruit	
Fresh	
– Nonplastic trays or containers	Class I
– With wood spacers	Class I
Furniture	
Wood	
– No plastic coverings or foam plastic cushioning	Class III
– With plastic coverings	Class IV
– With foam plastic cushioning	Group A plastics
Grains – Packaged in cartons	
– Barley	Class III
– Rice	Class III
– Oats	Class III
Ice Cream	Class I
Leather Goods	Class III
Leather Hides	
Baled	Class II
Light Fixtures	
Nonplastic	
– Cartoned	Class II

Table A-2-1.3 Alphabetized Listing of Commodity Classes, *Continued*

Commodity	Commodity Class
Lighters	
Butane	
– Blister-packed, cartoned	Group A plastics
– Loose in large containers (Level 3 aerosol)	Outside of scope
Liquor	
100 proof or less; 1 gal (3.8 L) or less, cartoned	
– Glass (palletized)[6]	Class IV
– Plastic bottles	Class IV
Marble	
Artificial sinks, countertops	
– Cartoned, crated	Class II
Margarine	
– Up to 50 percent oil (in paper or plastic containers)	Class III
– Between 50 percent and 80 percent oil (in any packaging)	Group A plastics
Matches	
Packaged, cartoned	
– Paper	Class IV
– Wood	Group A plastics
Mattresses	
– Standard (box spring)	Class III
– Foam (in finished form)	Group A plastics
Meat, Meat Products	
– Bulk	Class I
– Canned, cartoned	Class I
– Frozen, nonwaxed, nonplastic containers	Class I
– Frozen, waxed-paper containers	Class II
– Frozen, expanded plastic trays	Class II
Metal Desks	
With plastic tops and trim	Class I
Milk	
– Nonwaxed-paper containers	Class I
– Waxed-paper containers	Class I
– Plastic containers	Class I
– Containers in plastic crates	Group A plastics
Motors	
– Electric	Class I
Nail Polish	
– 1-oz to 2-oz (29.6-ml to 59.1-ml) glass, cartoned	Class IV
– 1-oz to 2-oz (29.6-ml to 59.1-ml) plastic bottles, cartoned	Group A plastics
Nuts	
– Canned, cartoned	Class I
– Packaged, cartoned	Class III
– Bagged	Class III
Paints	
Friction-top cans, cartoned	
– Water-based (latex)	Class I

(continues)

Table A-2-1.3 Alphabetized Listing of Commodity Classes, *Continued*

Commodity	Commodity Class
– Oil-based	Class IV
Paper Products	
– Books, magazines, stationery, plastic-coated paper food containers, newspapers, cardboard games, or cartoned tissue products	Class III
– Tissue products, uncartoned and plastic wrapped	Group A plastics
Paper, Rolled	
In racks or on side	
– Medium or heavyweight	Class III
In racks	
– Lightweight	Class IV
Paper, Waxed	
Packaged in cartons	Class IV
Pharmaceuticals	
Pills, powders	
– Glass bottles, cartoned	Class II
– Plastic bottles, cartoned	Class IV
Nonflammable liquids	
– Glass bottles, cartoned	Class II
Photographic Film	
– Motion picture or bulk rolls in polycarbonate, polyethylene, or metal cans; polyethylene bagged in cardboard boxes	Class II
– 35-mm in metal film cartridges in polyethylene cans in cardboard boxes	Class III
– Paper, in sheets, bagged in polyethylene, in cardboard boxes	Class III
– Rolls in polycarbonate plastic cassettes, bulk wrapped in cardboard boxes	Class IV
Plastic Containers (except PET)	
– Noncombustible liquids or semiliquids in plastic containers of less than 5 gal (18.9 L) capacity	Class I
– Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of $^1/_4$ in. (6.4 mm) or less and larger than 5 gal (18.9 L) capacity	Class II
– Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness greater than $^1/_4$ in. (6.4 mm) and larger than 5 gal (18.9 L) capacity	Group A plastics
Polyurethane	
Cartoned or uncartoned expanded	Group A plastics
Poultry Products	
– Canned, cartoned	Class I
– Frozen, nonwaxed, nonplastic containers	Class I
– Frozen (on paper or expanded plastic trays)	Class II
Powders (ordinary combustibles — free flowing)	
In paper bags (e.g., flour, sugar)	Class II
PVA (polyvinyl alcohol) Resins	
Bagged	Class IV
PVC (polyvinyl chloride)	
– Flexible (e.g., cable jackets, plasticized sheets)	Class III
– Rigid (e.g., pipe, pipe fittings)	Class III
– Bagged resins	Class III
Rags	
Baled	
– Natural fibers	Class III
– Synthetic fibers	Class IV
Rubber	
– Natural, blocks in cartons	Class IV
– Synthetic	Group A plastics
Salt	
– Bagged	Class I
– Packaged, cartoned	Class II
Shingles	
– Asphalt-coated fiberglass	Class III
– Asphalt-impregnated felt	Class IV
Shock Absorbers	
– Metal dust cover	Class II
– Plastic dust cover	Class III
Signatures	
Books, magazines	
– Solid array on pallet	Class II
Skis	
– Wood	Class III
– Foam core	Class IV
Stuffed Toys	
Foam or synthetic	Group A plastics
Syrup	
– Drummed (metal containers)	Class I
– Barreled, wood	Class II
Textiles	
Natural fiber clothing or textile products	Class III
Synthetics (except rayon and nylon) — 50/50 blend or less	
– Thread, yarn on wood or paper spools	Class III
– Fabrics	Class III
– Thread, yarn on plastic spools	Class IV
– Baled fiber	Group A plastics
Synthetics (except rayon and nylon) — greater than 50/50 blend	
– Thread, yarn on wood or paper spools	Class IV
– Fabrics	Class IV
– Baled fiber	Group A plastics
– Thread, yarn on plastic spools	Group A plastics
Rayon and nylon	

Table A-2-1.3 Alphabetized Listing of Commodity Classes, *Continued*

Commodity	Commodity Class
– Baled fiber	Class IV
– Thread, yarn on wood or paper spools	Class IV
– Fabrics	Class IV
– Thread, yarn on plastic spools	Group A plastics
Tobacco Products	
In paperboard cartons	Class III
Transformers	
Dry and oil filled	Class I
Vinyl-Coated Fabric	
Cartoned	Group A plastics
Vinyl Floor Coverings	
– Tiles in cartons	Class IV
– Rolled	Group A plastics
Wax-Coated Paper	
Cups, plates	
– Boxed or packaged inside cartons (emphasis on packaging)	Class IV
– Loose inside large cartons	Group A plastics
Wax	
Paraffin, blocks, cartoned	Group A plastics
Wire	
– Bare wire on metal spools on wood skids	Class I
– Bare wire on wood or cardboard spools on wood skids	Class II
– Bare wire on metal, wood, or cardboard spools in cardboard boxes on wood skids	Class II
– Single- or multiple-layer PVC-covered wire on metal spools on wood skids	Class II
– Insulated (PVC) cable on large wood or metal spools on wood skids	Class II
– Bare wire on plastic spools in cardboard boxes on wood skids	Class IV
– Single- or multiple-layer PVC-covered wire on plastic spools in cardboard boxes on wood skids	Class IV
– Single, multiple, or power cables (PVC) on large plastic spools	Class IV
– Bulk storage of empty plastic spools	Group A plastics
Wood Products	
– Solid piles — lumber, plywood, particleboard, pressboard (smooth ends and edges)	Class II
– Spools (empty)	Class III
– Toothpicks, clothespins, hangers in cartons	Class III
– Doors, windows, wood cabinets, and furniture	Class III
– Patterns	Class IV

[1]The product is presumed to be in a plastic-coated package in a corrugated carton. If packaged in a metal foil, it can be considered Class I.

[2]Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.

[3]As the openings in plastic crates become larger, the product behaves more like a Class III commodity. Conversely, as the openings become smaller, the product behaves more like a plastic.

[4]These items should be treated as idle pallets.

[5]Tests clearly indicate that a synthetic or synthetic blend is considered greater than Class III.

[6]Where liquor is stored in glass containers in racks, it should be considered a Class III commodity; where it is palletized, it should be considered a Class IV commodity.

A-2-1.3.1 See Table A-2-1.3.1.

Table A-2-1.3.1 Examples of Class I Commodities

Alcoholic Beverages
Cartoned or uncartoned
– Up to 20 percent alcohol in metal, glass, or ceramic containers
Appliances, Major (e.g., stoves, refrigerators)
– Not packaged, no appreciable plastic exterior trim
Batteries
Dry cells (nonlithium or similar exotic metals)
– Packaged in cartons
Automobile
– Filled*
Bottles, Jars
Empty, cartoned
– Glass
Filled noncombustible liquids
– Glass, cartoned
– Plastic, cartoned [less than 5 gal (18.9 L)]
Plastic, PET
Filled noncombustible powders
– Glass, cartoned
Canned Foods
In ordinary cartons
Cans
Metal
– Empty
Cement
Bagged
Coffee
– Canned, cartoned
Fertilizers
Bagged
– Phosphates
File Cabinets
Metal
– Cardboard box or shroud
Fish or Fish Products
Frozen
– Nonwaxed, nonplastic packaging
Canned
– Cartoned

(continues)

Table A-2-1.3.1 Examples of Class I Commodities, *Continued*

Frozen Foods
– Nonwaxed, nonplastic packaging
Fruit
Fresh
– Nonplastic trays or containers
– With wood spacers
Ice Cream
Meat, Meat Products
– Bulk
– Canned, cartoned
– Frozen, nonwaxed, nonplastic containers

Metal Desks
With plastic tops and trim
Milk
– Nonwaxed-paper containers
– Waxed-paper containers
– Plastic containers
Motors
Electric
Nuts
Canned, cartoned
Paints
Friction-top cans, cartoned
– Water-based (latex)
Plastic Containers
– Noncombustible liquids or semiliquids in plastic containers less than 5 gal (18.9 L) capacity
Poultry Products
– Canned, cartoned
– Frozen, nonwaxed, nonplastic containers
Salt
Bagged
Syrup
– Drummed (metal containers)

Transformers
Dry and oil filled
Wire
Bare wire on metal spools on wood skids

*Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.

A-2-1.3.2 See Table A-2-1.3.2.

Table A-2-1.3.2 Examples of Class II Commodities

Alcoholic Beverages
– Up to 20 percent alcohol in wood containers

Appliances, Major (e.g., stoves)
– Corrugated, cartoned (no appreciable plastic trim)
Baked Goods
Cookies, cakes, pies
– Frozen, packaged in cartons*

Table A-2-1.3.2 Examples of Class II Commodities, *Continued*

Batteries
Dry cells (nonlithium or similar exotic metals) in blister pack in cartons
Bottles, Jars
Filled noncombustible powders
– Plastic PET
Boxes, Crates
– Empty, wood, solid walls
Fertilizers
Bagged
– Nitrates
Fish or Fish Products
Frozen
– Waxed-paper containers, cartoned
– Boxed or barreled
Frozen Foods
– Waxed-paper containers, cartoned
Leather Hides
Baled

Light Fixtures
Nonplastic
– Cartoned
Marble
Artificial sinks, countertops
– Cartoned, crated
Meat, Meat Products
– Frozen, waxed-paper containers
– Frozen, expanded plastic trays
Pharmaceuticals
Pills, powders
– Glass bottles, cartoned
Nonflammable liquids
– Glass bottles, cartoned
Photographic Film
– Motion picture or bulk rolls in polycarbonate, polyethylene, or metal cans; polyethylene bagged in cardboard boxes
Plastic Containers
Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of $^1/_4$ in. (6.4 mm) or less and larger than 5 gal (18.9 L) capacity
Poultry Products
Frozen (on paper or expanded plastic trays)
Powders (ordinary combustibles — free flowing)
In paper bags (e.g., flour, sugar)
Salt
Packaged, cartoned
Shock Absorbers
Metal dust cover
Signatures
Books, magazines
– Solid array on pallet
Syrup
Barreled, wood

Table A-2-1.3.2 Examples of Class II Commodities, *Continued*

Wire
– Bare wire on wood or cardboard spools on wood skids
– Bare wire on metal, wood, or cardboard spools in cardboard boxes on wood skids
– Single-layer or multiple-layer PVC-covered wire on metal spools on wood skids
– Insulated (PVC) cable on large wood or metal spools on wood skids
Wood Products
Solid piles
– Lumber, plywood, particleboard, pressboard (smooth ends and edges)

*The product is in a plastic-coated package in a corrugated carton. If packaged in a metal foil, it can be considered Class I.

A-2-1.3.3 See Table A-2-1.3.3.

Table A-2-1.3.3 Examples of Class III Commodities

Aerosols
Cartoned or uncartoned
– Level 1
Baked Goods
Cookies, cakes, pies
– Packaged in cartons
Beans
Dried
– Packaged, cartoned
Bread
Wrapped, cartoned
Butter
Whipped spread
Candy
Packaged, cartoned
Cartons
Corrugated
– Unassembled (neat piles)
Cereals
Packaged, cartoned
Charcoal
Bagged
– Standard
Cheese
– Packaged, cartoned
– Wheels, cartoned
Chewing Gum
Packaged, cartoned
Chocolate
Packaged, cartoned
Cloth
Cartoned and not cartoned
– Natural fiber, viscose
Cocoa Products
Packaged, cartoned

Table A-2-1.3.3 Examples of Class III Commodities, *Continued*

Coffee
Packaged, cartoned
Coffee Beans
Bagged
Cotton
Packaged, cartoned
Diapers
Cotton, linen
Dried Foods
Packaged, cartoned
Fish or Fish Products
Frozen
– Plastic trays, cartoned
Frozen Foods
Plastic trays
Furniture
Wood
– No plastic coverings or foam plastic cushioning
Grains — Packaged in cartons
– Barley
– Rice
– Oats
Margarine
Up to 50 percent oil (in paper or plastic containers)
Mattresses
Standard (box spring)
Nuts
– Packaged, cartoned
– Bagged
Paper Products
Books, magazines, stationery, plastic-coated paper food containers, newspapers, cardboard games, cartoned tissue products
Paper, Rolled
In racks or on side
– Medium or heavyweight
Photographic Film
– 35-mm in metal film cartridges in polyethylene cans in cardboard boxes
– Paper, in sheets, bagged in polyethylene, in cardboard boxes
PVC (polyvinyl chloride)
– Flexible (e.g., cable jackets, plasticized sheets)
– Rigid (e.g., pipe, pipe fittings)
– Bagged resins
Rags
Baled
– Natural fibers
Shingles
Asphalt-coated fiberglass
Shock Absorbers
Plastic dust cover
Skis
Wood

(continues)

Table A-2-1.3.3 Examples of Class III Commodities, *Continued*

Textiles
Natural fiber clothing or textile products
Synthetics (except rayon and nylon) — 50/50 blend or less
– Thread, yarn on wood or paper spools
– Fabrics
Tobacco Products
In paperboard cartons
Wood Products
– Spools (empty)
– Toothpicks, clothespins, hangers in cartons
– Doors, windows, wood cabinets, furniture

A-2-1.3.4 See Table A-2-1.3.4.

Table A-2-1.3.4 Examples of Class IV Commodities

Ammunition
Small arms, shotgun
– Packaged, cartoned
Bottles, Jars
Empty, cartoned
– Plastic PET (polyethylene terephthalate)
Filled noncombustible powders
– Plastic, cartoned [less than 1 gal (3.8 L)]
Cartons
Corrugated
– Partially assembled
Cloth
Cartoned and not cartoned
– Synthetic[1]
Diapers
– Disposable with plastics and nonwoven fabric (in cartons)
Fiberglass Insulation
– Paper-backed rolls, bagged or unbagged
Furniture
Wood
– With plastic coverings
Liquor
100 proof or less, one gal (3.8 L) or less, cartoned
– Glass (palletized)[2]
– Plastic bottles
Matches
Packaged, cartoned
– Paper
Nail Polish
– 1-oz to 2-oz (29.6-ml to 59.1-ml) glass, cartoned
Paints
Friction-top cans, cartoned
– Oil based
Paper, Rolled
In racks
– Lightweight
Paper, Waxed
Packaged in cartons

Table A-2-1.3.4 Examples of Class IV Commodities, *Continued*

Pharmaceuticals
Pills, powders
– Plastic bottles, cartoned
Photographic Film
– Rolls in polycarbonate plastic cassettes, bulk wrapped in cardboard boxes
PVA (polyvinyl alcohol) Resins
Bagged
Rags
Baled
– Synthetic fibers
Rubber
Natural, blocks in cartons
Shingles
Asphalt-impregnated felt
Skis
Foam core
Textiles
Synthetics (except rayon and nylon) — 50/50 blend or less
– Thread, yarn on plastic spools
Synthetics (except rayon and nylon) — greater than 50/50 blend
– Thread, yarn on wood or paper spools
– Fabrics
Rayon and nylon
– Baled fiber
– Thread, yarn on wood or paper spools
– Fabrics
Vinyl Floor Coverings
Tiles in cartons
Wax-Coated Paper
Cups, plates
– Boxed or packaged inside cartons (emphasis on packaging)
Wire
– Bare wire on plastic spools in cardboard boxes on wood skids
– Single-layer or multiple-layer PVC-covered wire on plastic spools in cardboard boxes on wood skids
– Single, multiple, or power cables (PVC) on large plastic spools
Wood Products
Patterns

[1]Tests clearly indicate that a synthetic or synthetic blend is considered greater than Class III.
[2]Where liquor is stored in glass containers in racks, it should be considered a Class III commodity; where it is palletized, it should be considered a Class IV commodity.

A-2-1.4.1 See Table A-2-1.4.1.

Table A-2-1.4.1 Examples of Group A Plastic Commodities

Batteries
Truck or larger
– Empty or filled[1]

Table A-2-1.4.1 Examples of Group A Plastic Commodities, *Continued*

Bottles, Jars
Empty, cartoned
– Plastic (other than PET), any size
Filled noncombustible liquids
– Plastic, open or solid plastic crates[2]
Filled noncombustible powders
– Plastic, cartoned or uncartoned [greater than 1 gal (3.8 L)]
– Plastic, solid plastic crates
– Plastic, open plastic crates
Candles
Packaged, cartoned
– Treat as expanded plastic
Carpet Tiles
Cartoned
Cartons
Wax coated, single walled
Diapers
Disposable with plastics and nonwoven fabric (uncartoned), plastic wrapped
Furniture
Wood
– With foam plastic cushioning
Lighters
Butane
– Blister-packed, cartoned
Margarine
Between 50 percent and 80 percent oil (in any packaging)
Matches
Packaged, cartoned
– Wood
Mattresses
Foam (in finished form)
Milk
Containers in plastic crates
Nail Polish
1-oz to 2-oz (29.6-ml to 59.1-ml) plastic bottles, cartoned
Paper Products
Tissue products, uncartoned and plastic wrapped
Plastic Containers
– Combustible or noncombustible solids in plastic containers and empty plastic containers
– Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness greater than $^1/_4$ in. (6.4 mm) and larger than 5 gal (18.9 L) capacity
Polyurethane
Cartoned or uncartoned expanded
Rubber
Synthetic
Stuffed Toys
Foam or synthetic
Textiles
Synthetics (except rayon and nylon) — 50/50 blend or less
– Baled fiber
Synthetics (except rayon and nylon) — greater than 50/50 blend
– Baled fiber
– Thread, yarn on plastic spools
Rayon and nylon
– Thread, yarn on plastic spools
Vinyl-Coated Fabric
Cartoned
Vinyl Floor Coverings
Rolled
Wax-Coated Paper
Cups, plates
– Loose inside large cartons
Wax
Paraffin, blocks, cartoned
Wire
Bulk storage of empty plastic spools

[1]Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic. Truck batteries, even where filled, should be considered a Group A plastic because of their thicker walls.
[2]As the openings in plastic crates become larger, the product behaves more like a Class III commodity. Conversely, as the openings become smaller, the product behaves more like a plastic.

A-4-1 Rack storage as referred to in this standard is based on commodities in a rack structure, usually steel. Dimensions are varied. Racks can be configured as single-row, double-row, or multiple-row, with or without solid shelves. The standard commodity used in most of the tests was 42 in. (1.1 m) on a side. The types of racks covered in this standard are as follows:

(a) *Double-Row Rack.* The pallet of a double-row rack rests on two beams that are parallel to the aisle. Any number of pallets can be supported by one pair of beams. *[See Figures A-4-1(a) through (d).]*

(b) *Automatic Storage-Type Rack.* The pallet of an automatic storage-type rack is supported by two rails that run perpendicular to the aisle. *[See Figure A-4-1(e).]*

(c) *Multiple-Row Rack More than Two Pallets Deep, Measured Aisle to Aisle.* Such a multiple-row rack includes drive-in racks, drive-through racks, flow-through racks, portable racks that are arranged in the same manner as multiple-row racks, and conventional or automatic racks with aisles less than 42 in. (1.1 m) wide. *[See Figures A-4-1(f) through (i).]*

Movable Rack. A movable rack moves on fixed rails or guides. It can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. *[See Figure A-4-1(k).]*

Solid Shelving. Solid shelving consists of a conventional pallet rack with plywood shelves on the shelf beams *[see Figures A-4-1(c) and (d)]*. Solid shelving is used in special cases. *(See Chapter 5.)*

Cantilever Rack. The load of a cantilever rack is supported on arms that extend horizontally from columns. The load can rest on the arms or on shelves that are supported by the arms. *[See Figure A-4-1(j).]*

The load depth in conventional or automatic racks should be considered a nominal 4 ft (1.22 m). *[See Figure A-4-1(b).]*

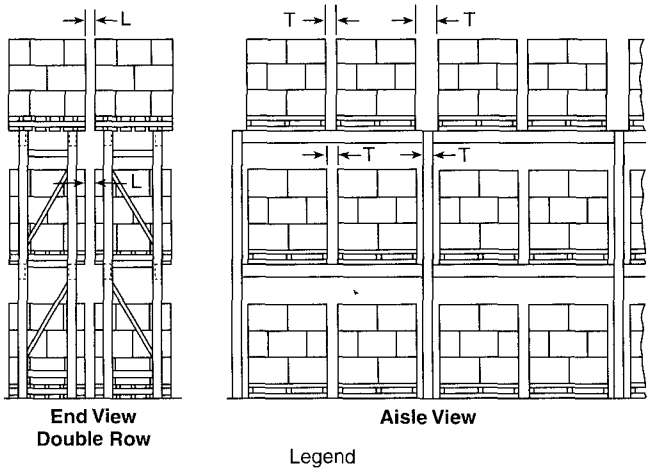


Figure A-4-1(a) Conventional pallet rack.

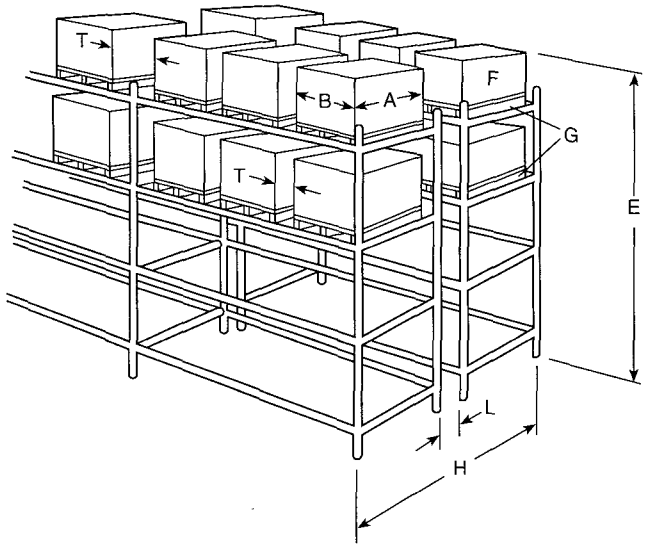


Figure A-4-1(b) Double-row racks without solid or slatted shelves.

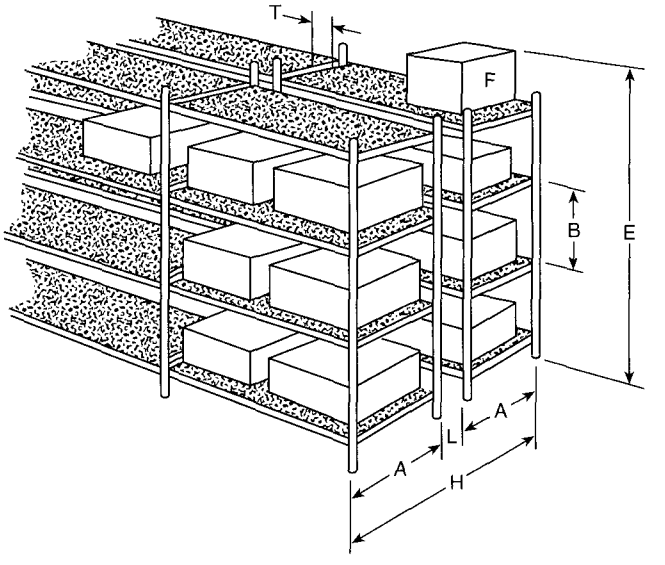


Figure A-4-1(c) Double-row racks with solid shelves.

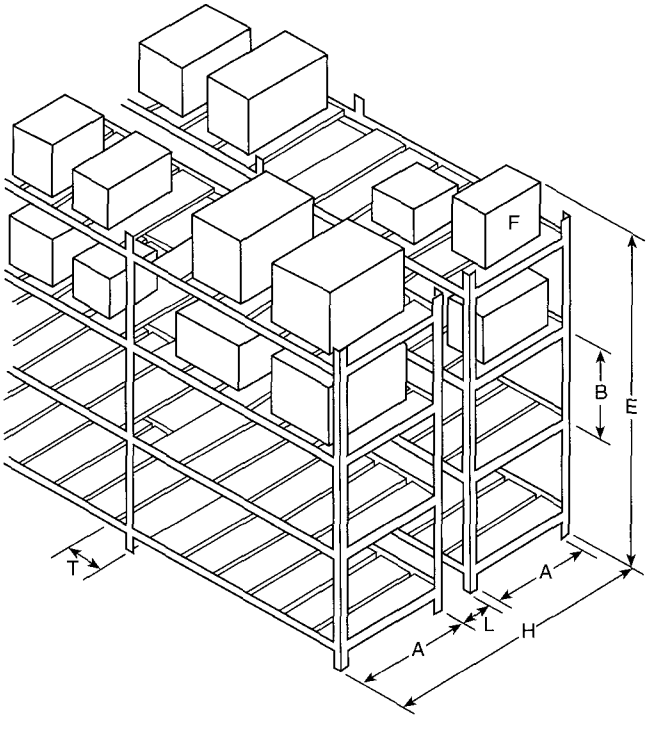
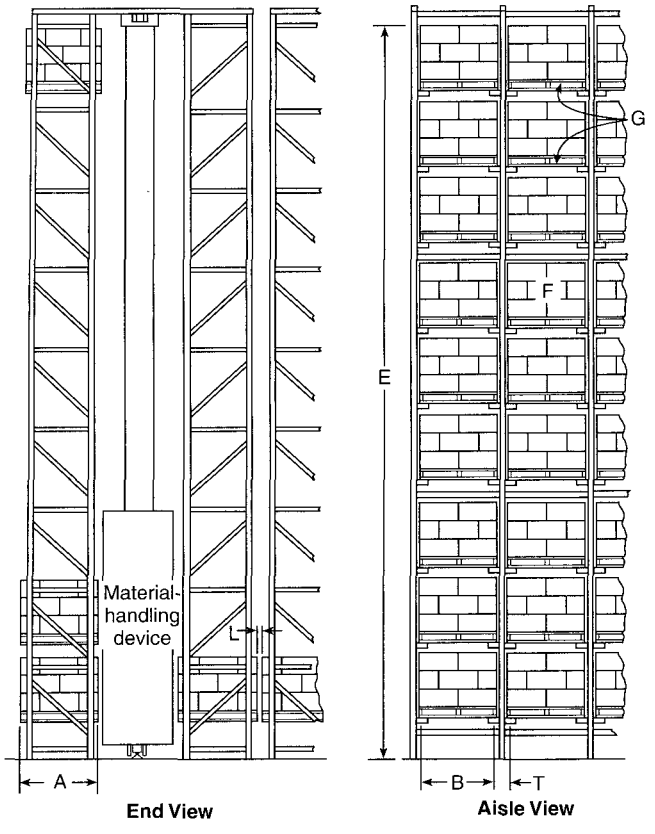


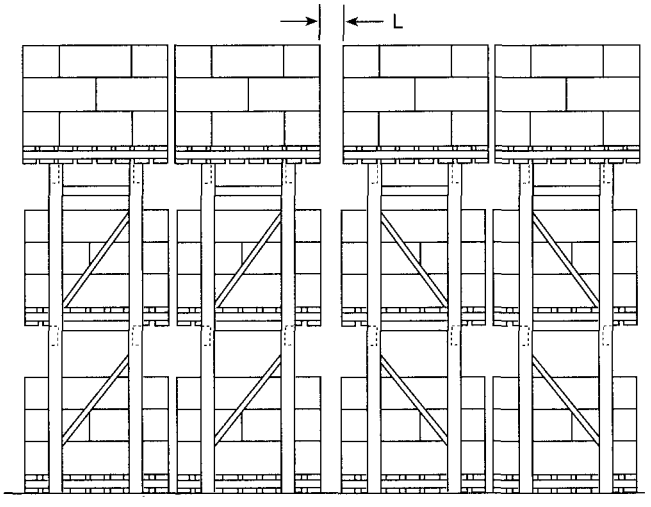
Figure A-4-1(d) Double-row racks with slatted shelves.



Legend

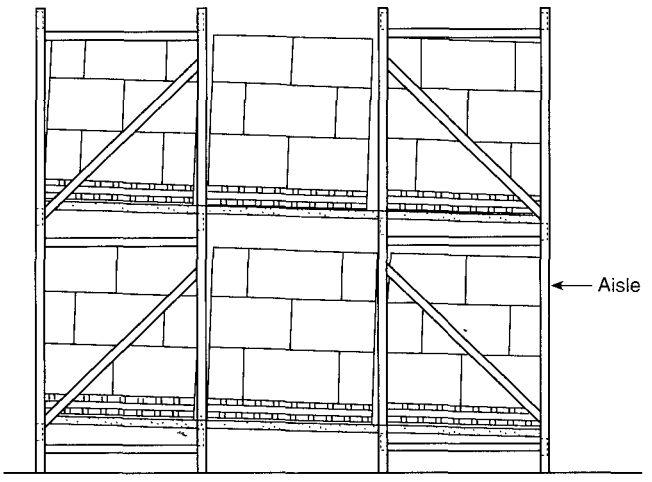
A – Load depth
B – Load width
E – Storage height
F – Commodity
G – Pallet
L – Longitudinal flue space
T – Transverse flue space

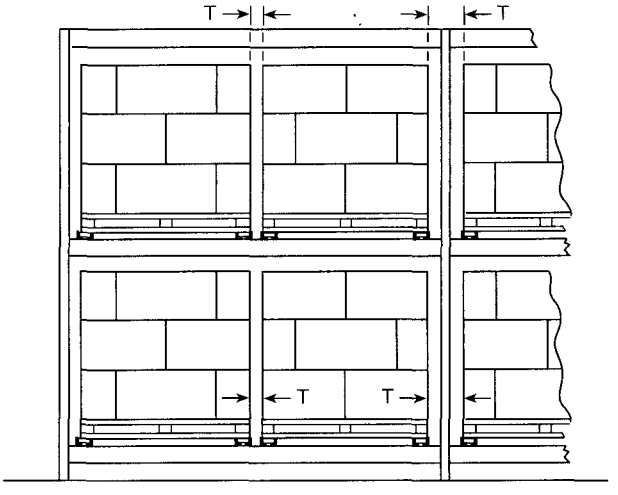
Figure A-4-1(e) Automatic storage-type rack.



L – Longitudinal flue space

Figure A-4-1(f) Multiple-row rack to be served by a reach truck.





T – Transverse flue space

Figure A-4-1(g) Flow-through pallet rack.