



New Developments in the Protection of Li-ion Battery Production and Tall Dense Storage

Steven Wolin

Sr. Vice President

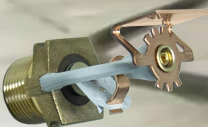
Product Technology & Compliance



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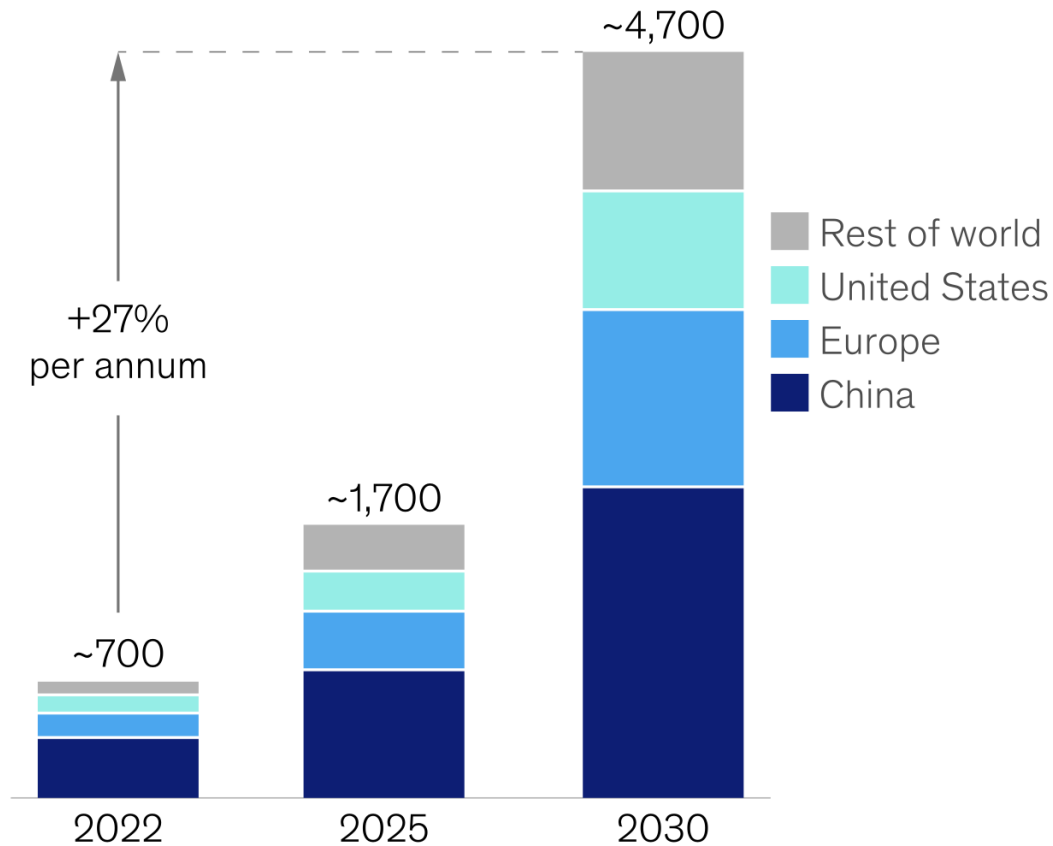


Reliable

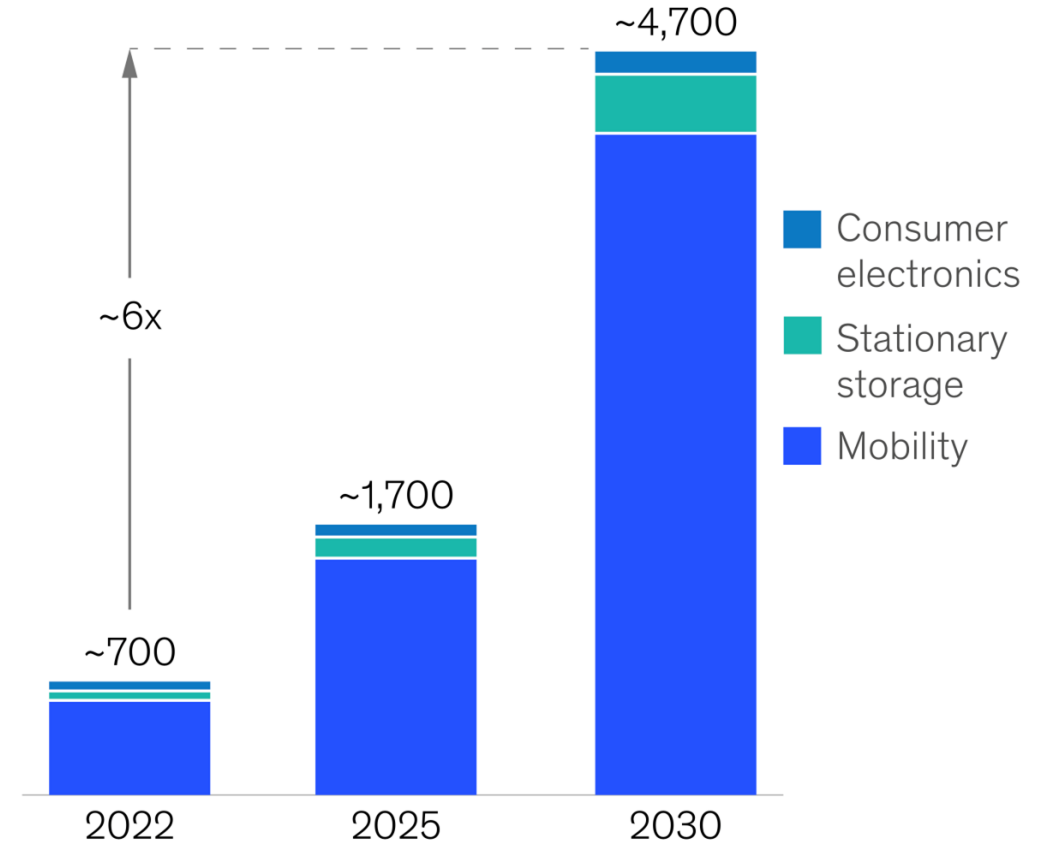
Li-ion battery demand is expected to grow by about 33 percent annually to reach around 4,700 GWh by 2030.

Global Li-ion battery cell demand, GWh, Base case

By region

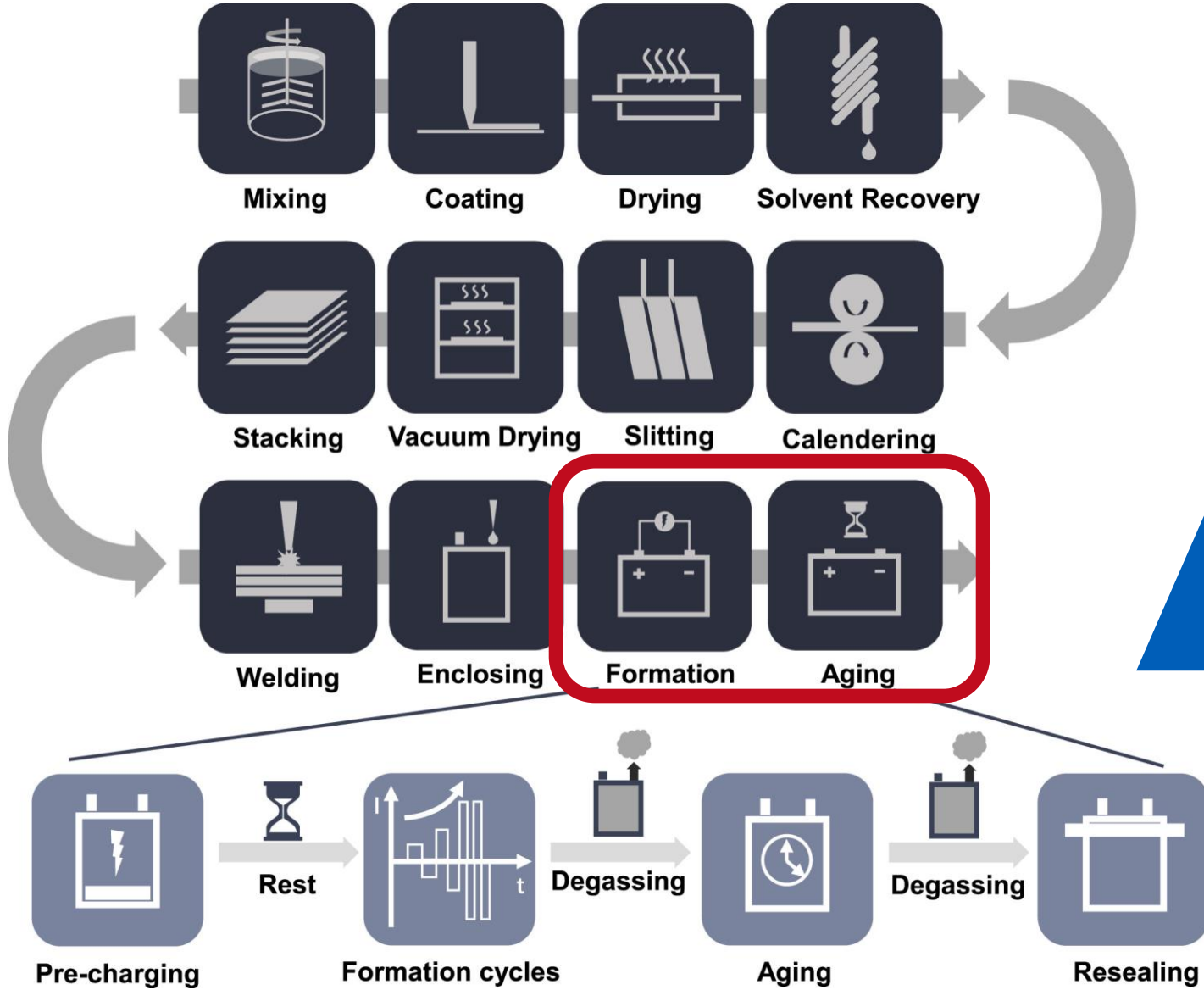


By sector



¹Including passenger cars, commercial vehicles, two-to-three wheelers, off-highway vehicles, and aviation.
Source: McKinsey Battery Insights Demand Model

Lithium-ion Battery Manufacturing Process



Formation and aging rooms typically include large racks that can charge and discharge millions of cells.

Different Types of Li-ion Cells



Class II Commodity



Class III Commodity



Class IV Commodity



Photo courtesy of FM Global

Cartoned Unexpanded Plastic Commodity



Cartoned Expanded Plastic Commodity



Uncartoned Unexpanded Plastic Commodity



Exposed Expanded Plastic Commodity

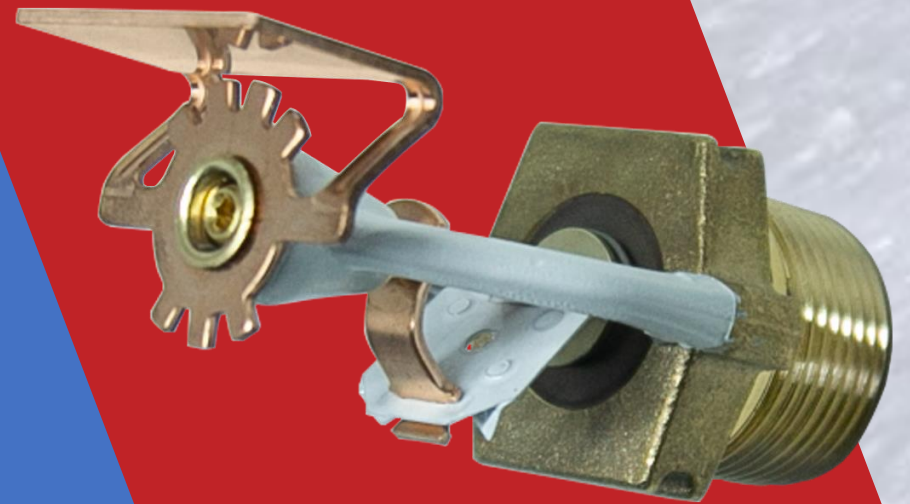


Why Create HSW Storage Sprinklers?



Reliable[®]

Model LB11
*Horizontal Sidewall
Storage Sprinkler*



Listed Specific Application Storage Arrangement

\\ Commodity:

- Class I-IV Commodity, Cartoned, Exposed, Nonexpanded, and Expanded Group A plastics

\\ Hydraulic design:

- 4 sprinklers (2 on 2 lines)
- 60 gpm (225 L/min) per sprinkler

\\ Hose stream:

- 250 gpm (950 L/min)

\\ Water supply duration:

- 1 hour

\\ Barriers:

- Horizontal (2 in. [50 mm] gaps at rack uprights)
- Vertical

\\ Balanced with ceiling-level sprinkler system:

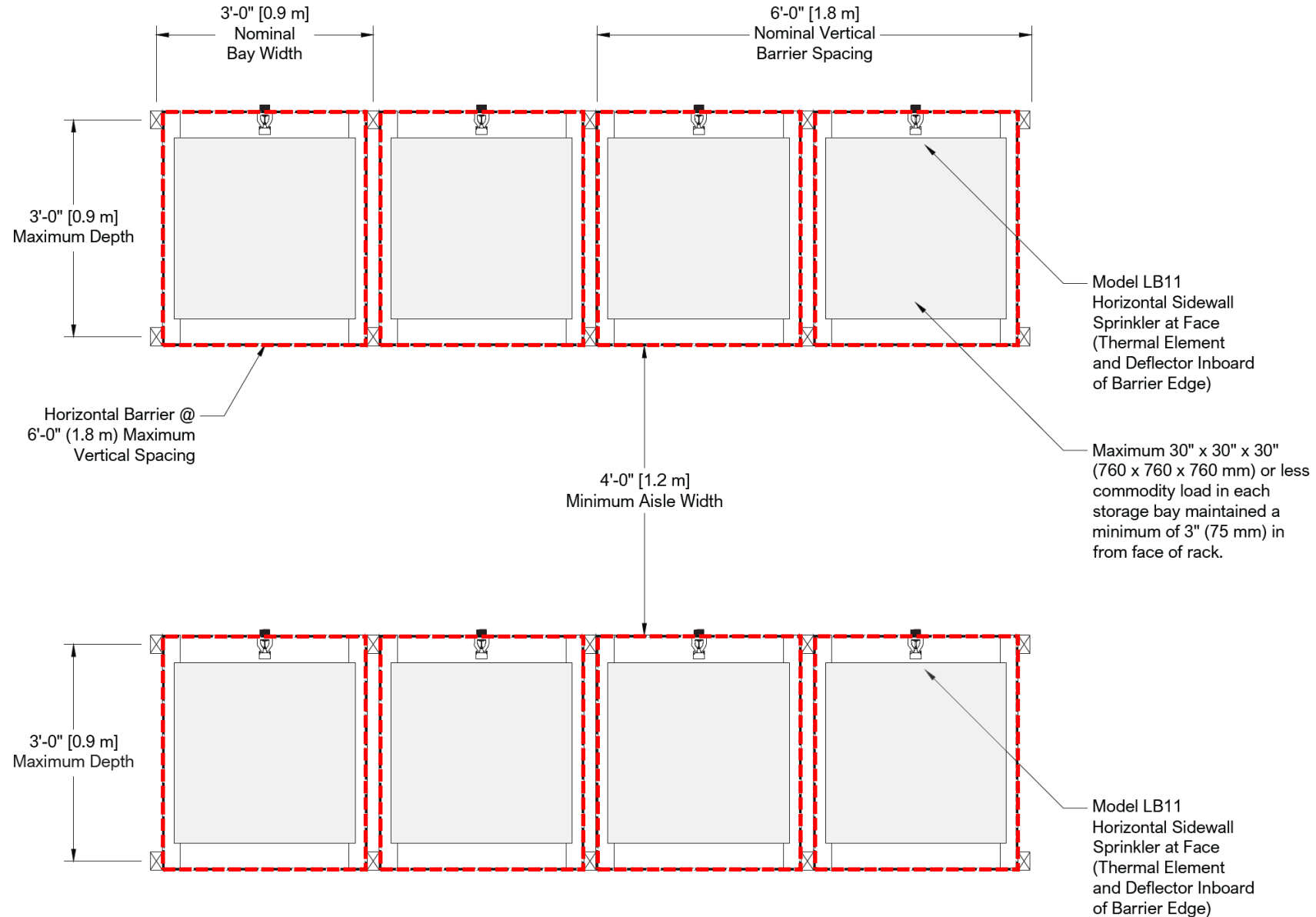
- Not required

Model LB11 Commodity Selection and Design Criteria

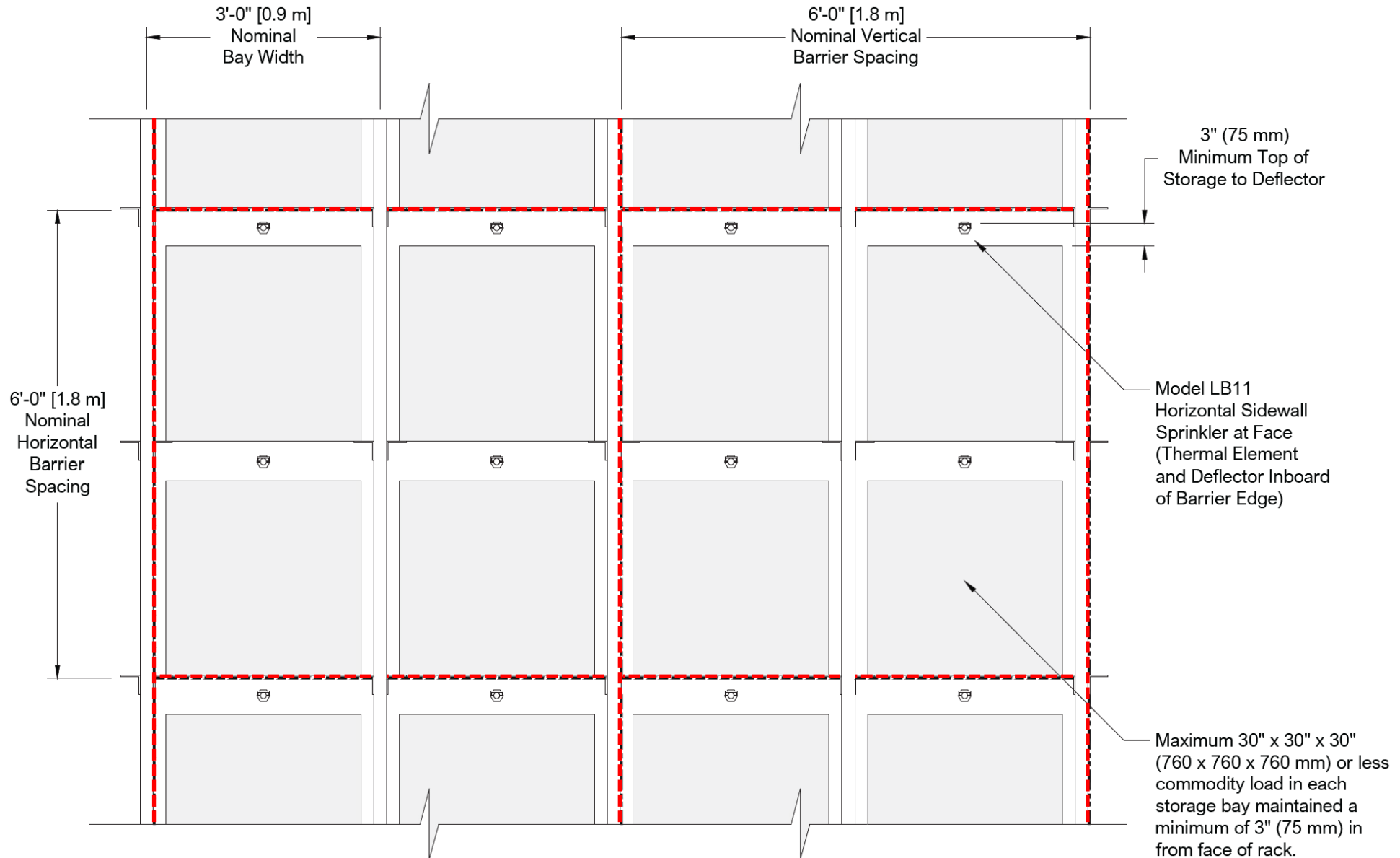
Table B

UL Specific Application Listing	
Model	LB11
Sprinkler Identification Number (SIN)	R505
Response Type	Fast
Orientation	Horizontal Sidewall
Nominal K-Factor, gpm/psi ^{1/2} (L/min/bar ^{1/2})	11.2 (160)
Temperature Rating °F (°C)	212 (100)
System Type	Wet, Single Interlock Preaction
Max. Sprinkler Spacing, ft (m) Lateral/Side-to-Side	4 (1.2)
Min. Deflector to Top of Storage Distance, in (mm)	3 (75)
Obstruction Criteria	Per NFPA 13
Max. Ceiling Height, ft (m)	Unlimited
Max. Storage Height, ft (m)	Unlimited
Storage Arrangement	Storage units consisting of combustible or non-combustible crates, totes, bins or boxes on a frame or rack in a single row configuration, with both horizontal and vertical barriers. Each storage bay nominally 3 ft wide by 3 ft tall (900 mm wide by 900 mm tall) and not exceeding 3 ft (0.9 m) deep. Vertical and horizontal barriers spaced 6 ft (1.8 m) apart. Storage units not exceeding 30 in. (760mm) on each side. Storage units maintained 3 in. (75mm) inboard of the face of the rack and barrier edges. See Figure 2 for storage and protection layout. Where open top containers are being protected the containers shall be provided with appropriate drainage.
Horizontal and vertical barrier construction	Horizontal and vertical barriers must be constructed of min. 3/8 in. (10 mm) plywood or particleboard, 22 gauge (0.7 mm) sheet metal, or equivalent. Vertical barriers must extend from a max. of 4 in. (100 mm) above the floor to the max. storage height. Horizontal barriers must extend from aisle to aisle. Horizontal barriers may have gaps of up to 2 in. (50 mm) at rack uprights only.
Min. Aisle Width, ft (m)	4 (1.2)
Flue Spaces	NA
Commodity	Encapsulated and unencapsulated Class I - IV commodities, cartoned, exposed, expanded, and unexpanded Group A plastic commodities.
Sprinkler System Design	Hydraulically calculate 4 sprinklers in the most remote area consisting of 2 sprinklers on 2 lines. Hydraulically calculate sprinklers at 60 gpm (225 L/min) each; not balanced with the ceiling-level sprinkler system; the ceiling-level sprinkler system must be designed in accordance with NFPA 13 to protect hazards and areas of the space not protected by the in-rack sprinkler system
Hose Stream Allowance, gpm (L/min)	250 (950)
Water Supply Duration, minutes	60
Installation Requirements Relative to Horizontal and Vertical Barriers	Sprinklers immediately below horizontal barriers shall be not more than 3 in. (75mm) below the barrier Four sprinklers shall be installed within each barriered area. All four sprinklers shall have deflectors and solder link located fully within the barriers. Maximum distance 20 in. (500 mm) from each vertical barrier to nearest sprinkler

Specific Application Storage Arrangement Plan View



Specific App. Storage Arrangement Elevation View



Model LB11 Horizontal Sidewall

\\ cULus Listed:

- 199K Outline of Investigation for Fire Testing Specific Application Horizontal Sidewall Sprinklers for Installation in Racks Having Vertical and Horizontal Barriers
- Specific Application design criteria applies

\\ K-factor:

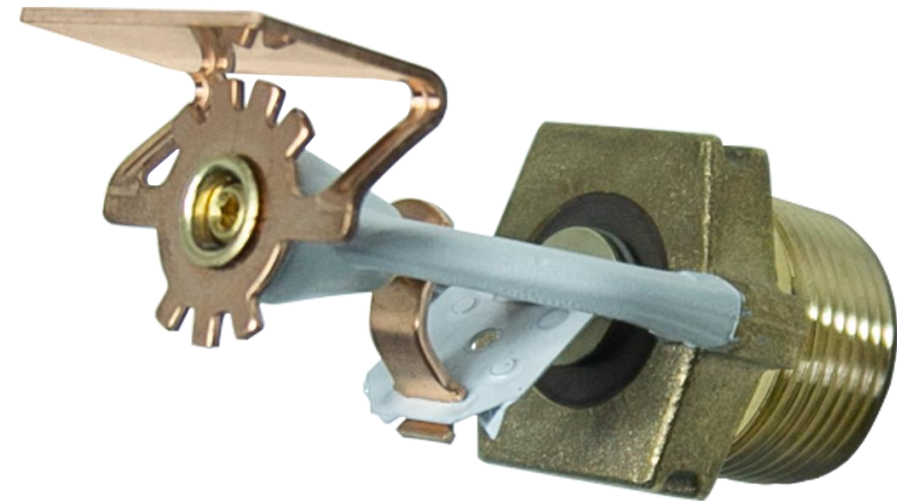
- 11.2 (160)

\\ Temperature rating:

- 212°F (100°C)

\\ Maximum pressure rating:

- 175 psi (12.1 bar)



Model
LB11 HSW








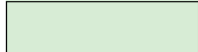

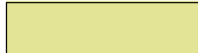

Lithium-ion Battery Large Scale Test Parameters

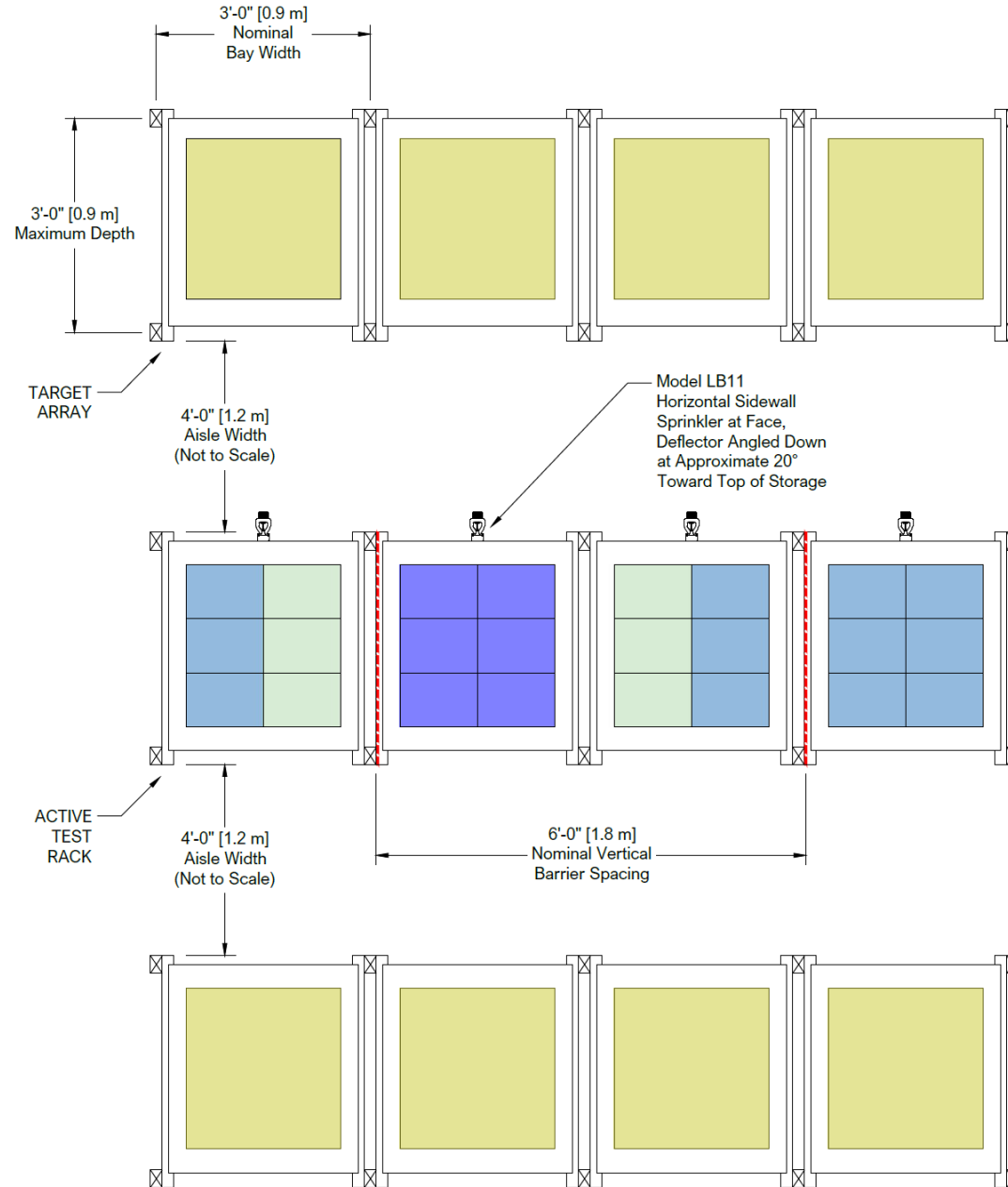
- \\ Cell configuration:
 - Cylindrical 18650
- \\ Cell cathode chemistry:
 - Nickel Cobalt Aluminum (NCA)
- \\ Cell capacity:
 - 3,500 mAh
- \\ Cell state of charge:
 - 100%
- \\ Storage configuration:
 - Non-reinforced polypropylene formation trays (160 cells per tray)
- \\ Cell quantity:
 - 8,000



Lithium-ion Battery Test - Plan View


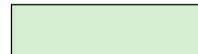



BATTERY LOADING LEGEND

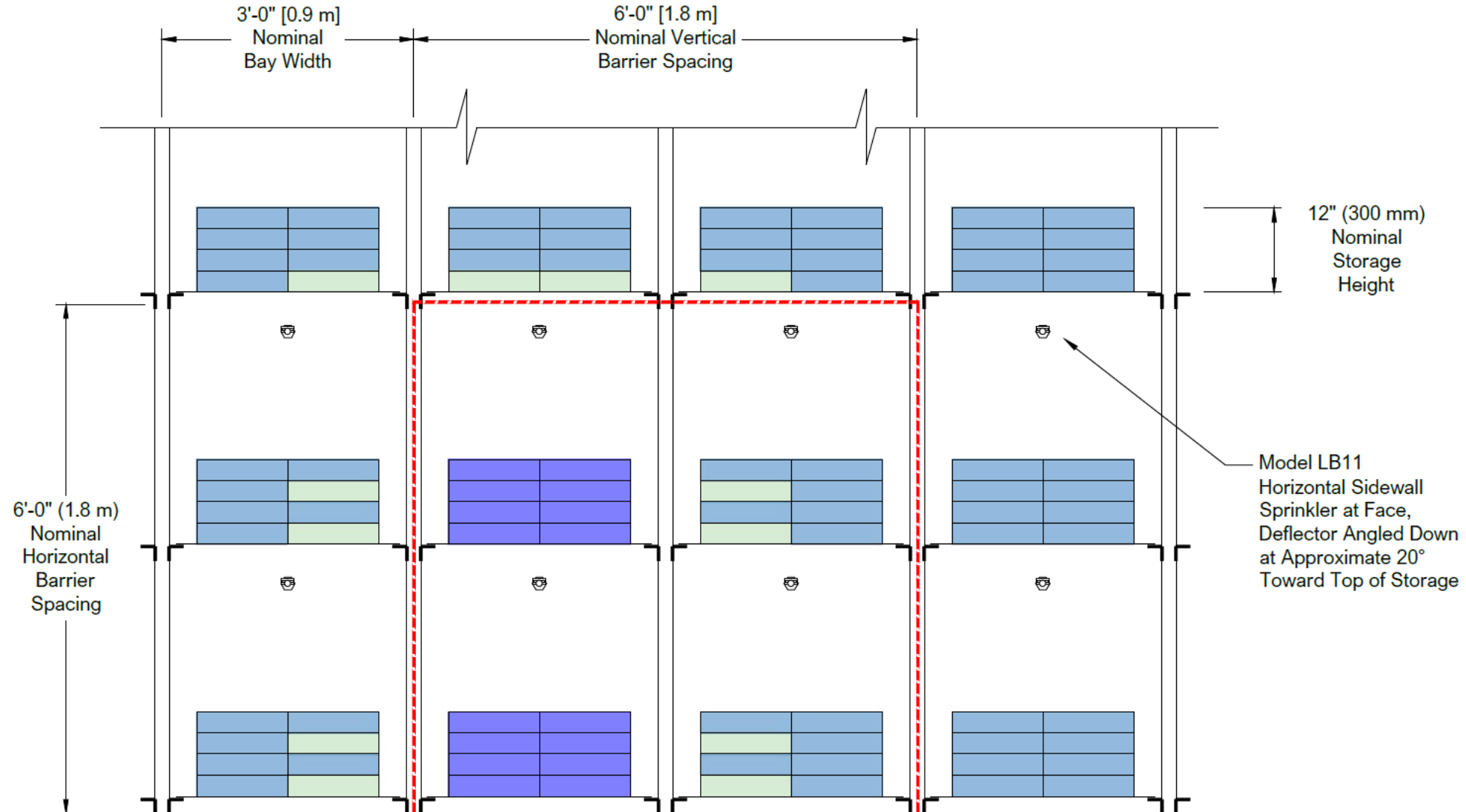
-  Full Tray (160 Cells)
-  (8) Cell Tray
-  Empty Tray
-  Cartoned Unexpanded Plastic Commodity
-  Horizontal or Vertical Barrier



Lithium-ion Battery Test - Elevation View

BATTERY LOADING LEGEND

-  Full Tray (160 Cells)
-  (8) Cell Tray
-  Empty Tray
-  Cartoned Unexpanded Plastic Commodity
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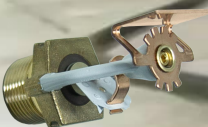




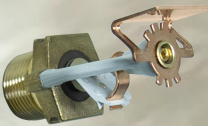
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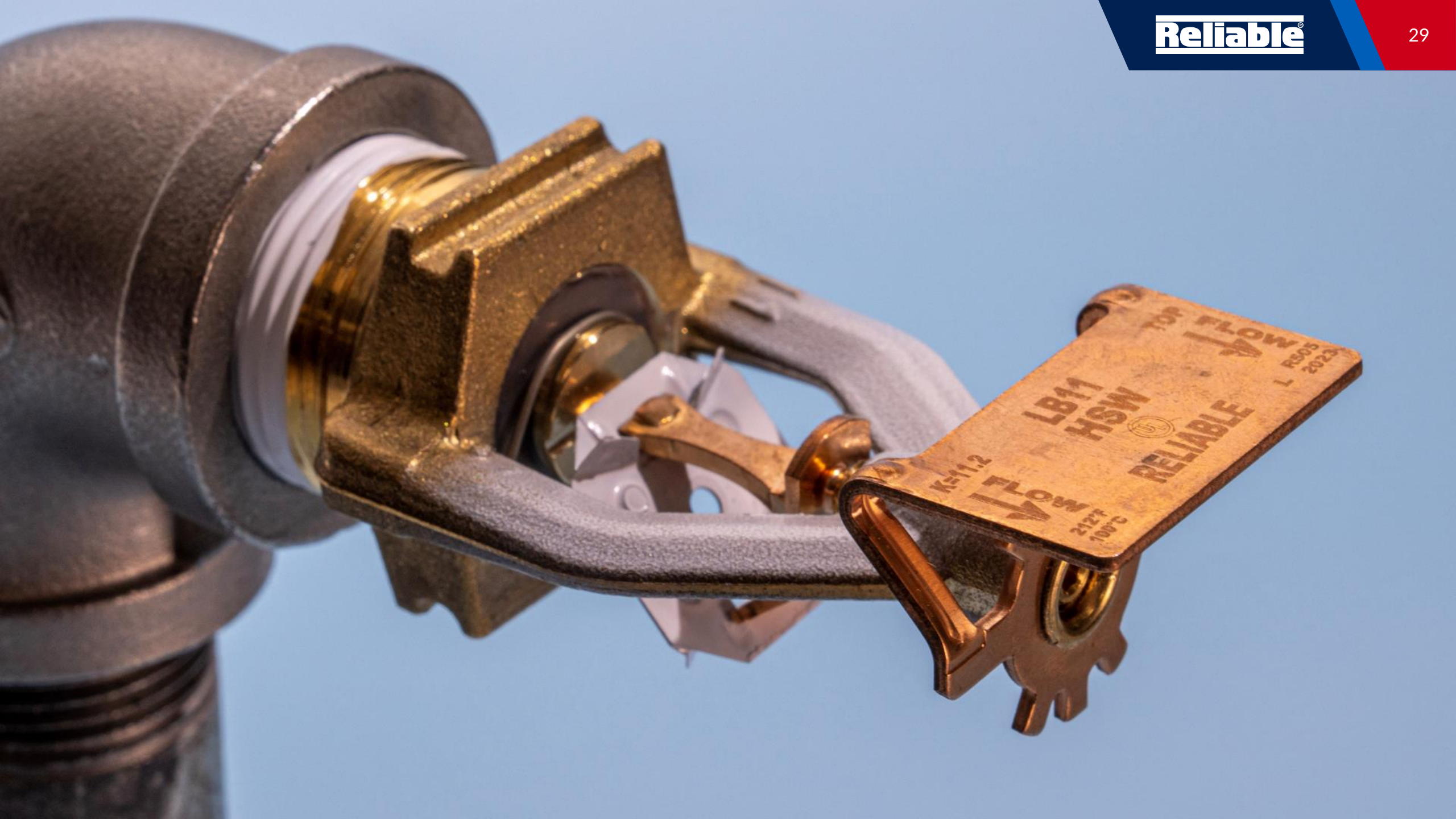


Reliable









Tall, Dense Rack Storage



Cartoned Unexpanded Plastic Commodity



Cartoned Unexpanded Group A Plastics

Ceiling Height, ft (m)	NFPA 13	UL Specific Application	FM DS 8-9
55 ft (16.8 m)			Min. aisle width: K28.0 (K400) = 8 ft (2.4 m) K33.6 (K480) = 6 ft (1.8 m)
50 ft (15.2 m)			
48 ft (14.6 m)			Min. aisle width: 6 ft (1.8 m)
45 ft (13.7 m)		Min. aisle width varies depending on sprinkler	
40 ft (12.0 m)	Min. aisle width: 4 ft (1.2 m)		Min. aisle width: 4 ft (1.2 m)

Cartoned Unexpanded Group A Plastics

Ceiling Height, ft (m)	NFPA 13	UL Specific Application	FM DS 8-9
55 ft (16.8 m)			Min. aisle width: K28.0 (K400) = 8 ft (2.4 m) K33.6 (K480) = 6 ft (1.8 m)
50 ft (15.2 m)			Min. aisle width: 6 ft (1.8 m)
48 ft (14.6 m)		Min. aisle width varies depending on sprinkler	
45 ft (13.7 m)	Min. aisle width: 4 ft (1.2 m)		
40 ft (12.0 m)			Min. aisle width: 4 ft (1.2 m)

UL Specific Application

Listing for the protection of stored commodities based on the end use limitations specified for the sprinkler.

Series of large-scale fire tests

- Storage height
- Ignition location
 - Under 1 sprinkler
 - Between 2 sprinklers
 - Between 4 sprinklers

- Max. ceiling height
- Min. aisle width
- Max. sprinkler to ceiling distance
- Min. discharge pressure



Listing for the protection of stored commodities based on the end use limitations specified for the sprinkler.

Acceptance Criteria

- No sustained combustion at the end of the main test array
- No sustained combustion at the outer edges of the target array
- Maximum 1 minute average ceiling steel temperature not exceeding 1,000°F (538°C)
- No more than 8 sprinklers operating
 - Except that no more than one test in the series may operate up to 9 sprinklers

The Original Sprinkler for 48 ft (14.6 m)

Reliable HL-22

K22.4 (K320)

212°F (100°C) temperature rating

Single- and double-row racks

8 ft (2.4 m) min. aisle width

55 psi (3.8 bar) operating pressure



Model N28T6 ESFR Pendent

SIN R603

- \\ K-factor: 28.0 (400)
- \\ Fast-response fusible alloy solder link
 - 212°F (100°C)
- \\ Approvals:
 - cULus Listed specific application
 - Building height 48 ft (14.6 m)
 - Storage height 43 ft (13.1 m)
- \\ Maximum working pressure:
 - 175 psi (12.1 bar)
- \\ Technical Bulletin 082
- \\ ASTM Environmental Product Declaration



Model N28T6
ESFR

Model N28T6 ESFR Specific Application



Model N28T6
ESFR

- \\ cULus Listed specific application
 - Building height 48 ft (14.6 m)
 - Storage height 43 ft (13.1 m)
- \\ Design pressure: 35 psi (2.4 bar)
- \\ Commodity class
 - Class I-IV
 - Cartoned unexpanded group A plastics
- \\ Storage arrangement
 - Open frame racks
 - Single
 - Double
 - Multiple
 - Portable racks
- \\ Aisle width
 - 4 ft (1.2 m)
- \\ Flue spaces
 - Per NFPA

TEST TIME 3947 Sec.
TEST IS COMPLETE!
 See Results Below
 Press "Reset" For New Test
 Reset Test

Temperature Drop: -25
 Array Spacing: 10' x 10'

Test Status 8
 Complete
 Total Nozzles: 42
 Released: 0
 Percent: 0

Configure

Special	8'x8'
8'x10'	10'x10'
12'x8'	12'x12'
14'x14'	15'x8'8"
15'x15'	16'x16'
18'x18'	20'x20'

Sample
 Air
 TC Tree
 Auto
 View
 Ambient

Beam TC's
 1. 23
 2. 23
 3. 23
 4. 23
 5. 23
 Avg. 23

Air TC's
 6. 22 6"
 7. 22 12"
 8. 22 18"

22	22	22	22	22	22
22	22	22	22	22	21
22	22	22	22	22	22
22	22	22	21	22	22
22	22	22	22	22	22
22	22	22	22	22	22
22	22	22	22	22	22

12/2/2021

Menu

09:09:03



Factors Influencing Storage Efficiency



Building Height



Sprinkler Selection




Rack Arrangement

Double-Row Rack Storage Efficiency

One Hundred Thousand Square Meter Warehouse

Design Criteria	Building Height m	Storage Height m	Aisle Width m	Sprinkler K-factor	Sprinkler Information	Available Storage Thousand m ³
NFPA 13	13.7	12.0	1.2	K320 – K360	All Manufacturers	811
FM DS 8-9	15.2	13.7	1.8	K320 – K480	All Manufacturers	783
FM DS 8-9	16.8	15.2	2.4	K400	Brand B	762
			1.8	K480	Brand A	872
UL Specific Application Listing (Aisle Width Specific to Each Manufacturer)	14.6	13.1	1.8	K400	Brand B	750
			1.5	K400	Brand B	808
			1.5	K360	Brand A / Brand C (Int.)	808
			1.2	K360	Brand C (Ord.)	875
K400	Reliable N28					

*Example based on one hundred thousand cubic meter warehouse with 2.4 m deep double-row racks.

A photograph of a large warehouse interior filled with multiple rows of industrial shelving racks. The racks are made of metal and have several levels. The lighting is bright, and the overall scene is a perspective view of the aisles between the racks.

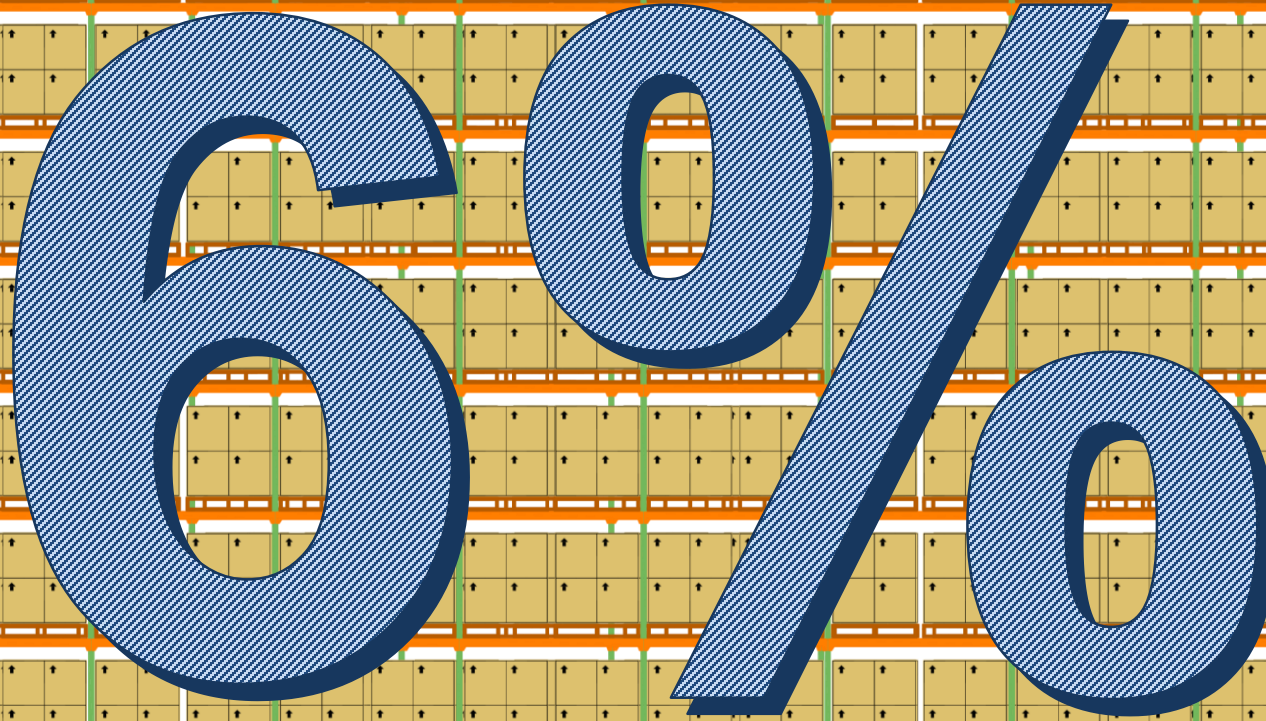
**What about
multiple-row racks?**

Model N28T3 ESFR Specific Application



Model N28T3
ESFR

- \\ cULus Listed specific application
 - Building height 48 ft (14.6 m)
 - Storage height 43 ft (13.1 m)
- \\ Design pressure: 35 psi (2.4 bar)
- \\ Storage arrangement
 - Open frame racks
 - Single
 - Double
 - Multiple
 - Portable racks
- \\ Aisle width
 - 4 ft (1.2 m)
- \\ Flue spaces
 - Per NFPA
 - Minimum 3 in. transverse flue space
 - Single-row racks
 - Double-row racks



60%



8' AISLES
6" TRANSVERSE FLUES



