

231C

NFPA 231C

Standard for

Rack Storage

of Materials

1998 Edition



National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101

An International Codes and Standards Organization



Documents

Document Sharing Hub

IMPORTANT NOTICE ABOUT THIS DOCUMENT

NFPA codes, standards, recommended practices, and guides, of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the NFPA list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

See inside back cover for additional important notices and information.

01 00 99 98 11 10 9 8 7 6 5 4 3 2 1

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

Copyright © 1999 All Rights Reserved
NATIONAL FIRE PROTECTION ASSOCIATION

CHARLES S. MORGAN LIBRARY
NATIONAL FIRE PROTECTION ASSOCIATION
1 BATTERYMARCH PARK
QUINCY, MA 02269-9101

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	Encap- sulated	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	1.2	No	6-11(a)	C&D A&B	Yes	6-11(a)	F&H E&G	Yes
		Yes	4	1.2	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	II	No	4	1.2	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4	1.2	No	6-11(e)	C&D A&B		6-11(e)	G&H E&F	Yes
	III	No	4	1.2	No	6-11(c)	C&D A&B		6-11(c)	G&H E&F	Yes
		Yes	4	1.2	One level	6-11(f)	C&D A&B		NA	NA	NA
	IV	No	4	1.2	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4	1.2	One level	6-11(g)	C&D A&B		NA	NA	NA
	I	No	4	1.2	No	6-11(a)	C&D A&B		6-11(a)	F&H E&G	Yes
		Yes	4	1.2	One level	6-11(e)	C&D A&B		NA	NA	NA
	II	No	4	1.2	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4	1.2	One level	6-11(e)	C&D A&B		NA	NA	NA
Over 20 ft (6.1 m) up to and including 22 ft (6.7 m)	III	No	4	1.2	No	6-11(c)	C&D A&B	No	6-11(c)	G&H E&F	Yes
		Yes	4	1.2	One level	6-11(f)	C&D A&B		NA	NA	NA
	IV	No	4	1.2	No	6-11(d)	C&D A&B		6-11(d)	G&H E&F	Yes
		Yes	4	1.2	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	1.2	No	6-11(a)	C&D A&B	No	6-11(a)	F&H E&G	Yes
		Yes	4	1.2	One level	6-11(e)	C&D A&B		NA	NA	NA
	II	No	4	1.2	No	6-11(b)	C&D A&B		6-11(b)	G&H E&F	Yes
		Yes	4	1.2	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	Encap- sulated	Aisles (44.1) (B-6-11.2)		Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
			ft	m		With In-Rack Sprinklers		Without In-Rack Sprinklers		Apply Figure 6-9.2	
						Figure	Curves	Figure	Curves	Figure	Curves
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 A&B	No	6-11(c)	G&H E&F	Yes
		Yes	4	1.2	One level	6-11(f)	C&D A&B		NA	NA	NA
	IV		No	4					1.2	One level	6-11(d)
		Yes		4	1.2	6-11(g)	C&D A&B		NA		
			Yes	8	2.4				6-11(g)		C&D A&B
		Yes		8	2.4	6-11(g)	C&D A&B				

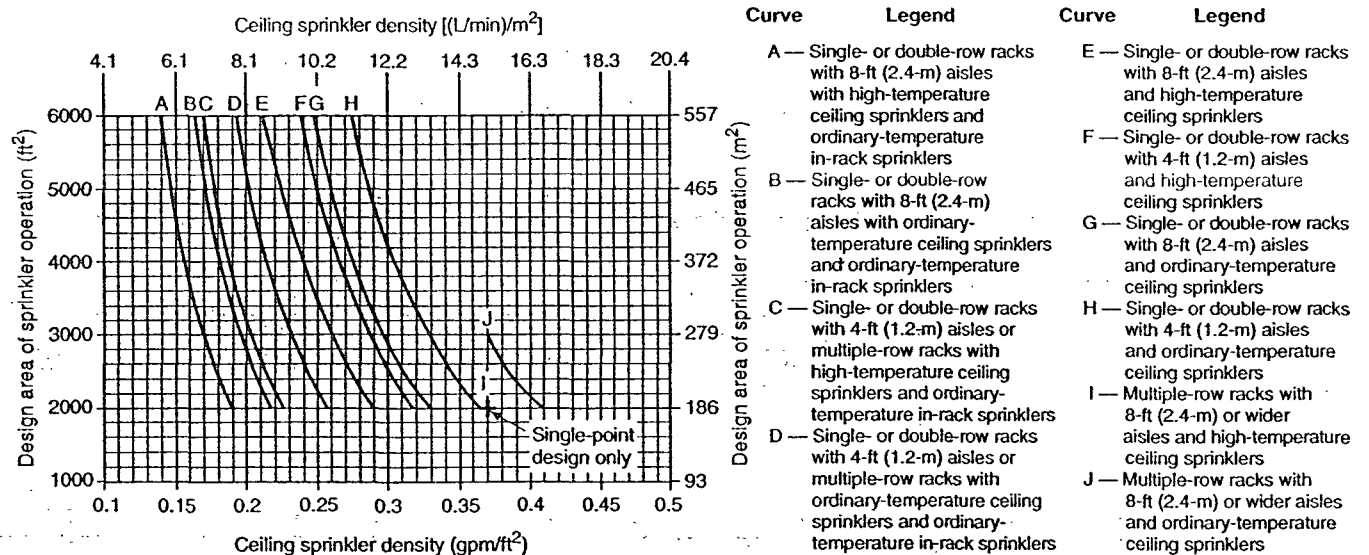


Figure 6-11(a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.

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)

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	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		6-11(d)			No	NA	NA	NA	NA
		Yes	Two levels	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	Encap- sulated	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)			I&J	Yes	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	Yes			
	III	No	6-11(c)	No			6-11(c)	I&J	Yes	No				
		Yes	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 × den- sity	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 × den- sity									
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	6-11(d)	No										
		Yes	Two levels	6-11(d)	1.50 × den- sity									

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

In-Rack Sprinklers — Approximate						Ceiling Sprinkler Density Clearance up to 10 ft ^{4,5,6}					
Commodity Class	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		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*

In-Rack Sprinklers — Approximate						Ceiling Sprinkler Density Clearance up to 10 ft ^{4,5,6}					
Commodity Class	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		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)	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
	Horizontal 10 ft (3.1 m)	Horizontal 10 ft (3.1 m)	7-8.1(i)		No			0.35	14.3	0.45	18.3
	Vertical 20 ft (6.1 m)	Vertical 20 ft (6.1 m) Horizontal 5 ft (1.5 m)									
	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

¹Minimum in-rack sprinkler discharge, 30 gpm (114 L/min) (see Section 7-6).

²Water shields required (see Sections 6-4 and 7-4).

³All in-rack sprinkler spacing dimensions start from the floor.

⁴For encapsulated commodity, increase density 25 percent (see 7-10.2).

⁵Clearance is distance between top of storage and ceiling.

⁶See 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).

⁷Install Sprinklers at least 3 in. (76.2 mm) from uprights (see Section 7-5).

⁸Face 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).

⁹In 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		Maximum Ceiling/Roof Height		Type of System	Number of Design Sprinklers by Minimum Operating Pressure [psi (bar)]			Hose Stream Demand		Water Supply Duration (hr)
	ft	m	ft	m		25 (1.7)	50 (3.4)	75 (5.2)	gal/min	L/min	
I, II	25	7.6	30	9.1	Wet	20	20	20	500	1900	1½
					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	1½
					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	1½
I, II, III	20	6.1	30	9.1	Wet	15	15	15	500	1900	1½
					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	1½
					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	1½
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
					Dry	NA	NA	NA			

Note: NA — Not allowed

Table B-8.2.1 Summary of Test Results for Plastic Commodities Using $\frac{5}{8}$ -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/ft² = 40.8 (L/min)/m²

¹Main (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.

²Main (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.

³Transverse flues spaced 8 ft (2.4 m) apart [versus 3¹/₂ ft (1.1 m) apart in all other tests].

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

⁵Minor surface damage to cartons.

⁶High water demand.

⁷Excessive fire spread; marginally high water demand.

Copyright © 1998 NFPA, All Rights Reserved

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.

CHARLES S. MORGAN LIBRARY
NATIONAL FIRE PROTECTION ASSOCIATION
1 BATTERY MARCH PARK
QUINCY, MA 02269-9101



Documents
Document Sharing Hub

Technical Committee on Rack Storage

William P. Thomas, Chair
Kemper Nat'l Insurance Cos., IL [I]

William M. Carey, Underwriters Laboratories Inc., IL [RT]
Ralph E. Collins, R. E. Collins Assoc., MA [SE]
Robert B. Combs, J&H Marsh & McLennan, WA [I]
Herbert N. Davidson, Liberty Mutual Insurance Co., MA [I]
 Rep. Alliance of American Insurers
Robert C. Everson, Calabash, NC [SE]
James G. Gallup, Rolf Jensen & Assoc., Inc., IL [SE]
William W. Glassmyer, St. Onge Ruff & Assoc., Inc., PA [SE]
William J. Gotto, Howell Township Fire Dept., NJ [E]
Anthony C. Gumkowski, Travelers Insurance Cos., CT [I]
Joseph B. Hankins, Jr., Factory Mutual Research Corp., MA [I]
Sultan M. Javeri, AXA - Global Risks, France [I]
Richard S. Johnson, Hilton Head, SC [U]
 Rep. TC on General Storage
Tom Lawrence, Smith Fire Sprinkler Co., Inc., FL [IM]
 Rep. American Fire Sprinkler Assn., Inc.
Novell Liston, Rapistan Systems, UT [IM]
 Rep. Material Handling Inst. Inc.
Peter J. McWilliams, Eastman Kodak Co., NY [U]

Navin D. Mehta, U.S. Defense Logistic Agency (MMBIS), VA [U]
Jerome P. Merkel, United Sprinkler, Inc., MN [IM]
Andy Miller, Hallmark Cards Inc., MO [U]
 Rep. NFPA Industrial Fire Protection Section
Gerald W. O'Rourke, O'Rourke & Co., CA [SE]
Gene V. Paolucci, Yasuda Fire & Marine Insurance Co. of America, NY [I]
 Rep. American Insurance Services Group, Inc.
Douglas Rice, Central Sprinkler Corp., PA [M]
 Rep. American Fire Sprinkler Assn., Inc.
Chester W. Schirmer, Schirmer Engr Corp., NC [SE]
Todd E. Schumann, Industrial Risk Insurers, IL [I]
 Rep. Industrial Risk Insurers
Jack Thacker, Allan Automatic Sprinkler Corp. of Southern California, CA [IM]
 Rep. Nat'l Fire Sprinkler Assn.
Peter Thomas, The Viking Corp., MI [M]
 Rep. Nat'l Fire Sprinkler Assn.
William J. Tones, Tones, Van Rickley and Assoc., GA [SE]
 Rep. Home Depot

Alternates

Donald "Don" D. Becker, Midland Automatic Sprinkler Co., Inc., MO [IM]
 (Alt. to T. Lawrence)
Roland J. Huggins, American Fire Sprinkler Assn., TX [M]
 (Alt. to D. Rice)
Kenneth E. Isman, Nat'l Fire Sprinkler Assn., NY [IM]
 (Alt. to J. Thacker)
Dennis P. Jenkins, Kemper Nat'l Insurance Cos., NC [I]
 (Alt. to W. P. Thomas, Jr.)
Keith C. Kremkow, J&H Marsh & McLennan, IL [I]
 (Alt. to R. B. Combs)
George E. Laverick, Underwriters Laboratories Inc., IL [RT]
 (Alt. to W. M. Carey)
Russell Leavitt, Tones, Van Rickley and Assoc., CA [SE]
 (Alt. to W. J. Tones)

Francis J. Miklouchich, Eastman Kodak Co., NY [U]
 (Alt. to P. J. McWilliams)
Donald C. Moeller, Rolf Jensen & Assoc., Inc., CA [SE]
 (Alt. to J. G. Gallup)
Mark Oliszewicz, Schirmer Engr Corp., IL [SE]
 (Alt. to C. W. Schirmer)
Paul F. Roberto, Wausau HPR Engr, MI [I]
 (Alt. to H. N. Davidson)
Arthur H. Roede, The DuPont Co., DE [U]
 (Alt. to A. Miller)
Robert D. Spaulding, Factory Mutual Research Corp., MA [I]
 (Alt. to J. B. Hankins, Jr.)
Lee F. West, Travelers Insurance Cos., CT [I]
 (Alt. to A. C. Gumkowski)
Roger Wilkins, Grinnel Corp./Tyco, RI [M]
 (Alt. to P. Thomas)

Nonvoting

Christopher T. Lummus,
Insurance Services Office Inc., TX [I]

Milosh T. Puchovsky, NFPA Staff Liaison

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

Chapter 1 Introduction	231C- 5	6-13 In-Rack Sprinkler Location	231C-18
1-1 Application and Scope	231C- 5	6-14 Ceiling Sprinkler Water Demand	231C-20
1-2 Retroactivity Clause	231C- 5		
1-3 Definitions	231C- 5	Chapter 7 Spray Sprinkler Protection for Classes I, II, III, and IV Commodities for Storage over 25 ft (7.6 m) in Height	231C-21
Chapter 2 Classification of Storage	231C- 7	7-1 In-Rack Sprinkler Type	231C-21
2-1 Commodity Classifications	231C- 7	7-2 In-Rack Sprinkler Spacing	231C-21
Chapter 3 Building Construction	231C- 8	7-3 In-Rack Sprinkler Pipe Size	231C-21
3-1 Construction	231C- 8	7-4 In-Rack Sprinkler Water Shields	231C-21
3-2 Fire Protection of Steel	231C- 8	7-5 In-Rack Sprinkler Location	231C-21
3-3 Vents and Draft Curtains	231C- 8	7-6 In-Rack Sprinkler Discharge	231C-21
Chapter 4 Storage Arrangement	231C- 8	7-7 In-Rack Sprinkler Water Demand	231C-21
4-1 Rack Structure	231C- 8	7-8 In-Rack Sprinkler Location	231C-21
4-2 Rack Loading	231C- 8	7-9 Horizontal Barriers and In-Rack Sprinklers	231C-31
4-3 Flue Space	231C- 8	7-10 Ceiling Sprinkler Water Demand	231C-31
4-4 Aisle Width	231C- 8	7-11 In-Rack Sprinkler Location	231C-31
4-5 Storage Heights	231C- 9	7-12 In-Rack Sprinkler Spacing	231C-31
4-6 Commodity Clearances	231C- 9	7-13 Ceiling Sprinkler Water Demand	231C-31
4-7 Storage of Idle Pallets	231C- 9	Chapter 8 Spray Sprinkler Protection for Plastic Commodities	231C-36
Chapter 5 Fire Protection — General	231C- 9	8-1 General	231C-36
5-1 Protective Systems	231C- 9	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)	231C-36
5-2 Ceiling Sprinklers	231C- 9	8-3 Single-Row, Double-Row, and Multiple-Row Racks — Storage over 25 ft (7.6 m) in Height	231C-41
5-3 Ceiling Sprinkler Spacing	231C- 9		
5-4 In-Rack Sprinklers	231C- 9	Chapter 9 Large-Drop Sprinklers	231C-47
5-5 Sprinkler Waterflow Alarm	231C-10	9-1 General	231C-47
5-6 Hose Connections	231C-10	9-2 Other Requirements	231C-48
5-7 Hose Demand	231C-10		
5-8 Duration of Water Supplies	231C-10	Chapter 10 Early Suppression Fast Response (ESFR) Sprinklers	231C-49
5-9 High-Expansion Foam	231C-10	10-1 General	231C-49
5-10 Solid and Slatted Shelves	231C-11	10-2 Sprinkler System Design	231C-49
5-11 Open-Top Combustible Containers	231C-11	10-3 Water Demand	231C-49
5-12 Movable Racks	231C-11	10-4 Other Requirements	231C-49
Chapter 6 Spray Sprinkler Protection for Classes I, II, III, and IV Commodities ..	231C-11	Chapter 11 Equipment	231C-50
6-1 General	231C-11	11-1 Mechanical Handling Equipment — Industrial Trucks	231C-50
6-2 In-Rack Sprinkler Type	231C-11		
6-3 In-Rack Sprinkler Pipe Size	231C-11	Chapter 12 Building Maintenance and Operation	231C-50
6-4 In-Rack Sprinkler Water Shields	231C-11	12-1 Building Operations Other than Storage ..	231C-50
6-5 In-Rack Sprinkler Location	231C-11	12-2 Waste Disposal	231C-50
6-6 In-Rack Sprinkler Spacing	231C-11	12-3 Smoking	231C-50
6-7 In-Rack Sprinkler Discharge Pressure ..	231C-12	12-4 Maintenance	231C-50
6-8 In-Rack Sprinkler Water Demand	231C-12		
6-9 Ceiling Sprinkler Water Demand	231C-12		
6-10 Ceiling Sprinkler Discharge Criteria for Plastics Storage	231C-13		
6-11 Ceiling Sprinkler Water Demand	231C-14		
6-12 In-Rack Sprinkler Location	231C-18		

12-5 Plant Emergency Organization	231C-50	Appendix B Explanation of Test Data and Procedures	231C-66
12-6 General Fire Protection	231C-50		
Chapter 13 Referenced Publications	231C-50	Appendix C Referenced Publications	231C-73
Appendix A Explanatory Material	231C-51	Index	231C-73

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).]

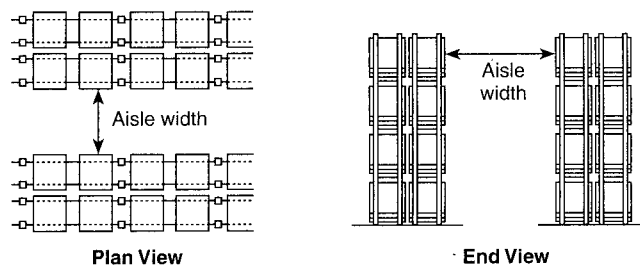


Figure 1-3(a) Illustration of aisle width.

Approved.* Acceptable to the authority having jurisdiction.

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

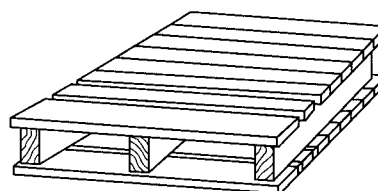
Bulkhead. A vertical barrier across the rack.

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).]



Conventional pallet

Solid flat-bottom wood pallet

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 ft² (372 m²) of the sprinklered area, whichever is greater. Such storage shall not exceed 1000 ft² (93 m²) 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).

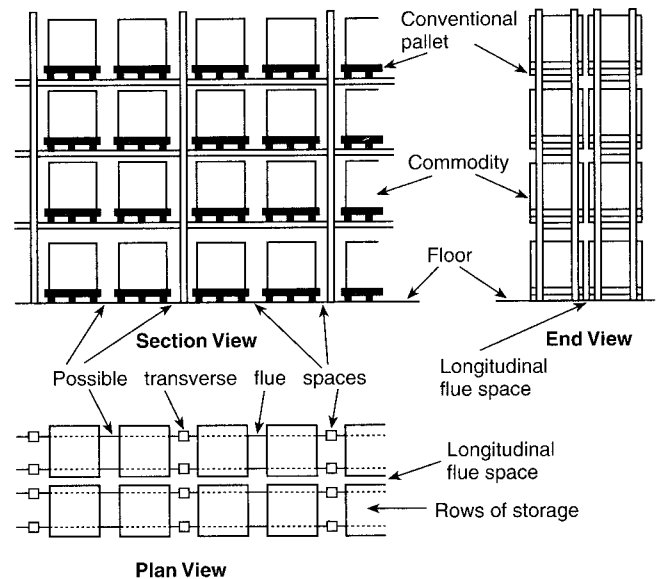


Figure 1-3(c) Typical double-row (back-to-back) rack arrangement.

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:

- It is placed directly on wooden pallets.
- It is placed in single-layer corrugated cartons, with or without single-thickness cardboard dividers, with or without pallets.
- 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:

- It is constructed partially or totally of Group B plastic.
- It consists of free-flowing Group A plastic materials.
- 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:

- Metal
- Wood
- Paper
- Natural or synthetic fibers
- 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 ft² (185.9 m²) 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.

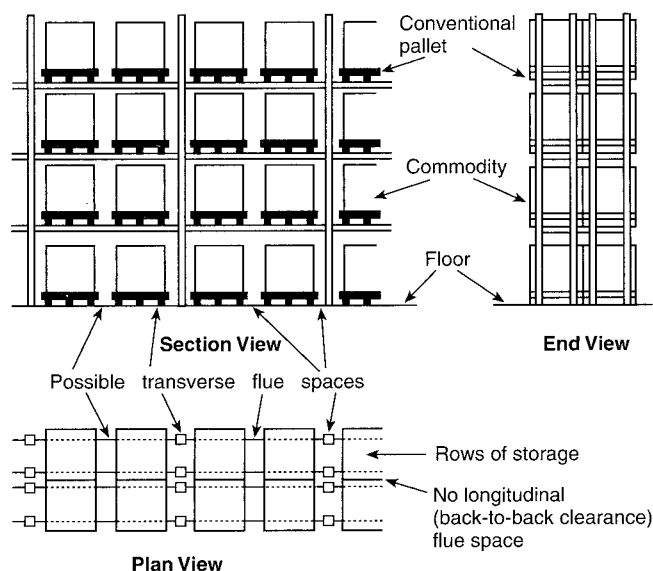
4-4.1 The aisle width and the depth of racks are determined by material-handling methods. The widths of aisles shall be considered in the design of the protection system. (See Chapters 5 through 7.)

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

Commodity Class	Aisle Width			
	4 ft (1.2 m)		8 ft (2.4 m)	
	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/ft² = (40.746 L/min)/m².



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 ft² (557.4 m²).

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 ft² (3716 m²) 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 [1½-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 1½ 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 1½ 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/ft² [(8.2 L/min)/m²] for Class I, II, or III commodities or 0.25 gpm/ft² [(10.2 L/min)/m²] for Class IV commodities for the most hydraulically remote 2000-ft² (186-m²) 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/ft² [(8.2 L/min)/m²] for Class I, II, or III commodities and 0.25 gpm/ft² [(10.2 L/min)/m²] for Class IV commodities for the most hydraulically remote 2000-ft² (186-m²) 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/ft² density [(24 L/min)/m²] over a minimum design area of 2000 ft² (186 m²) 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.)

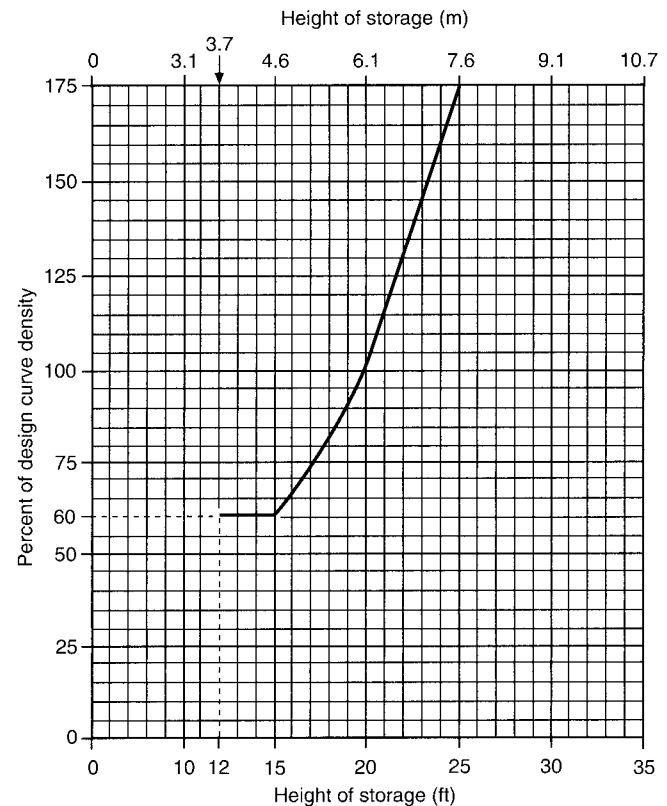


Figure 6-9.2 Ceiling sprinkler density versus storage height.

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 4½ 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 ft² (186 m²). (See 6-9.9.)

6-9.9 Where clearance from the ceiling to the top of Class I or Class II encapsulated storage is 1½ 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 ft² (186 m²).

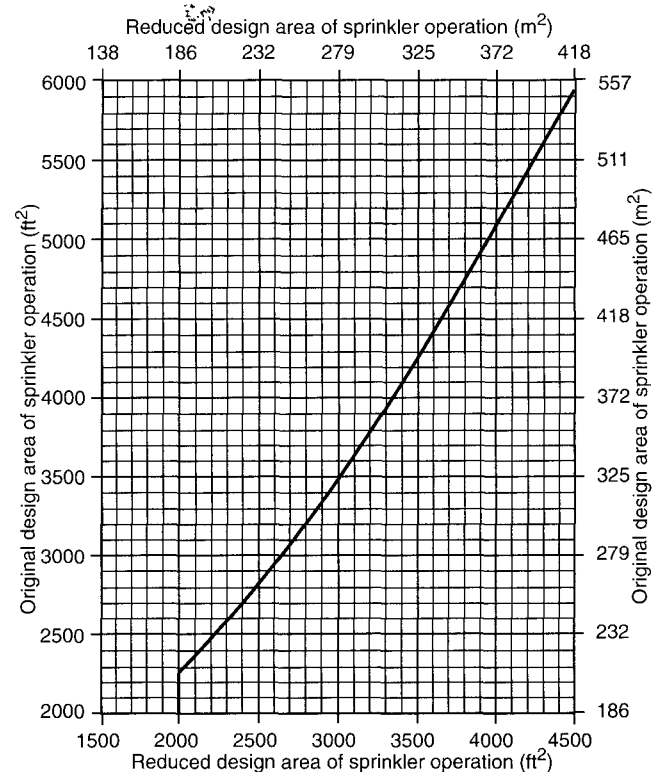


Figure 6-9.8 Adjustment of design area of sprinkler operation for clearance from top of storage to ceiling.

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/ft² [(L/min)/m²], and area of sprinkler operation [ft² (m²) 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

Height	Commodity Class	Encap- sulated	Aisles (4.4.1) (B-6-11.2)		Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand					
			ft	m		With In-Rack Sprinklers		Apply Figure 6-9.2	Without In-Rack Sprinklers		Apply Figure 6-9.2
						Figure	Curves		Figure	Curves	
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				

without Solid Shelves, Continued

Ceiling Sprinkler Water Demand													
Aisles (4-4.1) (B-6-11.2)													
With In-Rack Sprinklers													
Without In-Rack Sprinklers													
Apply Figure 6-9.2													
Apply Figure 6-9.2													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.2													
Curves													
Figure 6-9.													

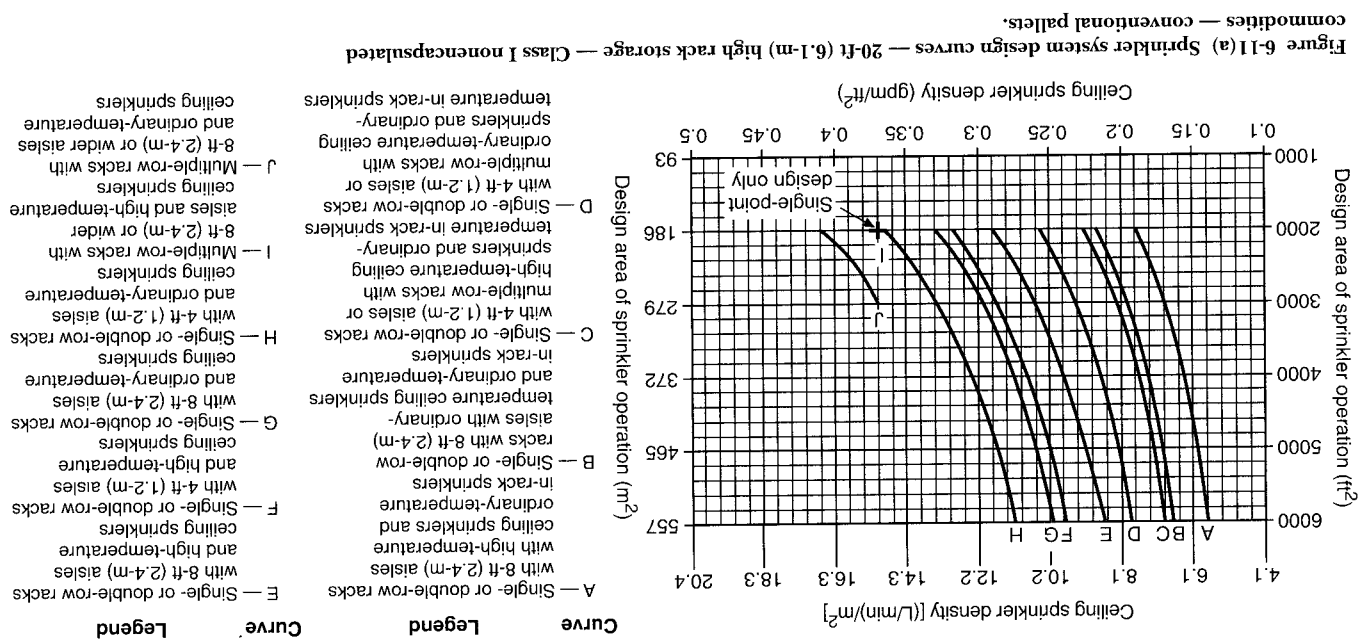


Figure 6-11 (a) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class I nonencapsulated commodities — conventional pallets.

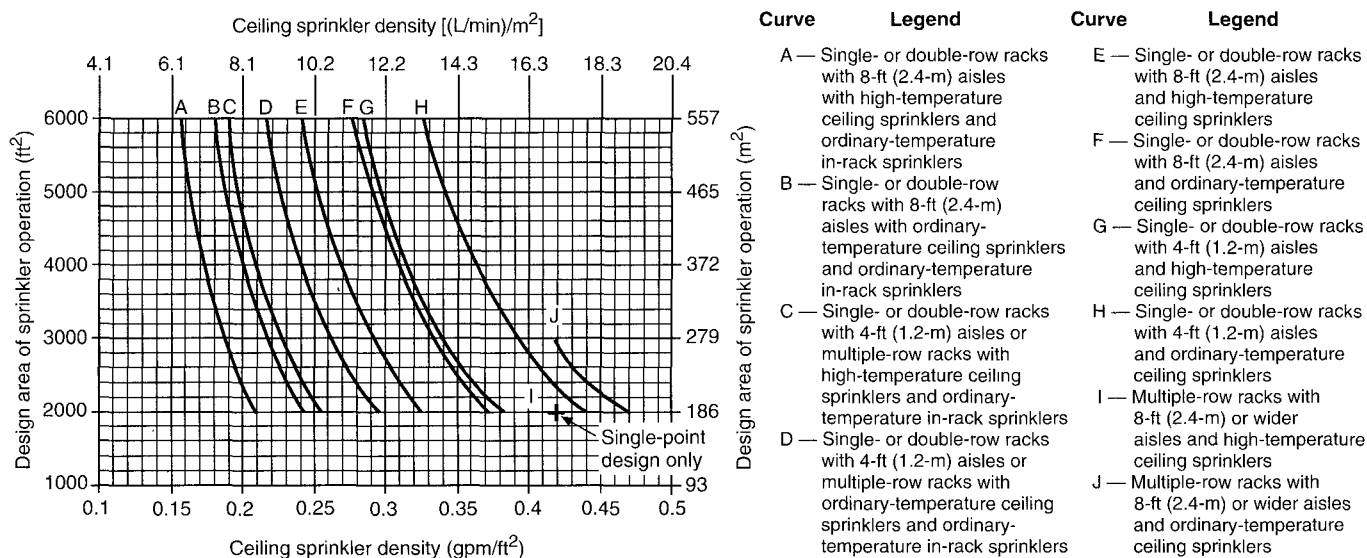


Figure 6-11(b) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class II nonencapsulated commodities — conventional pallets.

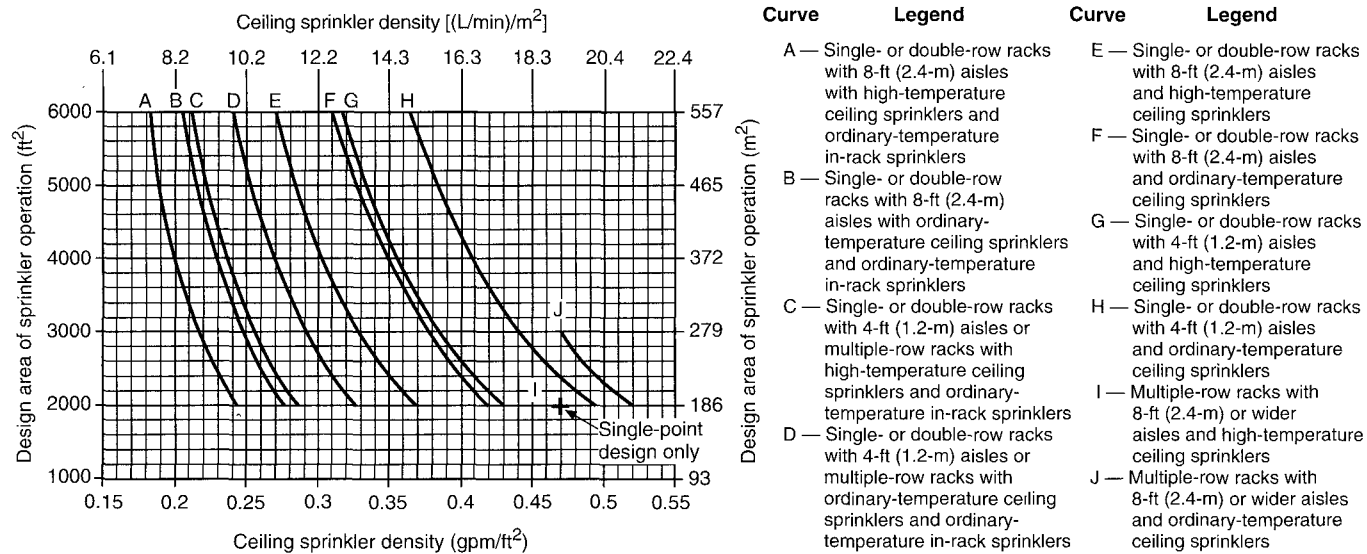


Figure 6-11(c) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class III nonencapsulated commodities — conventional pallets.

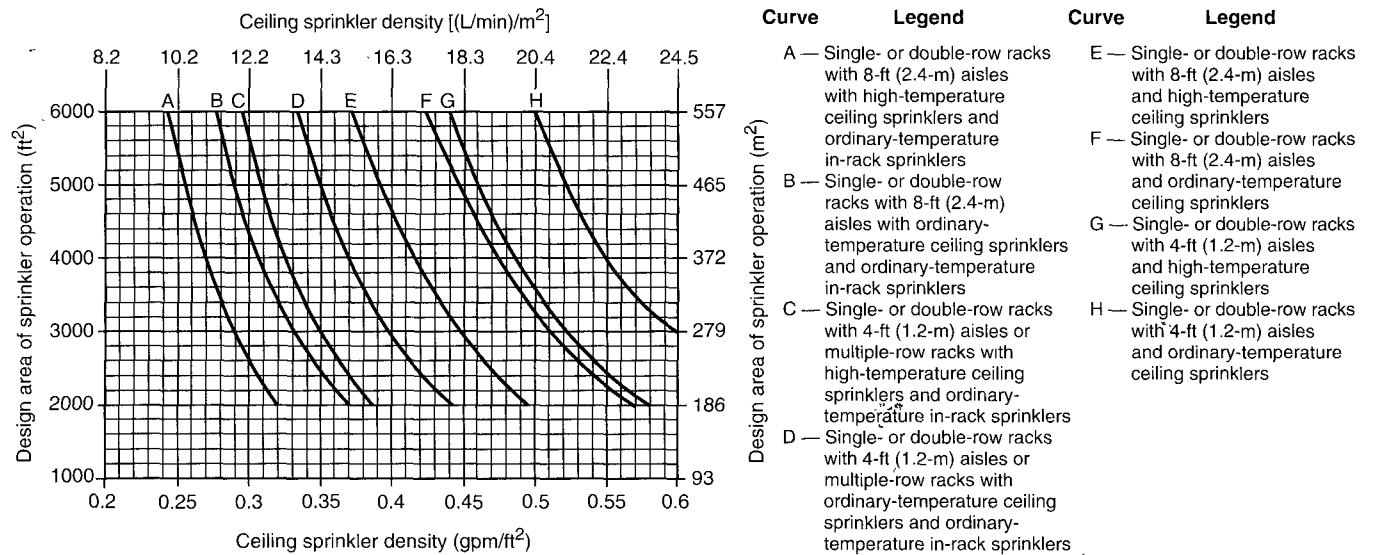


Figure 6-11(d) Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.

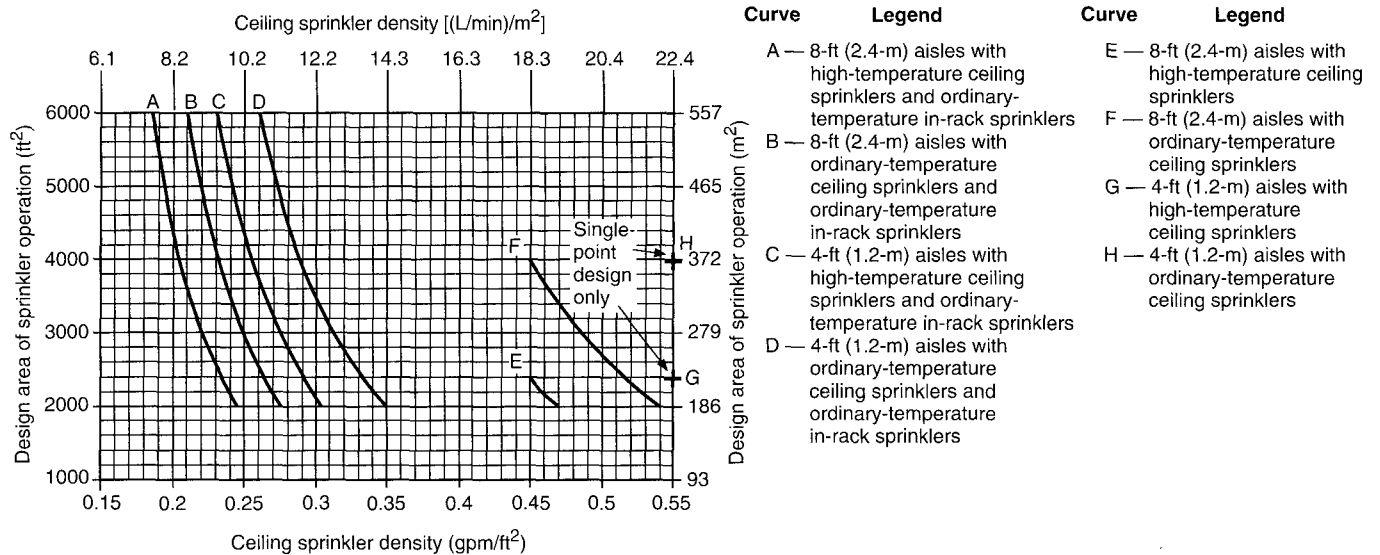


Figure 6-11(e) Single-row or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Classes I and II encapsulated commodities — conventional pallets.