

TRAINING

Storage Design and Installation
Metric

SEMINAR

WE **DEVELOP** THE CODE. WE **KNOW** THE CODE. WE **TEACH** THE CODE.

Seminar Information Sheet

Our goal is to make your professional development experience an informative and enjoyable one. Here is some helpful information for you.

Schedule:

Class starts at 8:00 AM. There will be a number of short breaks in the morning and in the afternoon. We will break for one hour for lunch, at about noon. We will finish at about 4:30 PM each day. **Please do not leave materials in the room overnight.**

Attire:

For your comfort, we recommend wearing layered clothing as meeting room temperatures may vary.

Completion Requirements and Certificates:

NFPA has been approved by the International Association for Continuing Education and Training as an Authorized CEU Provider. One Continuing Education Unit, or CEU, is equivalent to 10 contact hours of participation in an organized continuing education experience. Each full seminar day represents 7 hours of instruction (0.7 CEUs). To receive the CEUs awarded for each day of this seminar, you must:

1. Attend all class sessions
2. Sign each attendance sheet
3. Pass a brief post-seminar quiz

A sign-in sheet will be passed around the room twice each day. Please be sure to sign next to your name. To access the post-seminar quiz, evaluation, and certificate of attendance, log on to your NFPA Profile and go to "My Training" to access the course link. The Certificate of Educational Achievement (CEA) review, CEA exam, and certificate will also be available via the course link for those who have registered for that option.

Publication Offer:

You will find a book order form in the back of this workbook. If you would like to place an order using this form, please complete the order form and leave it with the Seminar Administrator. You may also order by phone, fax, or online; see order form for details.

NFPA Website:

NFPA's website, located at www.nfpa.org, contains the latest information about NFPA, including an explanation of the codes- and standards-making process, details about the NFPA Conference and Expo, our online catalog, and a complete listing of Training programs and schedules.

Transcripts:

Your CEUs for this seminar will be shown on your certificate of attendance. We will maintain a permanent record of your participation in all NFPA CEU programs for a minimum of seven years. If you would like a transcript of your Continuing Education Units, including any previous NFPA programs you have attended, please submit a request in writing, using the form below.

NFPA seminar participants will be awarded 0.7 CEUs for each day completed:

1 day ..... 0.7 CEUs
2 days ..... 1.4 CEUs
3 days ..... 2.1 CEUs
4 days ..... 2.8 CEUs
5 days ..... 3.5 CEUs

A $5.00 transcript processing fee includes all NFPA Seminars. Payment must accompany your request.

Please use the form below when requesting a transcript.

NAME : _____ SOCIAL SECURITY NO: _____

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Please list any seminar(s) you have attended:

TITLE OF SEMINAR: _____

LOCATION: _____ DATE: _____

TITLE OF SEMINAR: _____

LOCATION: _____ DATE: _____

TITLE OF SEMINAR: _____

LOCATION: _____ DATE: _____

TITLE OF SEMINAR: _____

LOCATION: _____ DATE: _____

Please complete and send to NFPA, Fulfillment Center, 11 Tracy Dr., Avon, MA 02322

Seminar Question Form

If you have questions you would like to submit to the instructors in writing, you may use this form.

Question:

Question:

Seminar Agenda

Module 1: Introduction to Storage Fire Protection
Module 2: Commodity and Packaging Classification
Module 3: Storage Fundamentals
Module 4: Storage Sprinkler Technology
Module 5: System Design
Module 6: Storage Applications
Module 7: Special Storage Designs
Module 8: Activity and Seminar Summary

Seminar Objectives

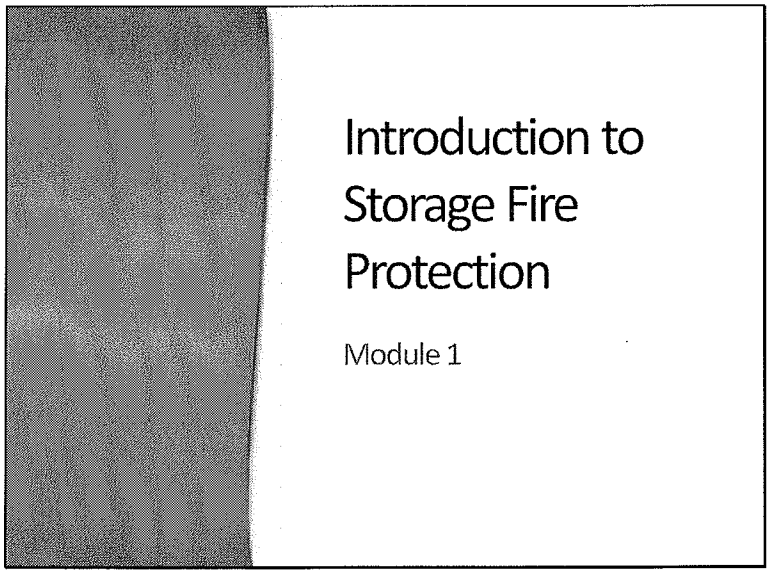
Module 1: Introduction to Storage Fire Protection
Upon completion participants should be able to: • Identify the storage chapters in NFPA 13 • Discuss the history of storage requirements • Explain what has driven change in storage requirements
Module 2: Commodity and Packaging Classification
Upon completion participants should be able to: • Apply the proper commodity classification to a given commodity • Describe the different parameters of the data analysis and classification process • Explain the effect packaging and containment types have on design approaches
Module 3: Storage Fundamentals
Upon completion participants should be able to: • Identify the information required in order to determine an acceptable design approach • Determine the impact of ceiling height on sprinkler system design • Apply the five steps of the sprinkler design process for rack storage applications • Describe additional considerations that will dictate design options
Module 4: Storage Sprinkler Technology
Upon completion participants should be able to: • Discuss the benefits and limitations of CMDA, CMSA, and ESFR sprinkler systems • Summarize the process and workflow for CMDA, CMSA, and ESFR sprinkler systems
Module 5: System Design
Upon completion participants should be able to: • Determine system demand • Discuss host stream and water supply • Explain the rationale for the room design method • Explain the three options for designing in facilities with mixed commodities

Module 6: Storage Applications
Upon completion participants should be able to: • Navigate through chapters 13-17 of NFPA 13 • Explain the structure of chapters 13-17 (including subsections) of NFPA 13 • Locate the appropriate chapter based on a given design approach • Select an appropriate sprinkler technology based on a given design approach • Explain in-rack rules • Explain the significance of the notes associated with figures in chapters 13-17 of NFPA 13 • Review hydraulic design requirements
Module 7: Special Storage Designs
Upon completion participants should be able to: • Identify the design rules for storage hazards not covered in chapters 13-17 of NFPA 13 • Discuss the definitions and storage arrangements associated with tire storage • Identify design options for roll paper storage • Locate protection criteria for storage schemes not covered within NFPA 13 • Explain criteria associated with the storage of idle pallets

Module 1: Introduction to Storage Fire Protection

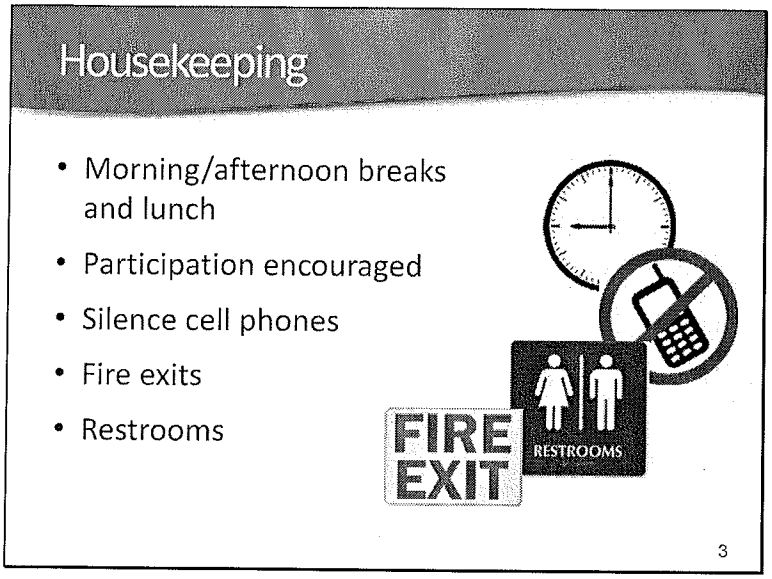
Presentation **Notes**





Module 1: Introduction to Storage Fire Protection

Presentation	Notes



Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Experience

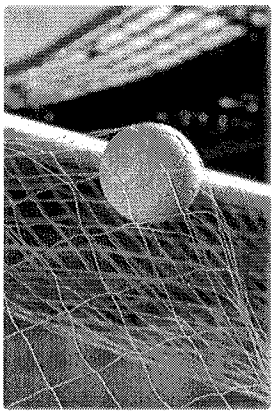
How many...

- have experience using NFPA 13 for less than 2 years?
- have experience more than 5 yrs? 10 yrs?
- serve as Enforcers? Manufacturers? Installer-Maintainers? Insurers? Architects/Engineers? Others?
- have attended an NFPA seminar before?

5

Seminar Goal

This seminar will allow you to be able to properly apply and understand the design principles of storage sprinkler systems and identify appropriate design solutions for given scenarios.



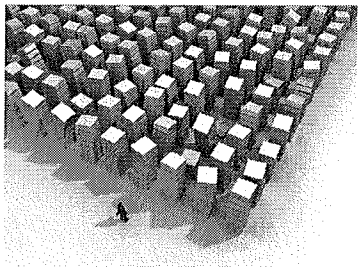
6

Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Agenda

- Introduction
- History
- Storage concepts
- Design approaches
- Special situations
- Hydraulics
- Practical application



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NFPA 13 Structure

- Scope, Application, and General (Ch 1,2,4)
- Definitions (Ch 3)
- Hazard and Commodity Classification (Ch 5)
- Installation Rules (Ch 6, 7, and 8)
- Seismic (Ch 9)
- Underground (Ch 10)
- Storage (Ch 12-21)
- Special Occupancies (Ch 22)
- Plans and Calculations (Ch 23)

8

Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Chapter 3 – Definitions

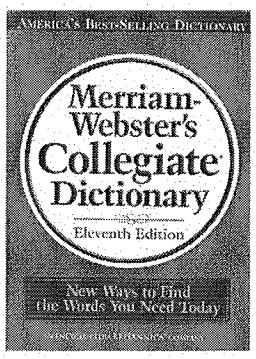
- 3.9 Storage Definitions
  - 3.9.1 General
  - 3.9.2 Palletized, Solid-Piled, Bin Box, and Shelf Storage
  - 3.9.3 Rack Storage
  - 3.9.4 Rubber Tire Storage Definitions
  - 3.9.5 Roll Paper Definitions
  - 3.9.6 Baled Cotton Definitions

9

Page: 13-21

Application of Definitions

- How the term is used in the Standard
- When in doubt:



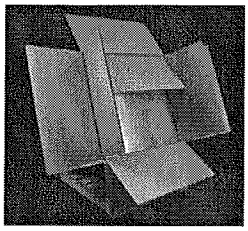
10

Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Chapter 5 – Commodity Classification

- Identify commodities
- Annex lists
- Occupancy classification as part of miscellaneous storage



11

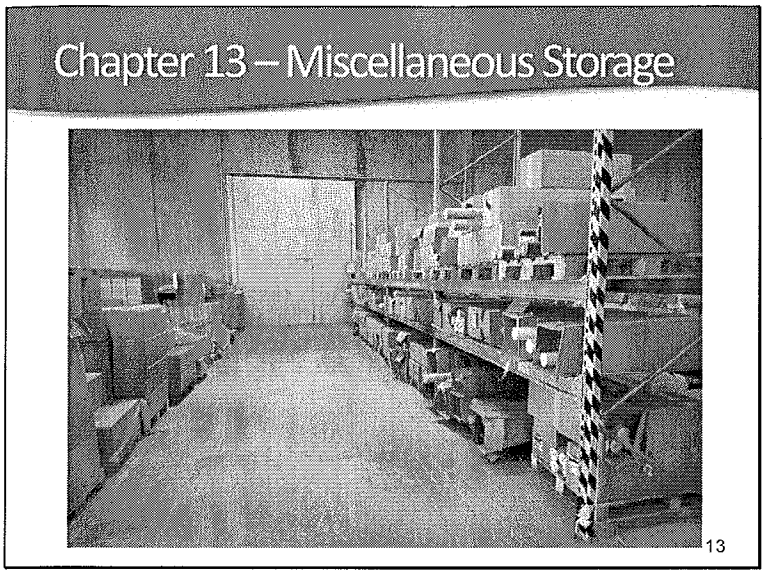
Chapter 12 – General Requirements

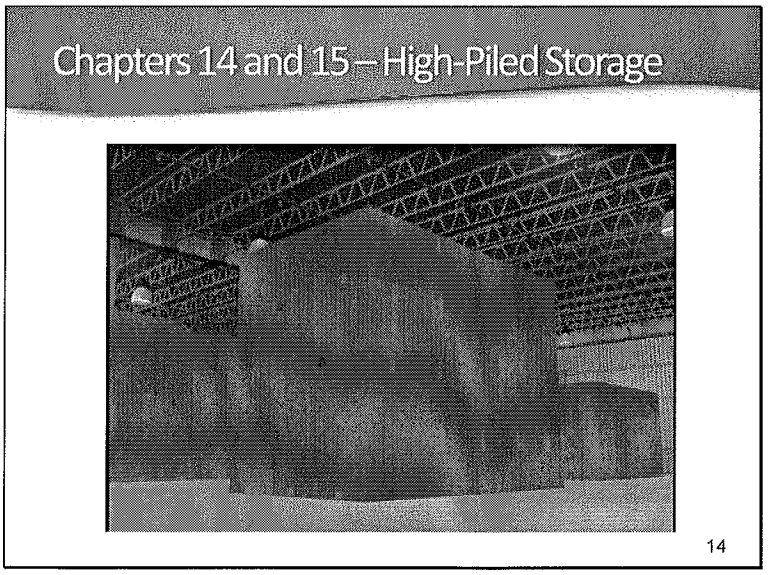
12.1	General	13–126
12.2	Hose Connections	13–127
12.3	Adjacent Hazards or Design Methods	13–127
12.4	Wet Pipe Systems	13–127
12.5	Dry Pipe and Preaction Systems	13–127
12.6	Storage Applications	13–127
12.7	Discharge Considerations	13–127
12.8	Hose Stream Allowance and Water Supply Duration	13–128
12.9	Restrictions	13–128
12.10	Room Design Method	13–130
12.11	High-Expansion Foam Systems	13–130
12.12	Protection of Idle Pallets	13–130

12

Module 1: Introduction to Storage Fire Protection

Presentation	Notes

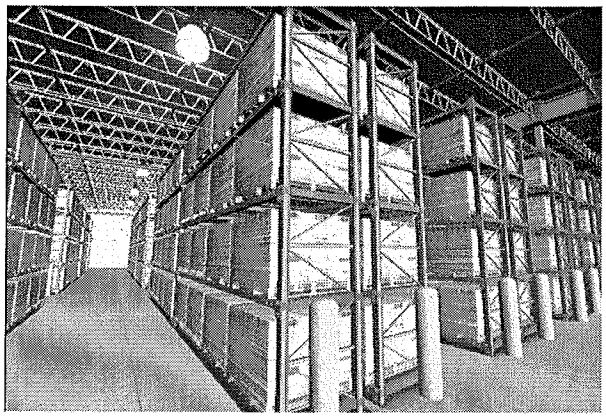




Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Chapters 16 and 17 – Rack Storage



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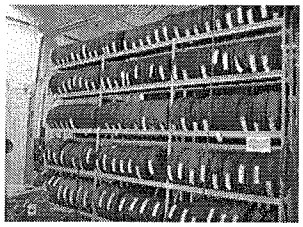
Special Storage Occupancies



- Chapter 18 – Tire Storage
- Chapter 19 – Roll Paper
- Chapter 20 – Special Situations
- Chapter 22 – Special Occupancy Requirements

16

Module 1: Introduction to Storage Fire Protection

Presentation	Notes

Chapter 21 – Performance Based Alternative

- New Chapter in 2013 Edition

21.1.1 Sprinklers intended to protect storage fire risks shall be permitted to be installed using water supply design criteria that are different from the design criteria specified for the sprinkler described in Chapters 12 through 20 when specifically listed for such use within the limitations described in this chapter.

17

Page: 13-210

History of Storage Requirements in NFPA 13

- NFPA 231 Series
  - Addressed stored goods
  - Miscellaneous storage in NFPA 13
  - Conflict between NFPA 13 and 231 series
  - NFPA 231 series shelved in 1999

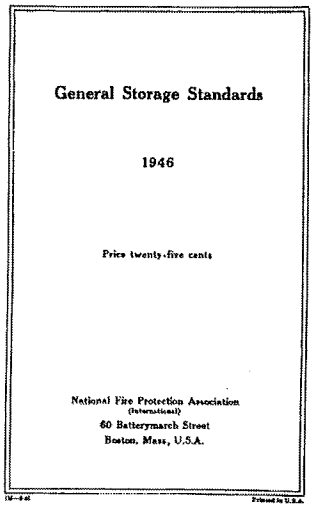
18

Module 1: Introduction to Storage Fire Protection

Presentation **Notes**

1946 Edition – Section IV Item 4

NFPA No. 231 - 1946



General Storage Standards

1946

Price twenty-five cents

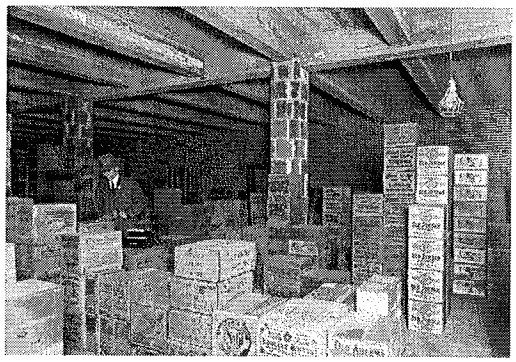
National Fire Protection Association
(International)
60 Batterymarch Street
Boston, Mass, U.S.A.

(4) Automatic Sprinklers. Automatic sprinklers with adequate water supplies are recommended for the protection of buildings of combustible construction or housing combustible contents. Automatic Sprinkler systems shall be provided with appropriate waterflow devices as specified in the NFPA standards for the installation of sprinkler equipment to provide notification in case of flow of water from any cause, unless specifically waived by the authority having jurisdiction.

19

Evolution of Requirements

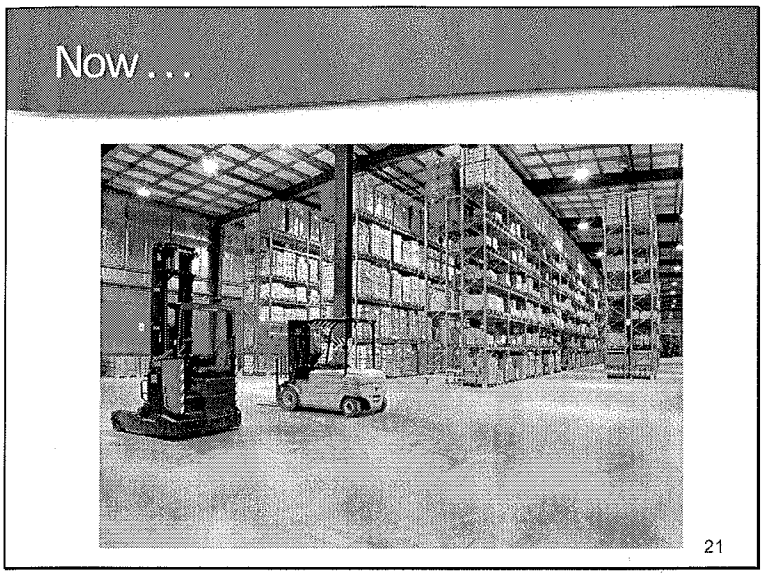
Storage height and dollar driven

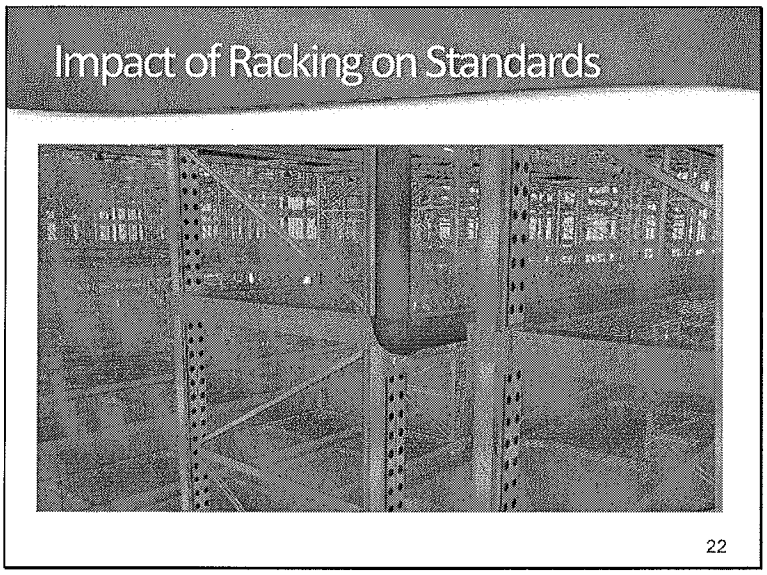


20

Module 1: Introduction to Storage Fire Protection

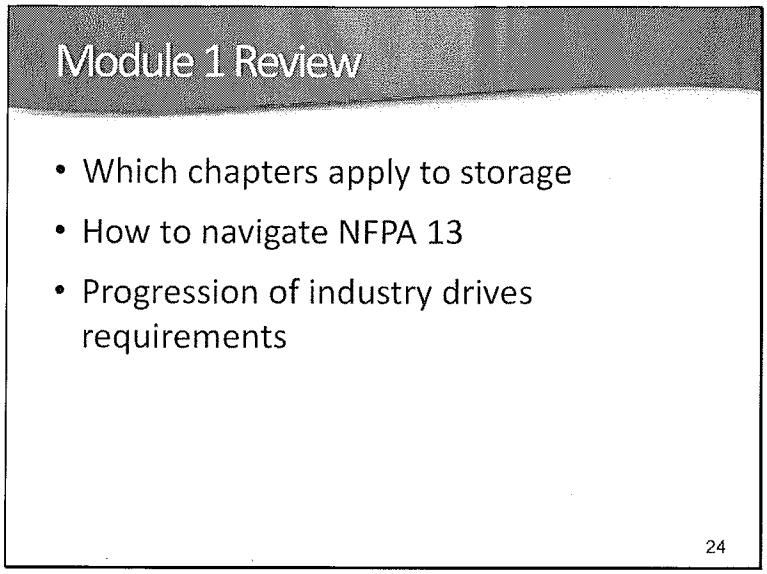
Presentation	Notes





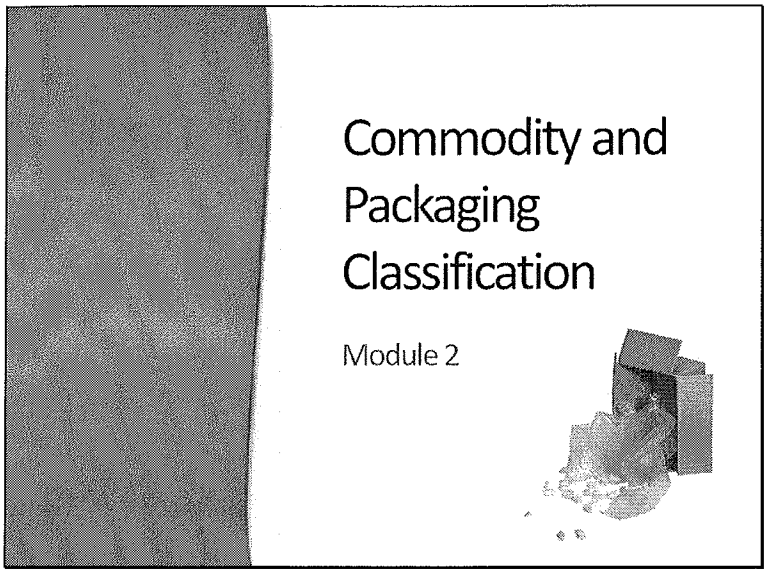
Module 1: Introduction to Storage Fire Protection

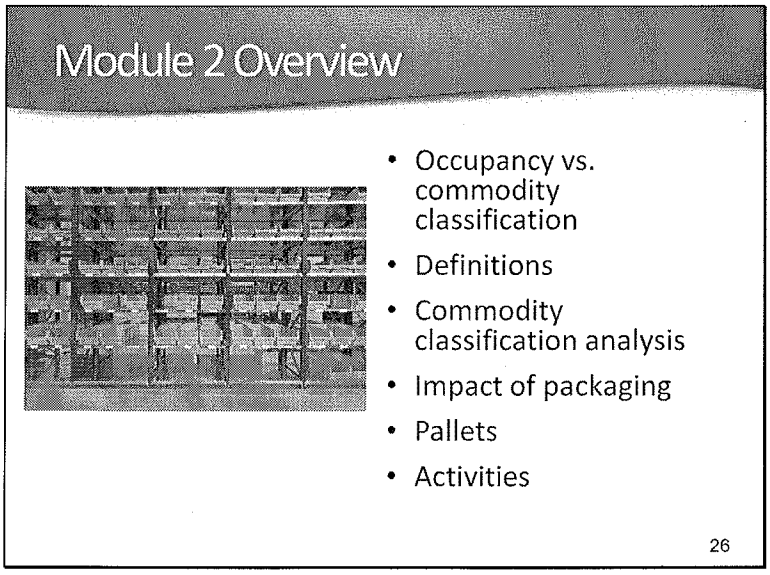
Presentation	Notes



Module 2: Commodity and Packaging Classification

Presentation **Notes**





Module 2: Commodity and Packaging Classification

Presentation	Notes

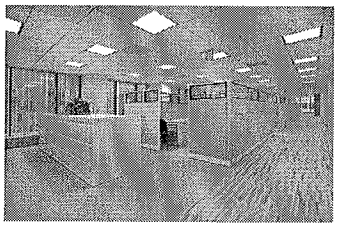
Module 2 Objectives

Upon completion attendees should be able to:

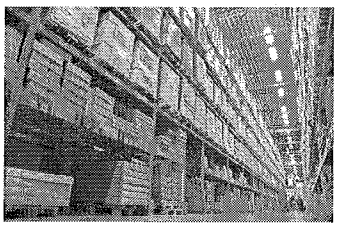
- Apply the proper commodity classification to a given commodity
- Describe the different parameters of the data analysis and classification process
- Explain the effect packaging and containment types have on design approaches

27

Chapter 5 – Occupancy vs. Storage



VS.

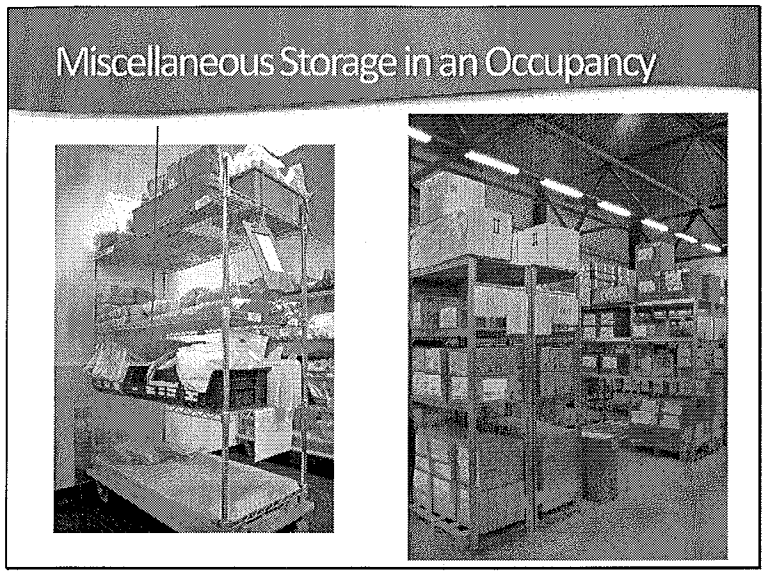


28

"In-use" "storage"

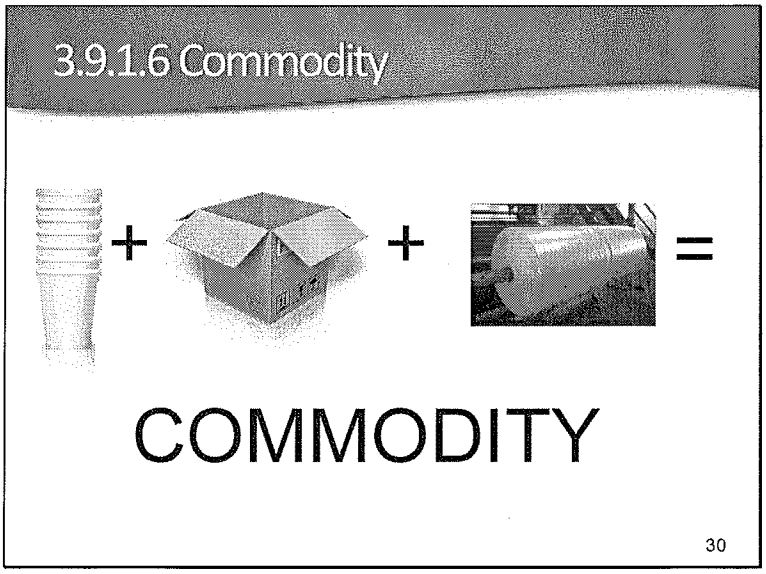
Module 2: Commodity and Packaging Classification

Presentation	Notes



Definition in
Clause 3.9.1.18 Appx B

- max 3.16m
- max 93m² or 10% bldg area, etc.

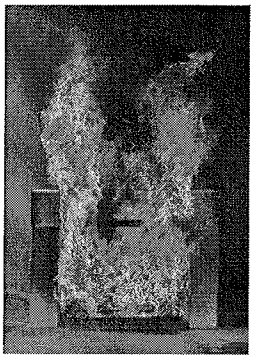


Module 2: Commodity and Packaging Classification

Presentation	Notes

Commodity Classification Overview

5.6.3.1 – Class I
5.6.3.2 – Class II
5.6.3.3 – Class III
5.6.3.4 – Class IV
5.6.4.1 – Group A
5.6.4.2 – Group B
5.6.4.2 – Group C



31

Page: 13-26

Commodity Classification Overview

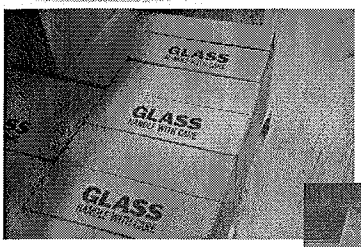
5.6.3.1 – Class I
5.6.3.2 – Class II
5.6.3.3 – Class III ⟸ 5.6.4.2 – Group C
5.6.3.4 – Class IV ⟸ 5.6.4.2 – Group B
5.6.4.1 – Group A

32

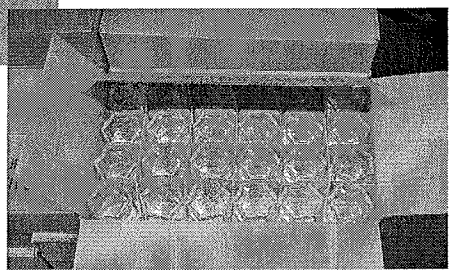
Module 2: Commodity and Packaging Classification

Presentation	Notes

Class I Commodity



- Noncombustible
- Stored on wood pallets

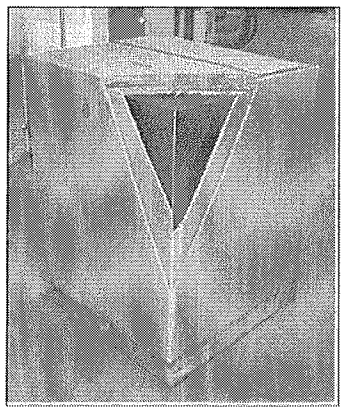


- In corrugated containers with or without single-thickness cardboard dividers

Page: 13-26 (5.6.3.1)

Class II Commodity

- Non combustible
- Slightly increased amounts of combustible packaging, or
- Trim



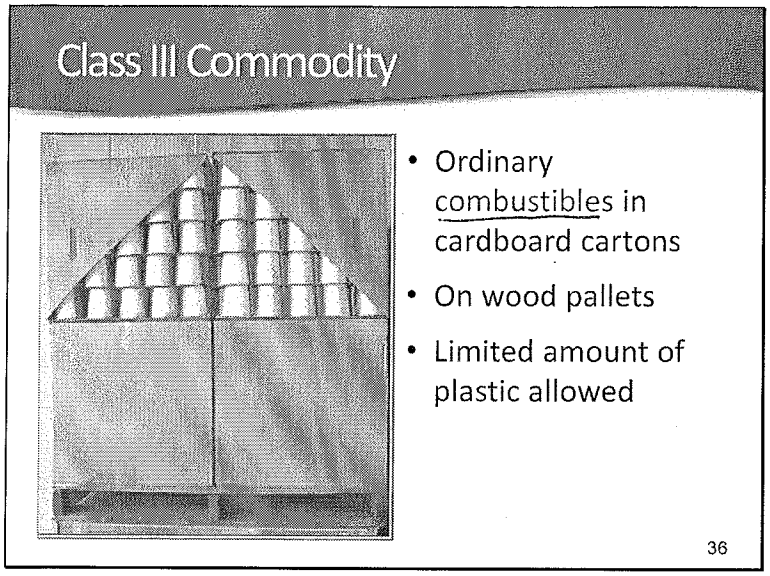
compared to class I

35

Page: 13-26 (5.6.3.2)

Module 2: Commodity and Packaging Classification

Presentation	Notes



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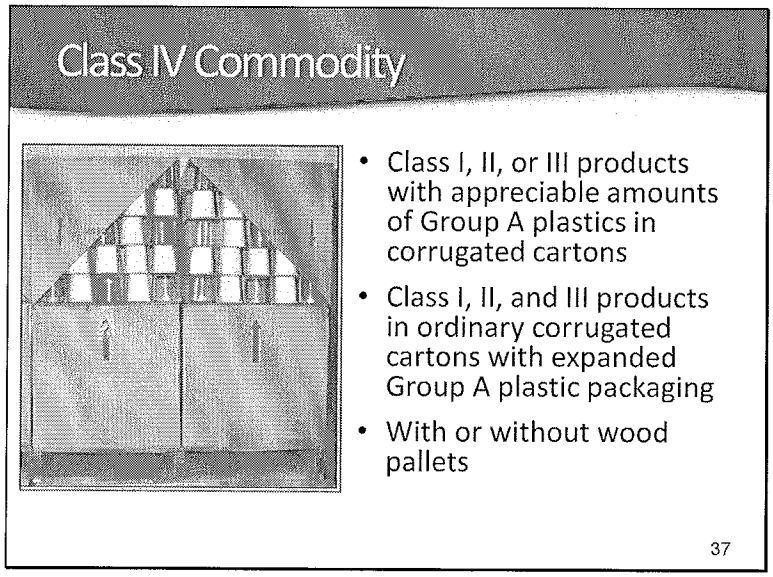

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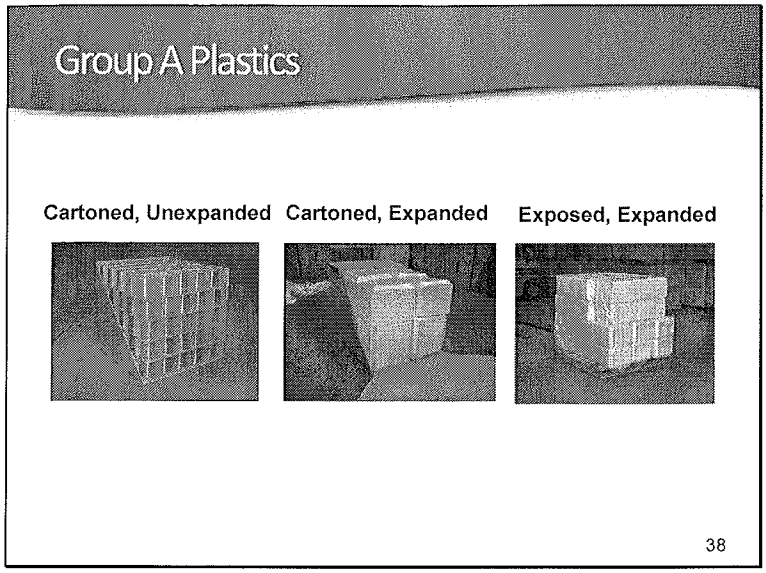
Module 2: Commodity and Packaging Classification

Presentation | **Notes**



Page: 13-26 (5.6.4.1)

expanded – plastic reduced in density of styrofoam

Annex Tables

TABLE A.5.6.3 Alphabetized Listing of Commodity Classes

Commodity	*Commodity Class*	*Commodity*	*Commodity Class*
Aerosols		Filled noncombustible liquids	
Cartoned or uncartoned — Level 1	Class III	- Glass, cartoned	Class I
Alcoholic Beverages		- Plastic, cartoned [less than 5 gal (18.9 L)]	Class I
Cartoned or uncartoned		- Plastic, open or solid plastic crates[c]	Group A plastics
- Up to 20 percent alcohol in metal, glass, or ceramic containers	Class I	- Plastic, PET	Class I
- Up to 20 percent alcohol in wood containers	Class II	Boxes, Crates	
Ammunition		- Empty, wood, solid walls	Class II
Small arms, shotgun — packaged, cartoned	Class IV	- Empty, wood, slatted	See Table A.5.6
Appliances, Major (e.g., stoves, refrigerators)		Bread	
- Not packaged, no appreciable plastic exterior trim	Class I	Wrapped cartoned	Class III
- Corrugated, cartoned (no appreciable plastic trim)	Class II	Butter	
Baked Goods		Whipped spread	Class III
Cookies, cakes, pies		Candles	
- Frozen, packaged in cartons[a]	Class II	Packaged, cartoned	
- Packaged, in cartons	Class III	- Treat as expanded plastic	Group A plastics
		Candy	
		Packaged, cartoned	Class III
		Canned Foods	
		In ordinary cartons	Class I

Page: 13-268

Module 2: Commodity and Packaging Classification

Presentation **Notes**

Annex Tables

TABLE A.5.6.3.2 Examples of Class II Commodities

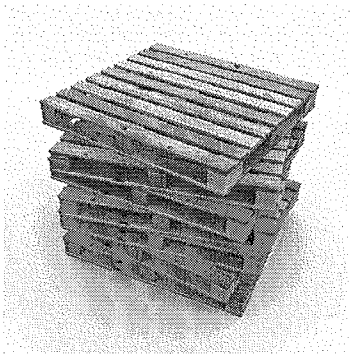
Alcoholic Beverages
  Up to 20 percent alcohol in wood containers
Appliances, Major (e.g., stoves)
  Corrugated, cartoned (no appreciable plastic trim)
Baked Goods
  Cookies, cakes, pies
  - Frozen, packaged in cartons*
Batteries
  Dry cells (nonlithium or similar exotic metals) in blister pack in cartons
Bottles, Jars
  Filled noncombustible powders
  - Plastic PET
Boxes, Crates
  Empty, wood, solid walls
Fertilizers
  Bagged
Nonflammable liquids
  - Glass bottles, cartoned
Photographic Film
  - Motion picture or bulk rolls of film in polycarbonate, polyethylene, or metal cans; polyethylene bagged in cardboard boxes
Plastic Containers
  Noncombustible liquids or semiliquids (such as ketchup) in plastic containers with nominal wall thickness of ¼ in. (6.4 mm) or less and larger than 5 gal (18.9 L) capacity
Poultry Products
  Frozen (on paper or expanded plastic trays)
Powders (ordinary combustibles — free flowing)
  In paper bags (e.g., flour, sugar)
Salt
  Packaged, cartoned

40

Page: 13-272

Pallets

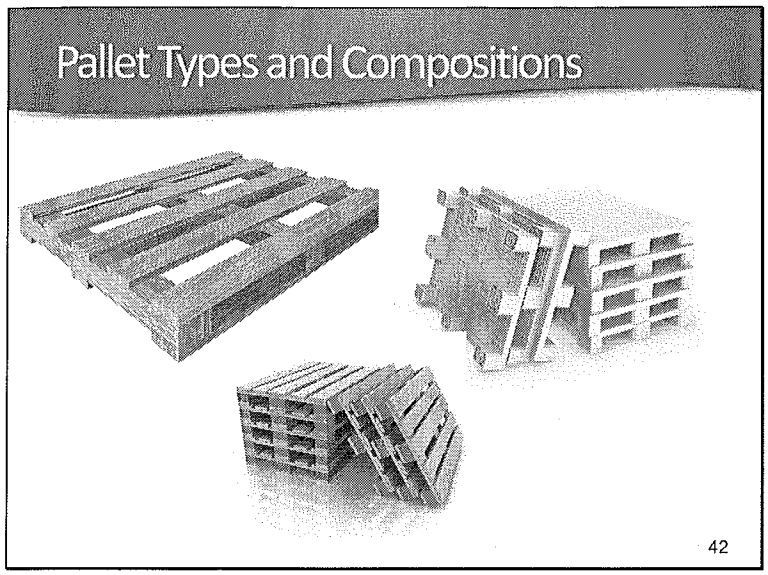
- Varying materials and compositions
- Not required but common
- NFPA 13 assumes wood pallets
- ARS system pallets

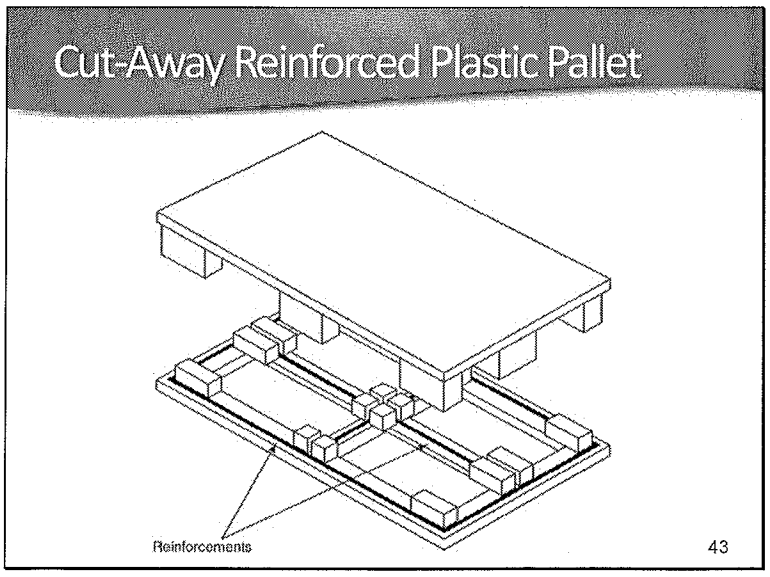


41

Module 2: Commodity and Packaging Classification

Presentation	Notes



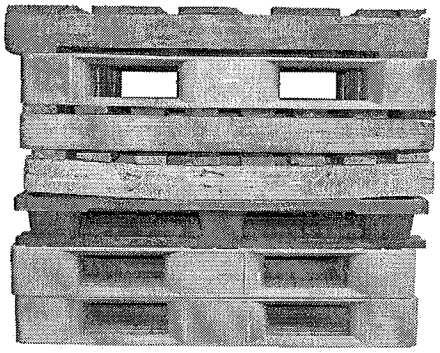


Page: 13-259 (Figure A.3.9.1.22(a))

Module 2: Commodity and Packaging Classification

Presentation	Notes

What if I have both?



44

Pallet Modifiers

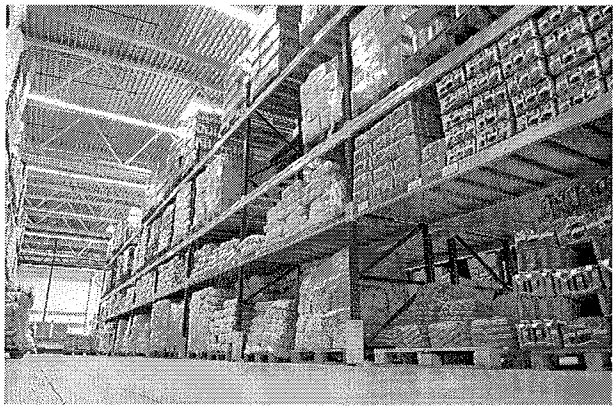
- One class upgrade for un-reinforced plastic pallets
  - Class II -> Class III
  - Class IV -> Group A Plastics
- Two class upgrade for reinforced plastic pallets
  - Class II -> Class IV
  - Class III -> Group A Plastics

45

Module 2: Commodity and Packaging Classification

Presentation	Notes

Mixed Commodities



46

Page: 13-25 (5.6.1.2)

WARNING!!

- Critical step in the design process
- Annex is for guidance
- Responsibility of design professional
- Check local requirements
  - Discuss with insurance representative
  - Discuss with building owner representative

47

Module 2: Commodity and Packaging Classification

Presentation	Notes

Management of Change

- Change in storage facility operation
  - Ownership
  - Stored commodity
  - Packaging
  - Storage schemes

48

Why can't I just use the Annex?

- Evolution of packaging
  - Raw material availability
  - Raw material price
  - Product design
  - Packaging technologies and design

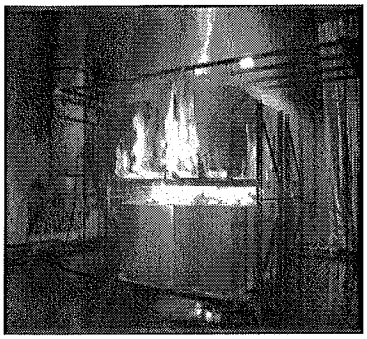
49

Module 2: Commodity and Packaging Classification

Presentation	Notes

Commodity Classification Testing

- Process developed by *FM Global*
- Full-scale testing of a product with packaging arrangement
- Classification based on sprinkler density



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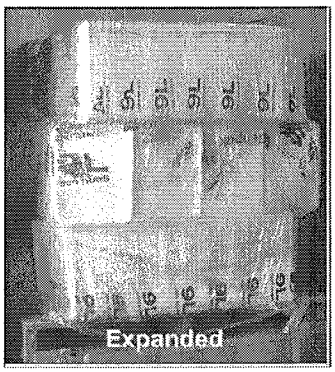
What is Commodity Classification Testing?

- A standardized test method
- Assessment of the ability of a stored commodity to be protected by water
- This methodology assesses the relative fire risk of the stored commodity



51

Module 2: Commodity and Packaging Classification

Presentation	Notes

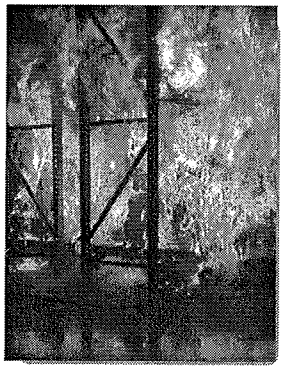
Commodity Classification Testing Output

- Uses pre-established sprinkler densities
- Determine the resulting energy output (HRR)
- Use a series of four rankings to develop the classification
  - Total HRR
  - Convective HRR
  - Effective control
  - Total convective energy

52

Value of Commodity Classification Testing

- Provides product specific results
- Limits risk from insurer/owner
- Customized protection schemes
- More efficient design focus



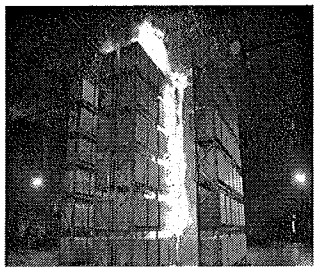
54

Module 2: Commodity and Packaging Classification

Presentation	Notes

Storage Fire Protection Variables

- Warehouse storage parameters
  - Building and storage height
  - Aisle width
  - Storage arrangement
  - Sprinkler clearance
- Sprinkler system design
  - Sprinkler orifice size (K factor)
  - Temperature rating
  - Sprinkler type
  - Sprinkler spacing
  - System design characteristics (density, pressure, number of sprinklers, etc.)
- Fire hazard of stored commodity



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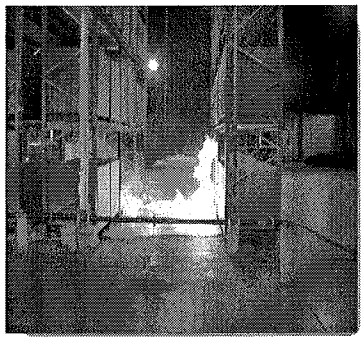
Limitations of Commodity Classification Testing

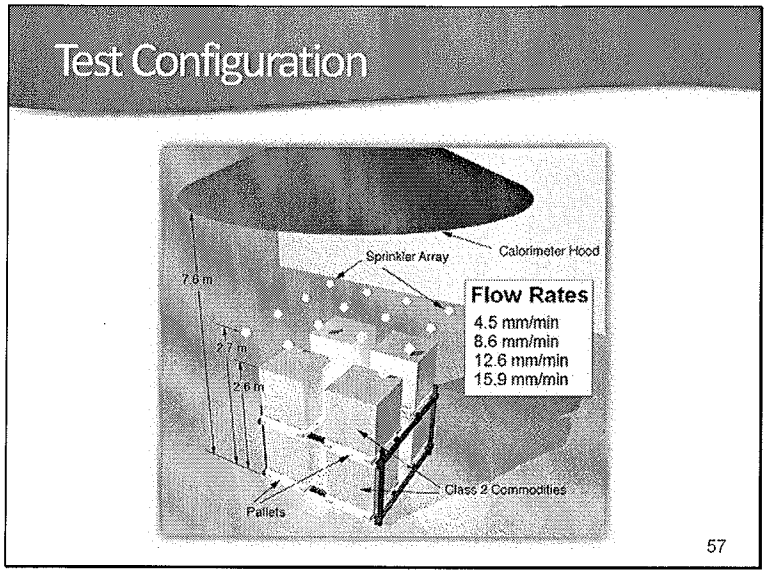
- Does not address flammable and combustible liquids
- Pool fires not included
- IBC's

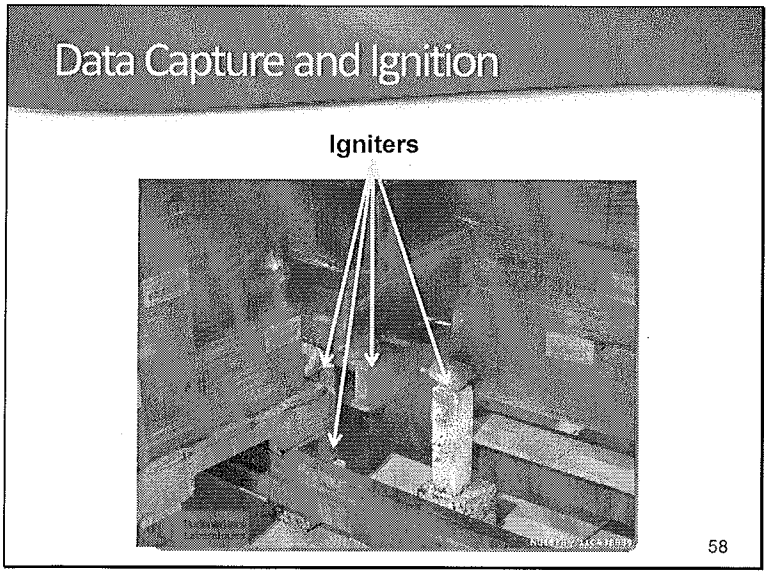


56

Module 2: Commodity and Packaging Classification

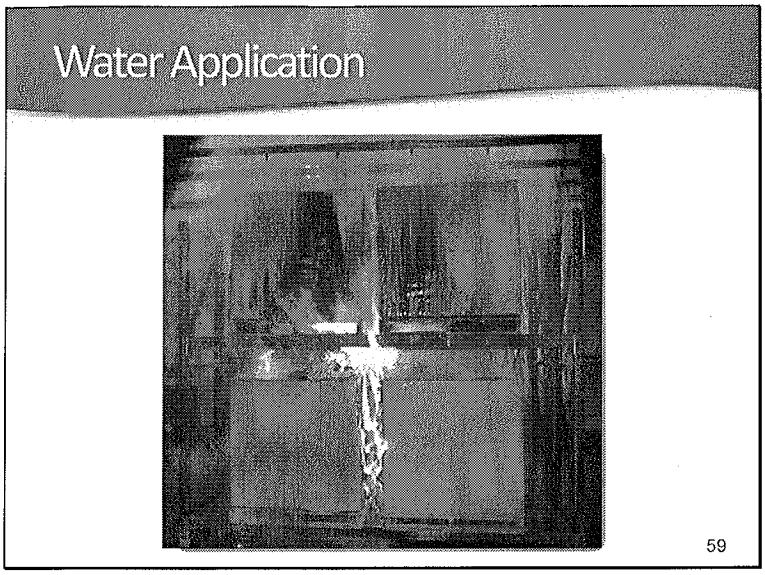
Presentation	Notes

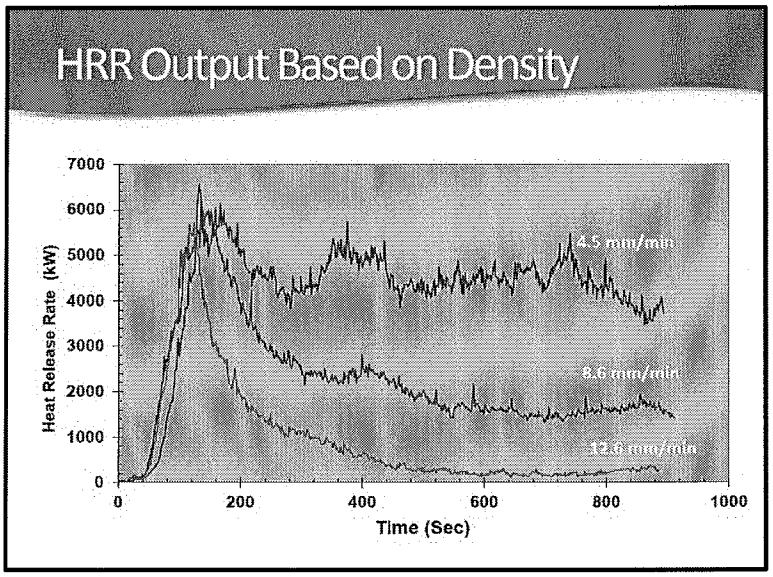




Module 2: Commodity and Packaging Classification

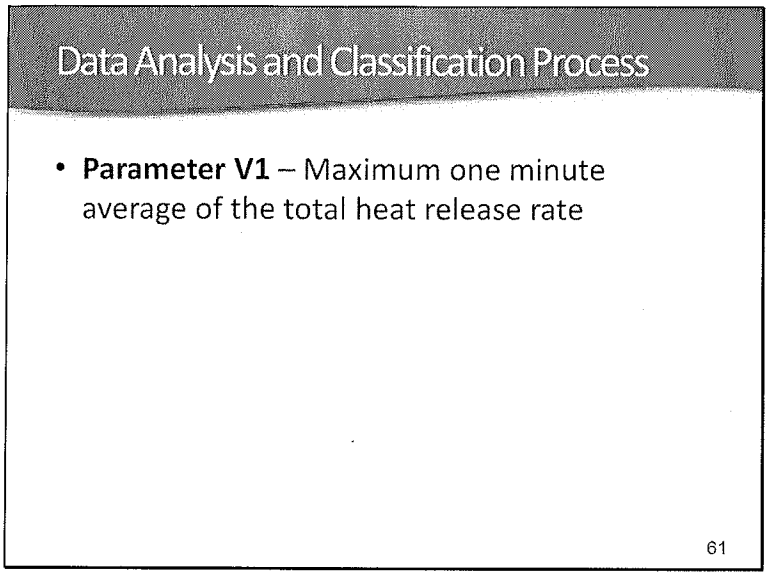
Presentation	Notes

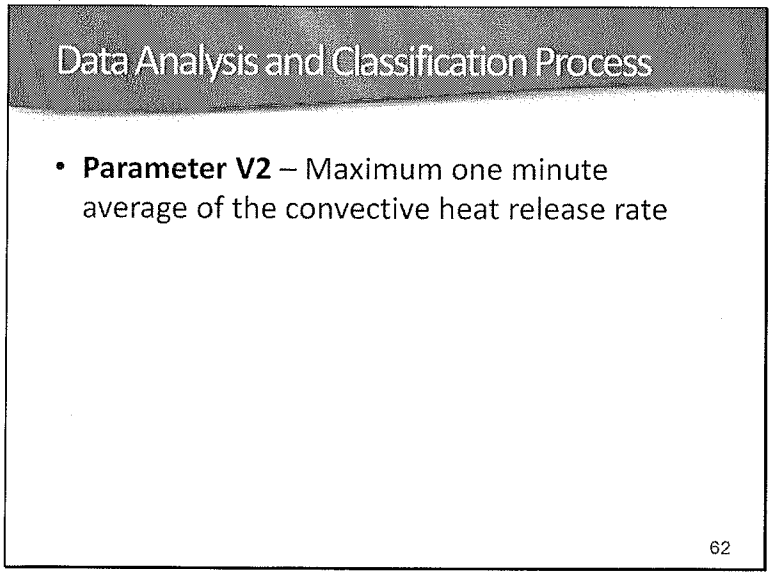




Module 2: Commodity and Packaging Classification

Presentation	Notes





Module 2: Commodity and Packaging Classification

Presentation	Notes

Data Analysis and Classification Process

- **Parameter V3** – Effective convective heat release rate, defined as the average convective heat release rate measured over the five minutes of the most intense fire

63

Data Analysis and Classification Process

- **Parameter V4** – Convective energy, the total convective energy measured over the 10 minutes of most severe burning

64

Module 2: Commodity and Packaging Classification

Presentation **Notes**

Parameter Ranking System

Delivered density: 0.11 gpm/ft² (4.5 mm/min)				
	V1	V2	V3	V4
Rank	Maximum total heat release rate, kW	Maximum convective heat release rate, kW	Effective convective heat release rate, kW	Total convective energy, MJ
0.50	0 – 3830	0 – 1970	0 – 620	
0.75	3840 – 4150	1980 – 2180	630 – 1040	199
1.00	4160 – 4520	2190 – 2410	1050 – 1460	200 – 589
1.25	4530 – 4910	2420 – 2660	1480 – 1880	590 – 940
1.50	4920 – 5310	2670 – 2940	1890 – 2300	941 – 1232
1.75	5320 – 5770	2950 – 3240	2310 – 2730	1233 – 1481
2.00	5780 – 6260	3250 – 3590	2740 – 3170	1482 – 1773
2.25	6270 – 6800	3600 – 3960	3180 – 3590	1774 – 1894
2.50	6810 – 7380	3970 – 4360	3600 – 4010	1895 – 2068
2.75	7390 – 7930	4370 – 4820	4020 – 4430	2069 – 2121
3.00	7940 – 8700	4830 – 5330	4440 – 4850	2122 – 2371
3.25	8710 – 9460	5340 – 5870	4860 – 5280	2372 – 2504
3.50	9470 – 10270	5880 – 6490	5290 – 5700	2505 – 2628
3.75	10280 – 11140	6500 – 7170	5710 – 6120	2629 – 2744
4.00	11150 – 12090	7180 – 7910	6130 – 6560	2745 – 2853
4.25	12100 – 13110	7920 – 8740	6570 – 6980	2854 – 2954
4.50	13120 – 14240	8750 – 9650	6990 – 7400	2955 – 3051
4.75	14250 – 15470	9660 – 10650	7410 – 7820	3052 – 3142
5.00	15480 – 16780	10660 – 11760	7830 – 8250	3143 – 3228

Commodity Class Designations for Mean Total Rank Values

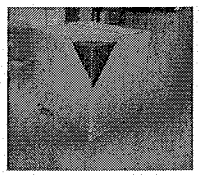
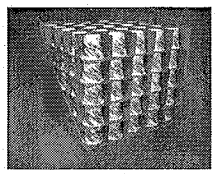
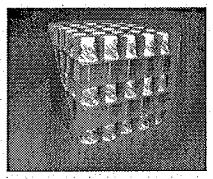
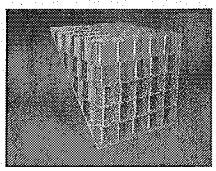
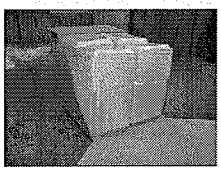
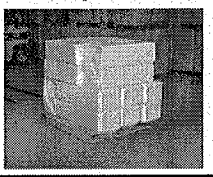
Commodity Class Designations for Mean Total Rank Values		*Rank*
Mean Total Rank	*Commodity Class*	
Less than 1.5	I	1
Equal to or greater than 1.5 but less than 2.5	II	2
Equal to or greater than 2.5 but less than 3.5	III	3
Equal to or greater than 3.5 but less than 4.5	IV	4
Equal to or greater than 4.5 but less than 5.5	Cartoned Group B Unexpanded Plastic	5
Equal to or greater than 5.5 but less than 6.5	Cartoned Group A Unexpanded Plastic	6
Equal to or greater than 6.5 but less than 7.0	Cartoned Group A Expanded Plastic	7

Source: FM4995, Figure A-4 (Approval Standard for Commodity Classification of Idle Plastic Pallets)

Module 2: Commodity and Packaging Classification

Presentation	Notes

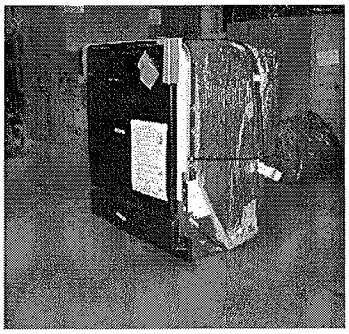
Standardized Test Commodities

Class II	Class III	Class IV
		
Cartoned, Unexpanded Group A Plastic	Cartoned, Expanded Group A Plastic	Exposed, Expanded Group A Plastic
		

Case Study – Dishwashers

Product and Packaging:

- Dishwasher
- Plastic and metal components
- Insulated wrapping material
- Cartoned



68

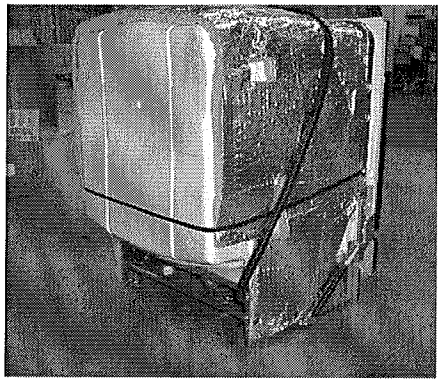
Module 2: Commodity and Packaging Classification

Presentation	Notes

Case Study – Dishwashers

Testing:

- Packaged as intended to be stored
- Tested per procedure reviewed above



69

Case Study – Dishwashers



Results:

Stored dishwashers created a fire challenge similar to cartoned, unexpanded Group A plastic commodity

70

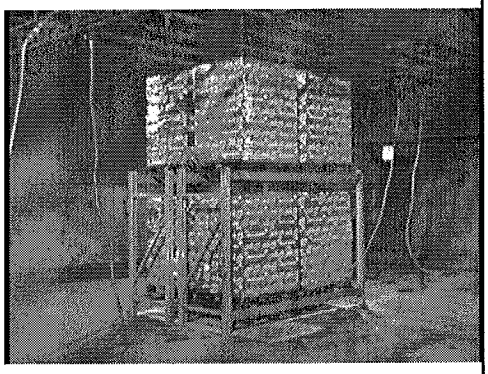
Module 2: Commodity and Packaging Classification

Presentation	Notes

Case Study – Beverage Company

Situation:

- Attempted cost savings measure
- Switch to lighter more durable pallet
- Impact of plastic pallet unknown
- Current suppression scheme acceptable?



71

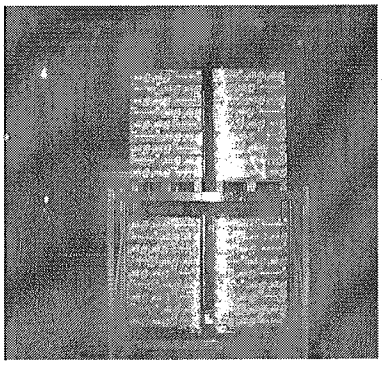
Case Study – Beverage Company

Testing:

- Glass bottled and canned beer in paperboard
- Two pallet types

Results:

- Performed like wood pallet
- Saved on system modifications
- Class I on plastic pallets

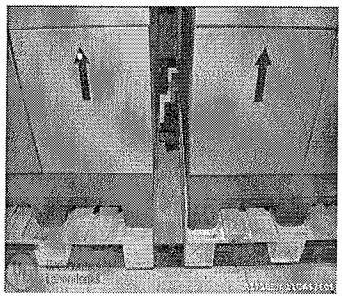


72

Module 2: Commodity and Packaging Classification

Presentation	Notes

Case Study – Plastic / Wood Pallet Combination



Situation:

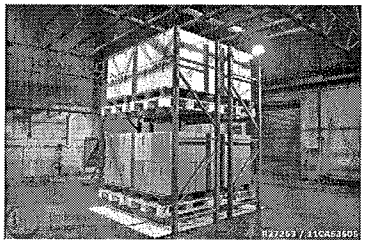
- Existing warehouse with Class IV commodity protection scheme
- Retrofitting in an Automated Storage and Retrieval System (ASRS)
- Potentially required the use of a plastic pallet
- What is the impact of the combination pallet?

73

Case Study – Plastic / Wood Pallet Combination

Testing:

- Class IV commodity placed on customer-supplied wood pallets
- Class IV commodity placed on customer-supplied plastic pallets placed on top of customer-supplied wood pallets



74

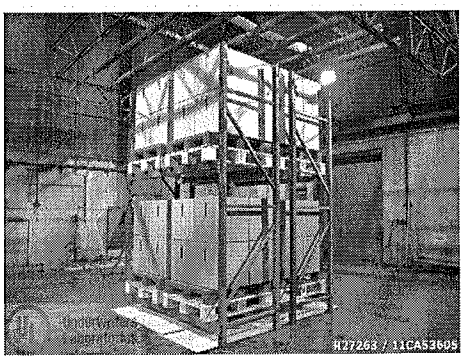
Module 2: Commodity and Packaging Classification

Presentation	Notes

Case Study – Plastic / Wood Pallet Combination

Results

- Presence of plastics increased fire intensity
- Increase in commodity class per NFPA 13 required



75

Case Study – Electric Shavers

Situation

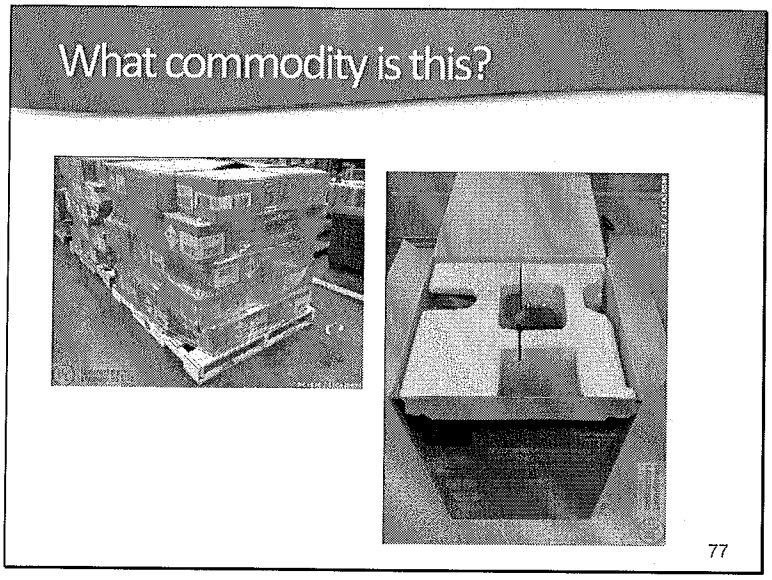
- Hazard of commodity unknown
- Shaver with charging base and cleaning solution
- Styrofoam packing
- Paperboard boxes
- Shaver tested with and without the cleaning solution

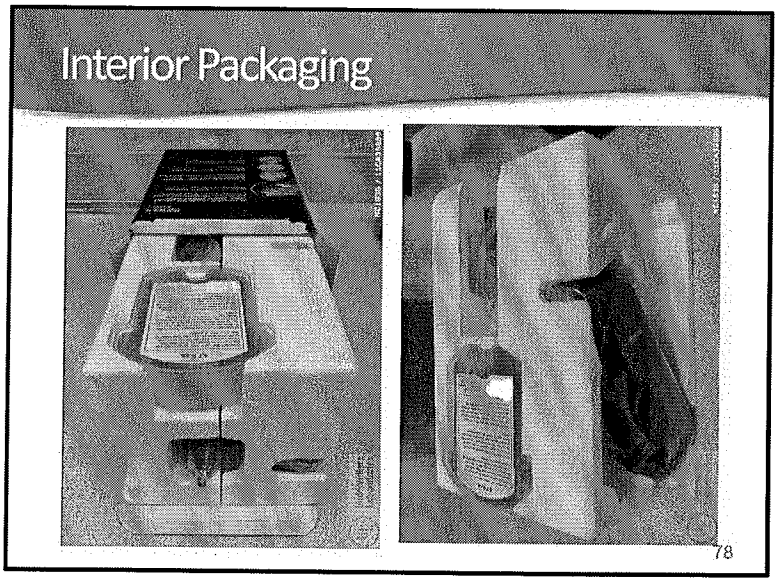


76

Module 2: Commodity and Packaging Classification

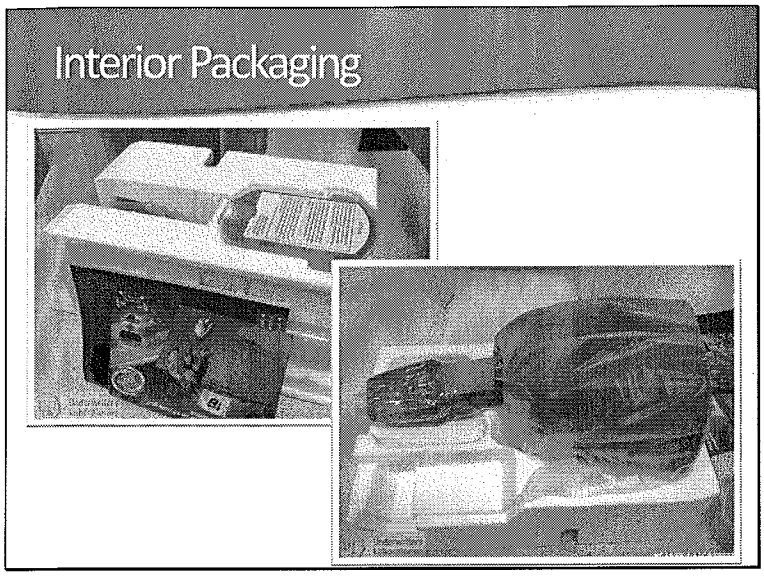
Presentation	Notes





Module 2: Commodity and Packaging Classification

Presentation	Notes

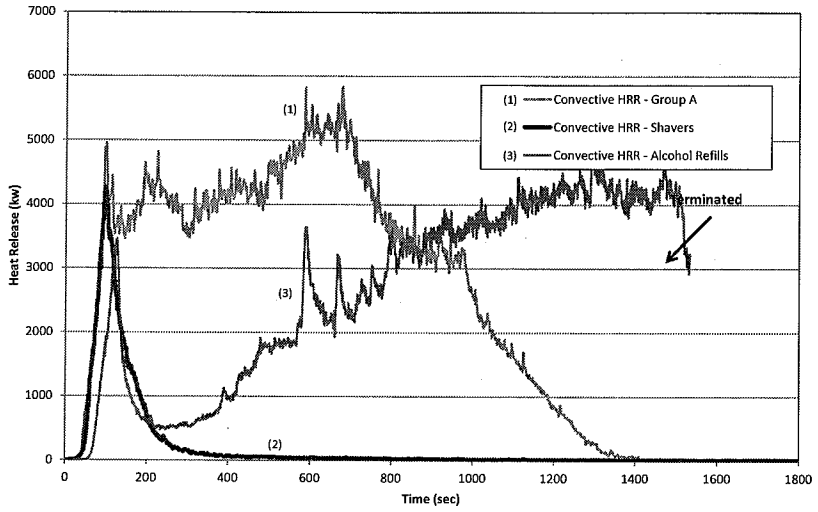




Module 2: Commodity and Packaging Classification

Presentation **Notes**

Test Output Data



82

Electric Shaver Kits – Results



83

Module 2: Commodity and Packaging Classification

Presentation	Notes

Electric Shaver Kits – Results

Results

- Electric shaver kits created a fire challenge that was less than cartoned, unexpanded Group A plastic
- Client realized a substantial cost savings by eliminating off-site storage of the shaver kits
- Alcohol refills are stored at an offsite facility



84

Commodity Testing Summary

- Provides specific data
- Avoids "Annex A" pitfall
- Flammable liquids difficult to assess

85

Module 2: Commodity and Packaging Classification

Activity 2.1

Instructions: Working in groups, determine the commodity classification, storage arrangement, and the referenced chapter in NFPA 13 for the given examples.

Example 1: Wooden desks with an appreciable amount of plastic parts stacked a maximum of 5 desks high.

1. What is the commodity classification?

Class III → Class IV pg 13 - 27

2. What is the storage arrangement?

High Pile Storage. pg 13-22

3. In what chapter of NFPA 13 would the rules be found?

Chapter 14.

Example 2: A three story office building with a 111.5 m^2 storage area located on the first floor. The storage area will have supplies of paper products and cleaning supplies on 2.4 meter high shelves .

Class III ↑ Group A Plastics.

1. What is the commodity classification?

Class III.

2. What is the storage arrangement?

High pile due to exceedy $93m^2$ limit for miscellaneous.

3. In what chapter of NFPA 13 would the rules be found?

Chapter 14

Module 2: Commodity and Packaging Classification

Example 3: Cartoned empty glass wine bottles stored on racks 4.3 meters high.

1. What is the commodity classification?

   Class I

2. What is the storage arrangement?

   High pile — Rack less th 7.6m

3. In what chapter of NFPA 13 would the rules be found?

   Chapte 16.2.

Example 4: Small plastic bottles of nail polish in cartons stored on 5.5 meter high racks.

1. What is the commodity classification?

   Class IV

2. What is the storage arrangement?

   High pile — Rack less the 7.6m.

3. In what chapter of NFPA 13 would the rules be found?

   Chapte 17

Example 5: Pallets of cartoned carpet tiles stacked a maximum of 3 pallets high.

1. What is the commodity classification? — Group A plastics.

2. What is the storage arrangement?

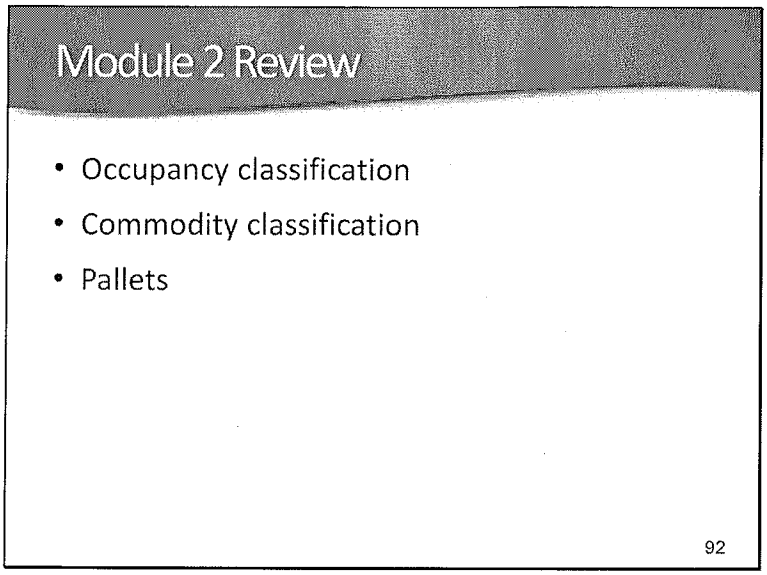
   Palletized storage @ X.6m high

3. In what chapter of NFPA 13 would the rules be found?

   Chapte 15.

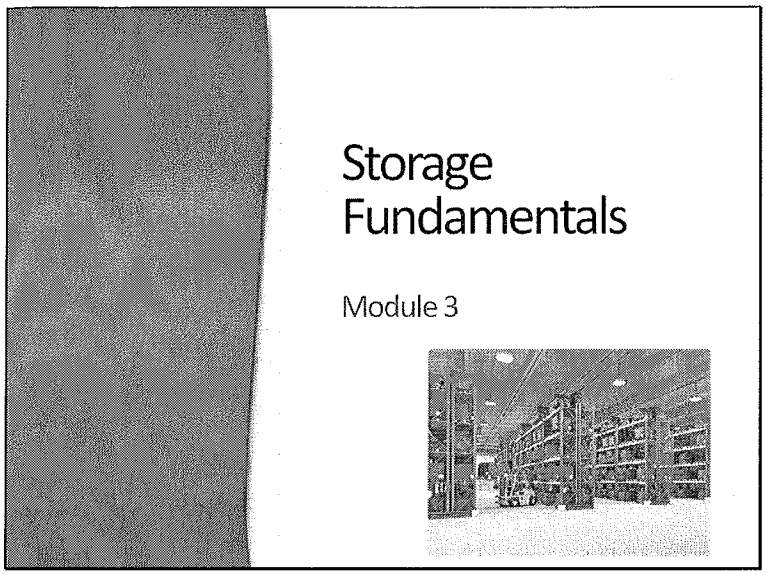
Module 2: Commodity and Packaging Classification

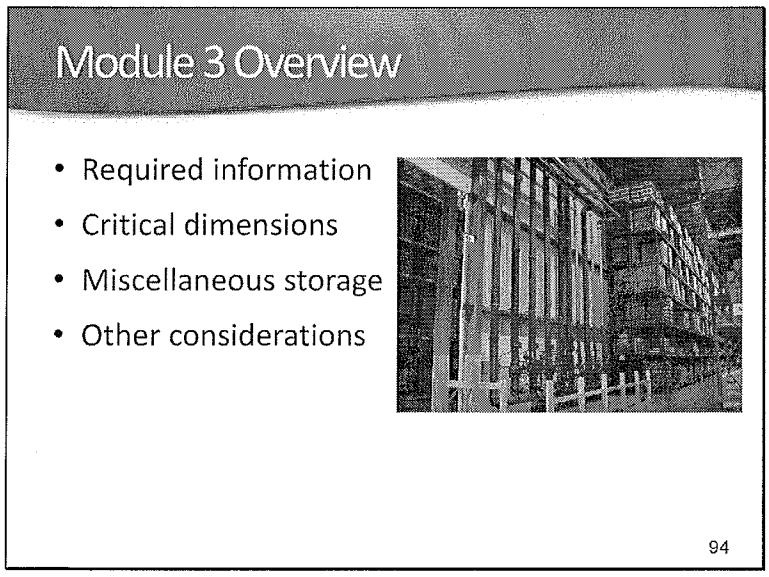
Presentation	Notes



Module 3: Storage Fundamentals

Presentation	Notes





Module 3: Storage Fundamentals

Presentation	Notes

Module 3 Objectives

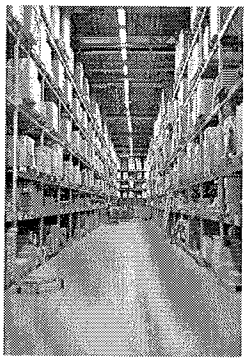
Upon completion attendees should be able to:

- Identify the information required in order to determine an acceptable design approach
- Determine the impact of ceiling height on sprinkler system design
- Apply the five steps of the sprinkler design process for rack storage applications
- Describe additional considerations that will dictate design options

95

General Storage Type – Rack vs. Piled

(Palletized, Bin Box, Shelf, and Back-to-Back Shelf Storage)



OR



96

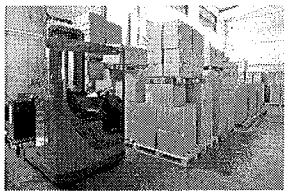
Module 3: Storage Fundamentals

Presentation | **Notes**

Required Information Before Proceeding to the Applicable Chapters for Class I, II, III, IV and Plastic Commodities

Palletized, Solid Piled, Bin Box, Shelf, and Back-to-Back Shelf Storage

- Determine commodity class — Section 5.6.3
- Determine ceiling height — Section 12.1.3.1
- Storage height:
  - From floor — Section 12.1.3.3
  - Clearance to sprinkler minimum — Section 8.5.6
  - Clearance to ceiling — Section 12.1.3.4
- Storage arrangement — Section 3.9.2
- Miscellaneous storage — Section 3.9.1.18 (Go to Chapter 13)
- General storage – Chapter 14 and 15
- Special occupancies – Chapter 22



97

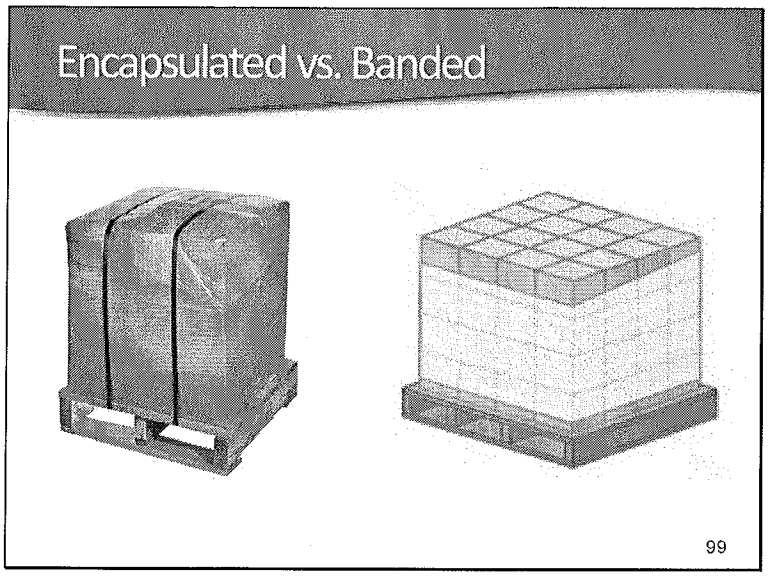
Palletized and Piled Storage – Step 1 Identify Commodity

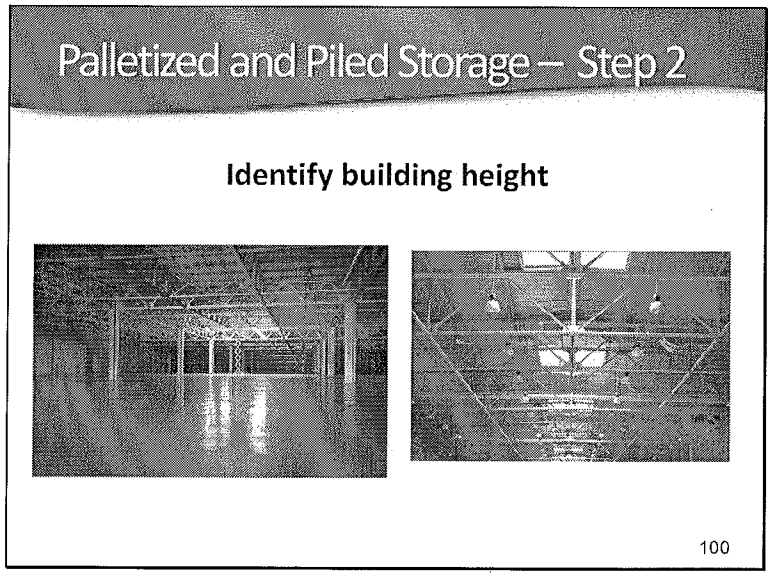
- Chapter 5
- Annex material
- What is the product?
- How is it packaged?
  - Encapsulated/banded?
- Will the packaging change?
- Variations on the product?

98

Module 3: Storage Fundamentals

Presentation	Notes



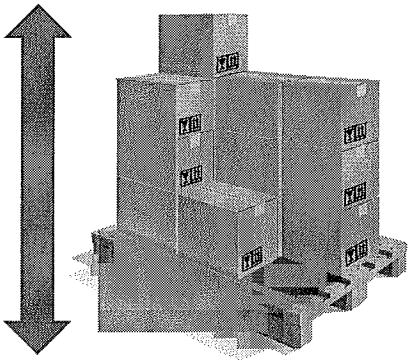


Module 3: Storage Fundamentals

Presentation	Notes

Palletized and Piled Storage – Step 3

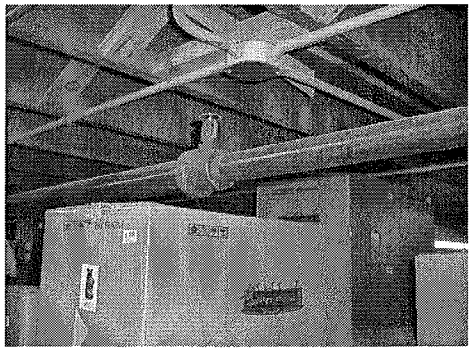
Establishing storage height



101

Palletized and Piled Storage – Step 4

Clearance to sprinkler minimum



102

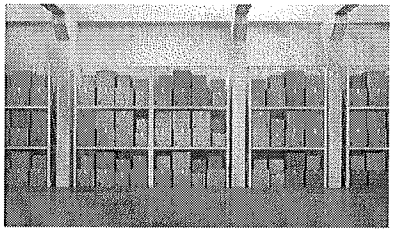
Module 3: Storage Fundamentals

Presentation	Notes

Palletized and Piled Storage – Step 4

8.5.6 Clearance from Deflector to Storage

- General rule is 457 mm
- "Special sprinklers" require 914 mm clearance
- Rubber tire storage requires 914 mm clearance
- Reduced with large scale testing



103

Page: 13-52

Palletized and Piled Storage Step 5 – Clearance to Ceiling

12.1.3.4 Clearance to Ceiling.

12.1.3.4.1* The clearance to ceiling shall be measured in accordance with 12.1.3.4.1.1 and 12.1.3.4.1.2.

104

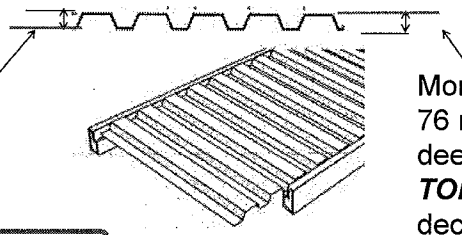
Page: 13-126

Module 3: Storage Fundamentals

Presentation	Notes

Where's the ceiling? Corrugated Metal

For corrugated metal deck roofs up to 76 mm in depth, the clearance to ceiling shall be measured from the top of storage to the bottom of the deck. For deeper decks, the clearance to ceiling shall be measured to the highest point on the deck.



12.1.3.4.1.1 and 12.1.3.4.1.2

105

Page: 13-126

Where's the ceiling? Insulation Attached

12.1.3.4.1.3 For ceilings that have insulation attached directly to underside of the ceiling or roof structure, the clearance to ceiling shall be measured from the top of storage to the bottom of the insulation and shall be in accordance with 12.1.3.4.1.3(A) or 12.1.3.4.1.3(B).

106

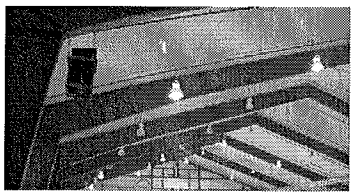
Page: 13-126

Module 3: Storage Fundamentals

Presentation	Notes

Where's the ceiling? Insulation (A)

12.1.3.4.1.3(A) For insulation that is attached directly to the ceiling or roof structure and is installed flat and parallel to the ceiling or roof structure, the clearance to ceiling shall be measured from the top of storage to the underside of the insulation.



107

Page: 13-26

Where's the ceiling? Insulation (B)

12.1.3.4.1.3 (B) For insulation that is installed in a manner that causes it to deflect or sag down from the ceiling or roof structure, the clearance to ceiling shall be measured from the top of storage to a point half of the distance of the deflection from the insulation high point to the insulation low point. If the deflection or sag in the insulation exceeds 152 mm, the clearance to ceiling shall be measured from the top of storage to the high point of the insulation.

108

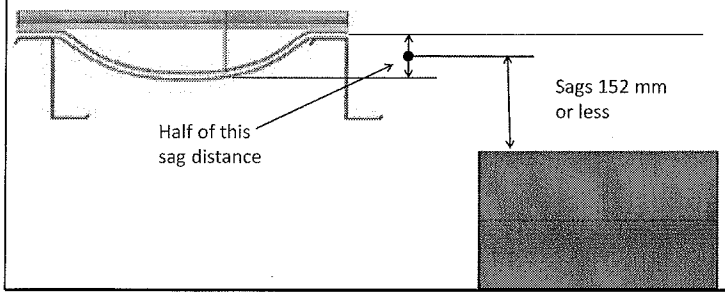
Page: 13-126

Module 3: Storage Fundamentals

Presentation **Notes**

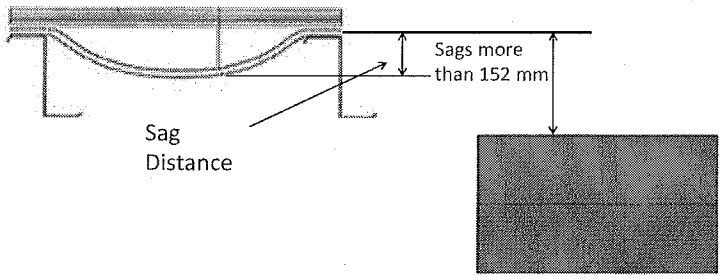
Where's the ceiling? Insulation (B1)

(B) For insulation that ... deflect or sag down ..., the clearance to ceiling shall be measured from the top of storage to a point ***half of the distance of the deflection*** from the insulation high point to the insulation low point.



Where's the ceiling? Insulation (B2)

(B) ...If the deflection or sag in the insulation exceeds 152 mm, the clearance to ceiling shall be measured from the top of storage to ***the high point of the insulation.***



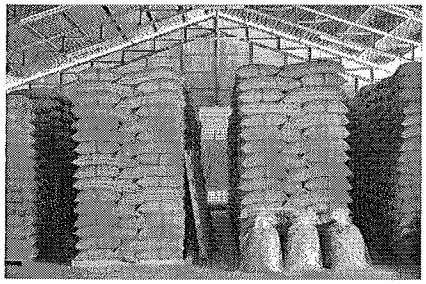
Module 3: Storage Fundamentals

Presentation	Notes

Palletized and Piled Storage – Step 6

Define storage arrangement

- Array
- Container type
- Shelf type
- Stability



111

Page: 13-22

Pile Stability

- **3.9.2.4 Stable Piles.** Those arrays where collapse, spillage of content, or leaning of stacks across flue spaces is not likely to occur soon after initial fire development.
- **3.9.2.5 Unstable Piles.** Those arrays where collapse, spillage of contents, or leaning of stacks across flue spaces occurs soon after initial fire development

112

Module 3: Storage Fundamentals

Presentation	Notes

Palletized and Piled Storage – Step 7

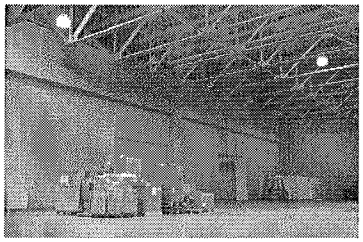
- Do I have miscellaneous storage?



114

Chapter 13 – Miscellaneous Storage

- All of the following conditions must be met:
  - Max 3.7 m
  - Incidental to occupancy
  - Max 10% or 372 m^2 of sprinklered area
  - Max 93 m^2 pile
  - 7.6 m separation

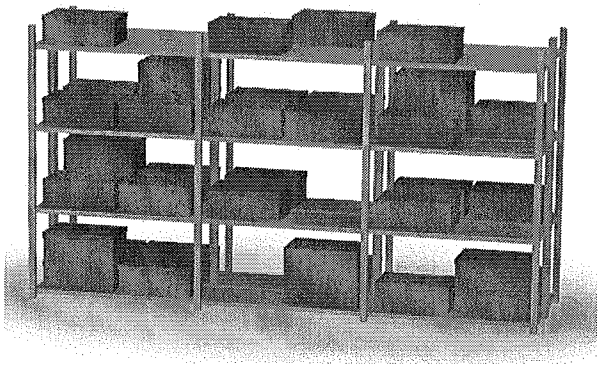


115

Module 3: Storage Fundamentals

Presentation	Notes

Miscellaneous Storage



116

Palletized and Piled Storage – Step 8

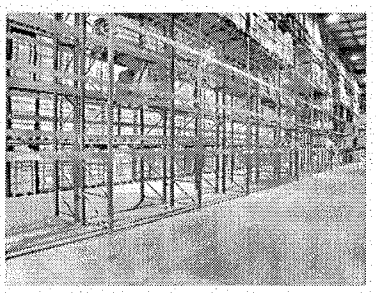
- Determine design criteria and sprinkler technology
- Additional considerations
- Chapter 14 or 15

117

Module 3: Storage Fundamentals

Presentation **Notes**

Required Information Before Proceeding to the Applicable Chapters for Class I, II, III, IV and Plastic Commodities



Rack Storage

- Determine Commodity Class — Section 5.6.3
- Determine Ceiling Height — Section 12.1.3.1
- Storage Height on Racks
  - From Floor — Section 12.1.3.3
  - Clearance to Sprinkler Minimum — Section 8.5.6
  - Clearance to Ceiling — Section 12.1.3.4
- Rack Type — Section 3.9.9
- Shelf Type — Section 3.9.3
- Miscellaneous Storage —Section 3.9.1.18 (Go to Chapter 13)
- Rack Storage — Chapters 16, 17, 20 and 22

118

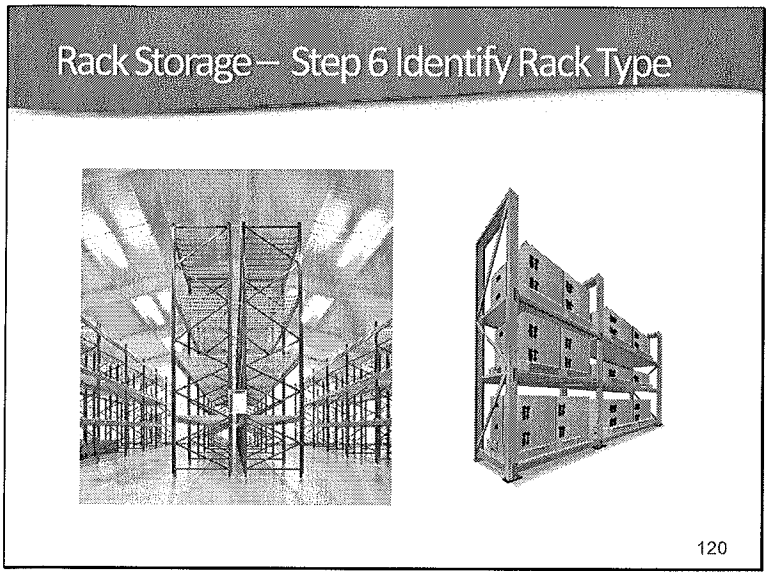
Rack Storage – Steps 1-5

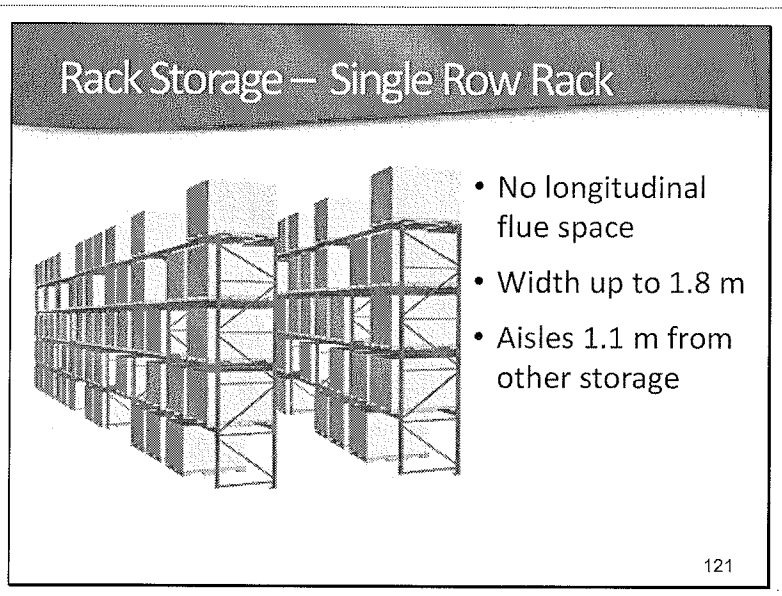
- Step 1: Identify commodity
- Step 2: Identify building height
- Step 3: Identify rack height with stored goods
- Step 4: Confirm clearance to sprinklers
- Step 5: Identify clearance to ceiling

119

Module 3: Storage Fundamentals

Presentation	Notes





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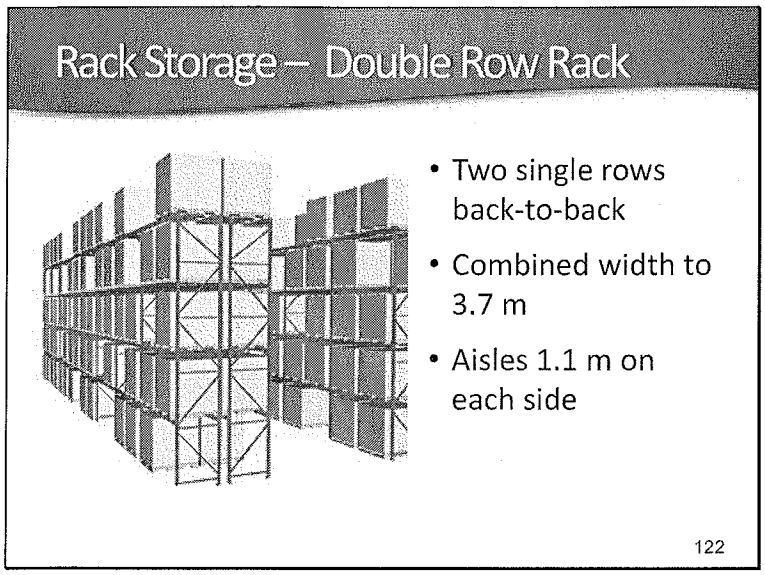
Module 3: Storage Fundamentals

Presentation	Notes



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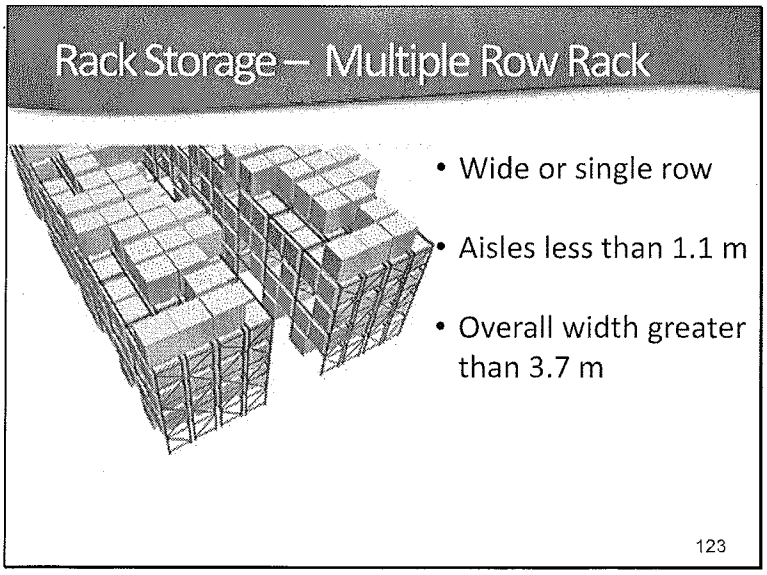

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Module 3: Storage Fundamentals

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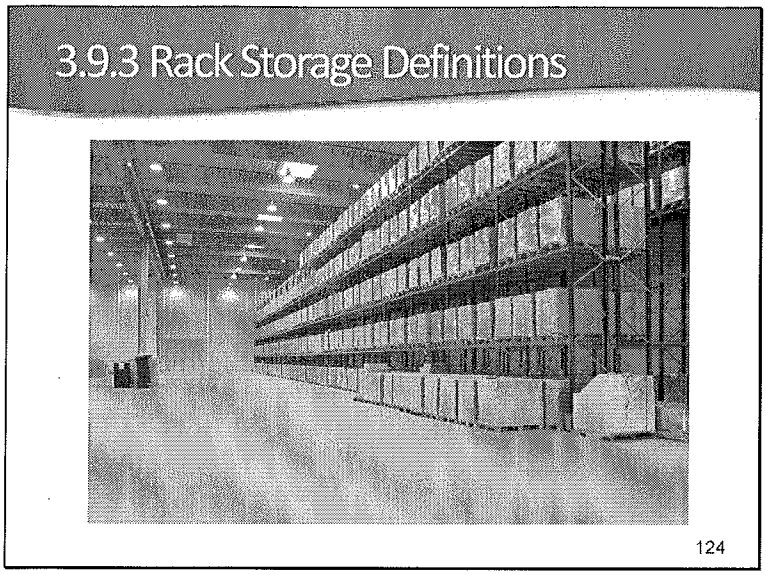

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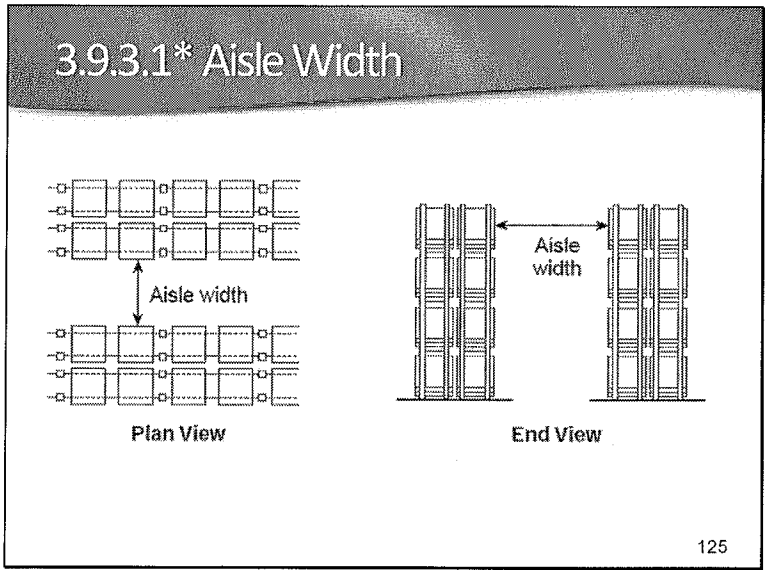

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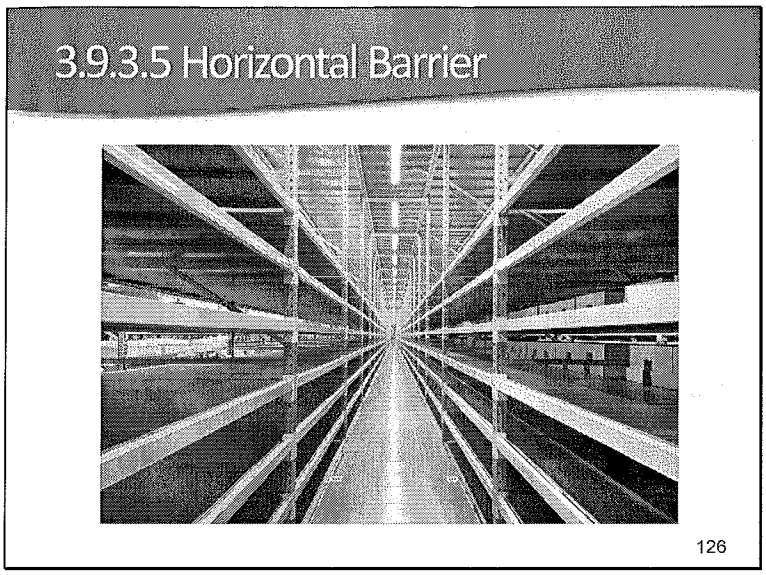
Module 3: Storage Fundamentals

Presentation	Notes



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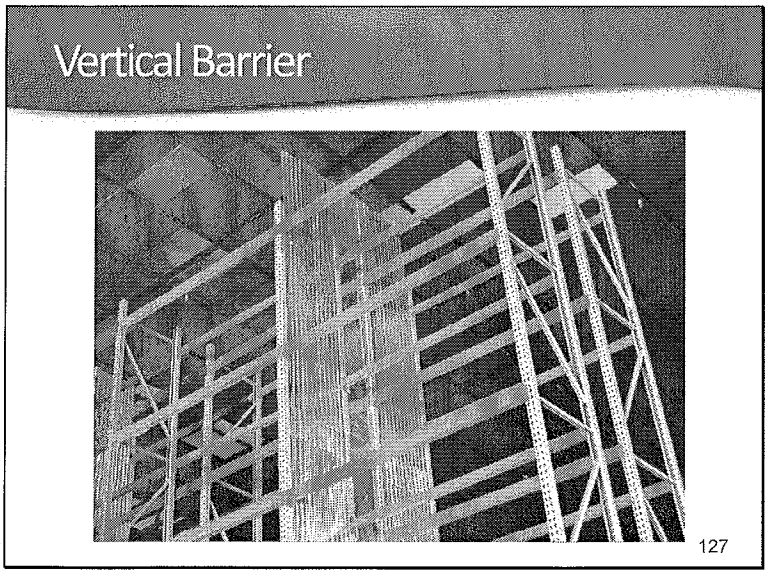

Module 3: Storage Fundamentals

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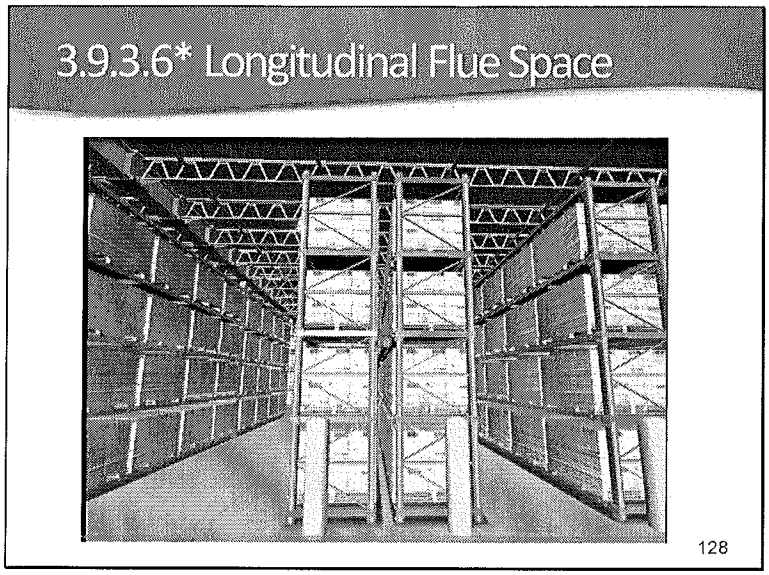

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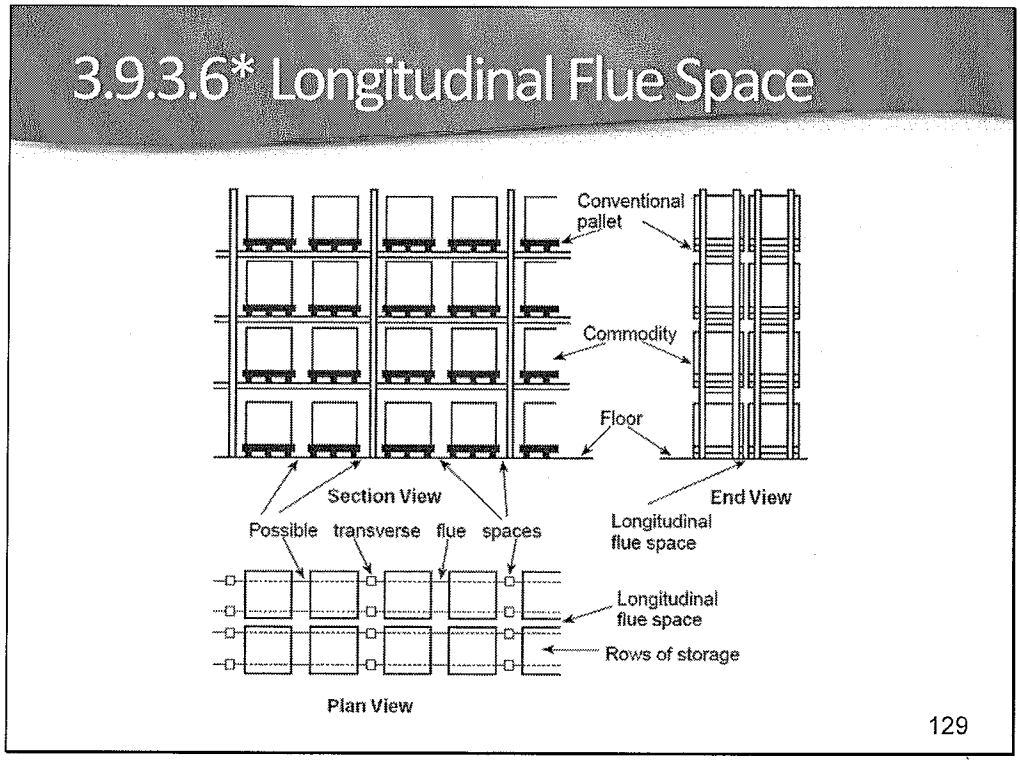

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Module 3: Storage Fundamentals

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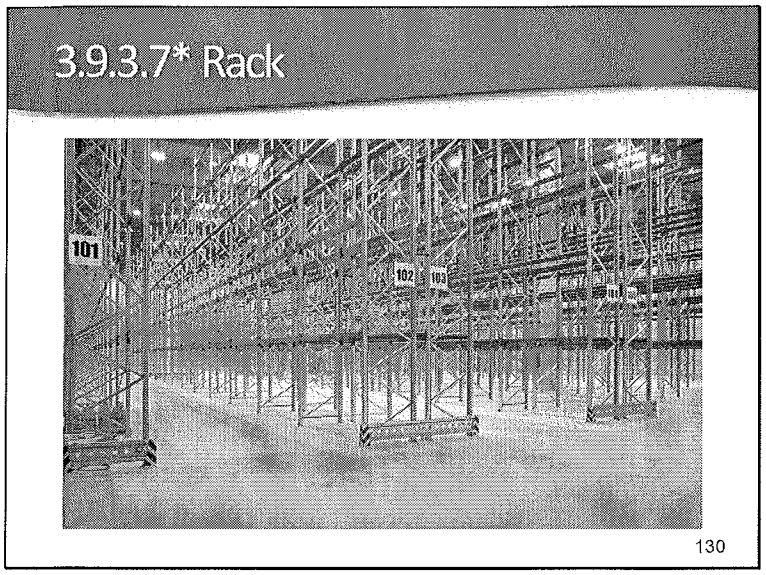

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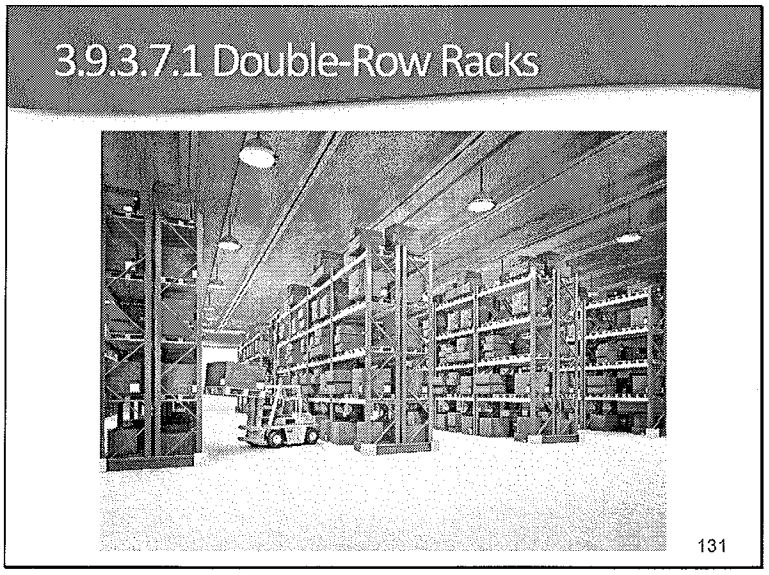

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Module 3: Storage Fundamentals

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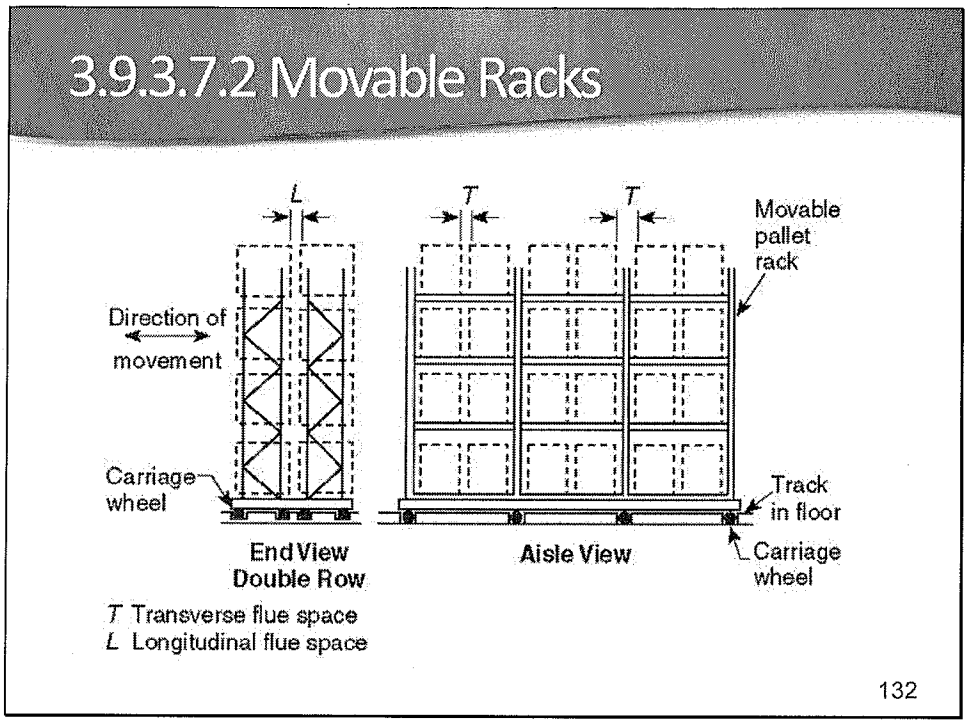

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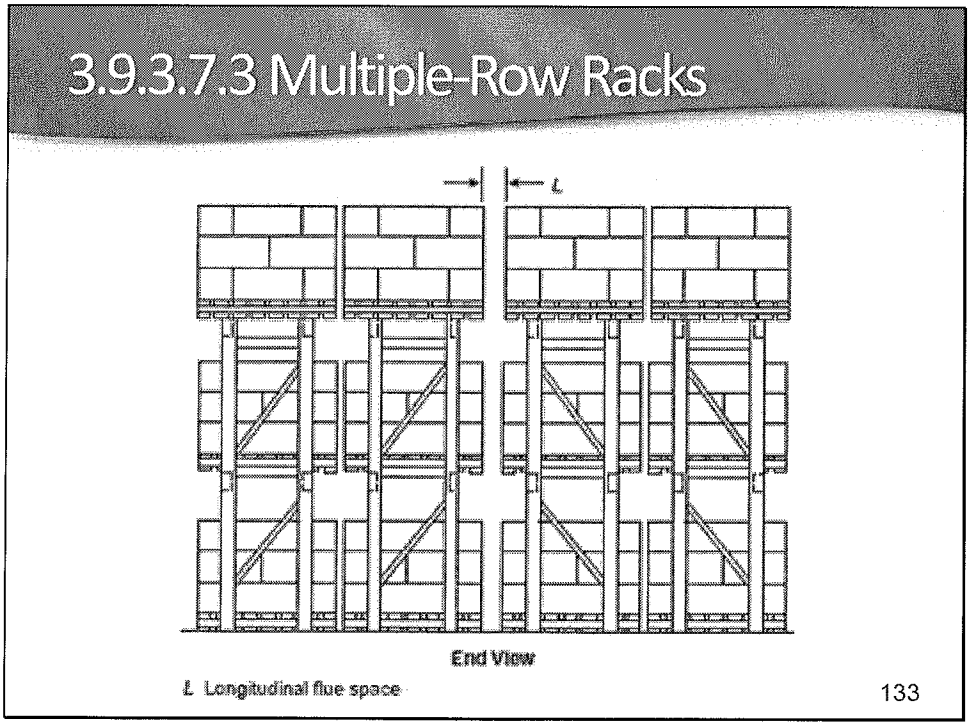
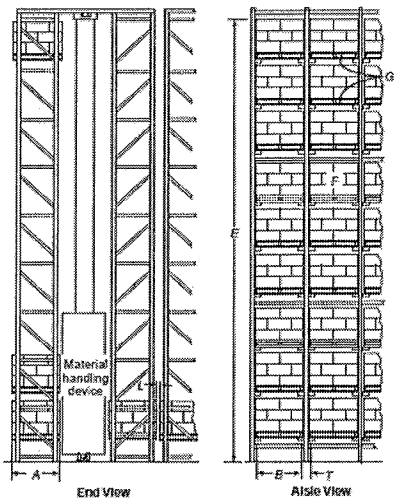


Page: 13-23

Module 3: Storage Fundamentals

Presentation	Notes

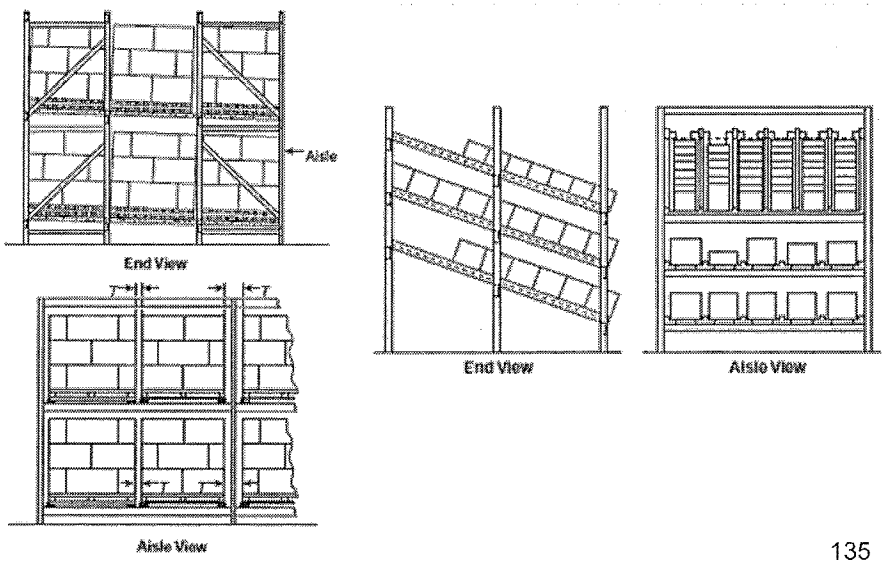
Automatic Storage-Type Rack



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

134

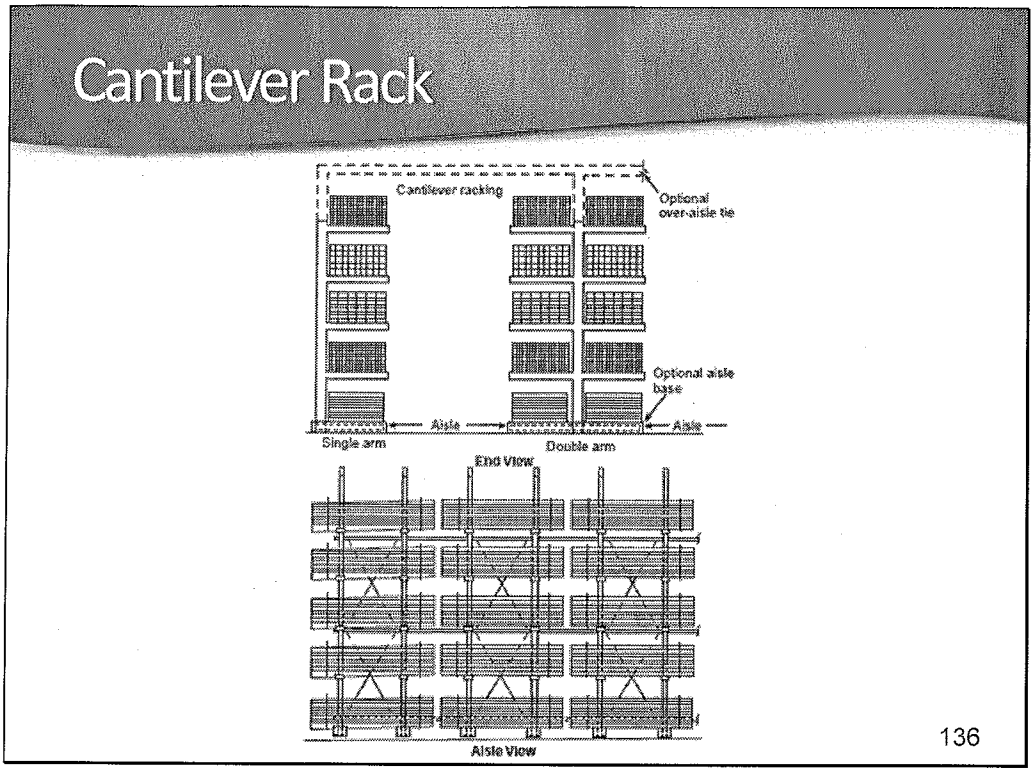
Flow-Through Racks

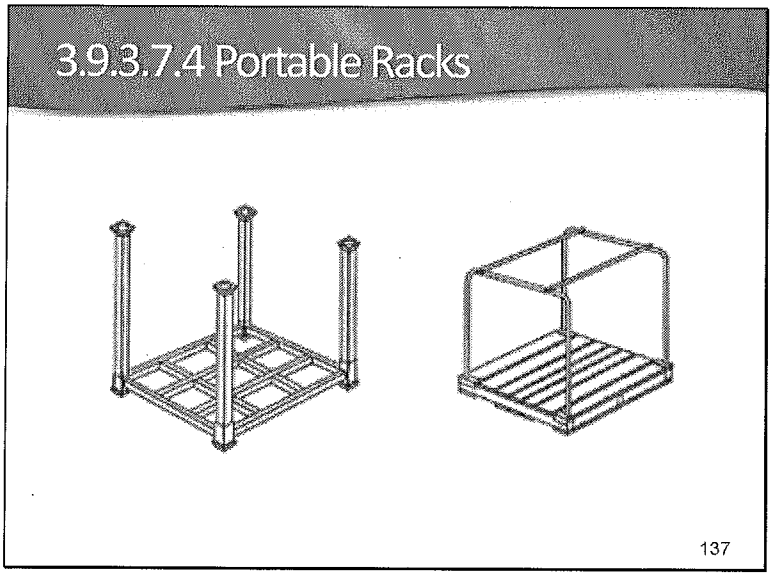


135

Module 3: Storage Fundamentals

Presentation **Notes**





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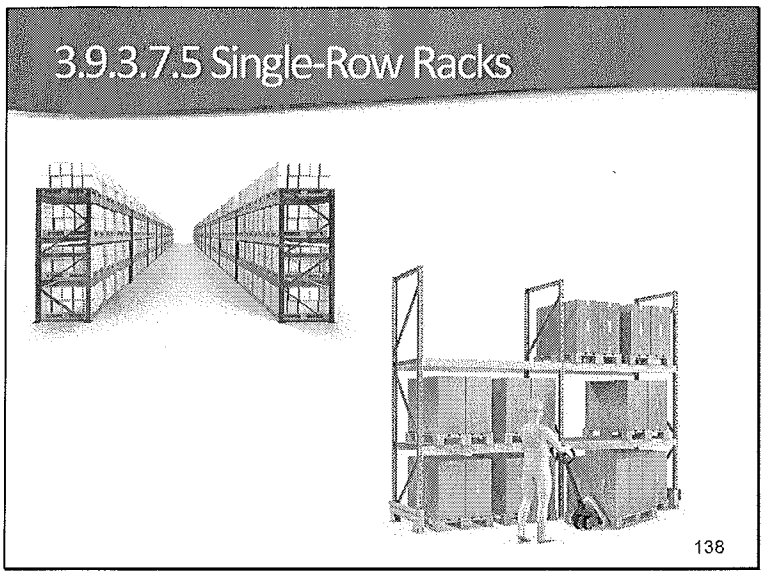
Module 3: Storage Fundamentals

Presentation	Notes



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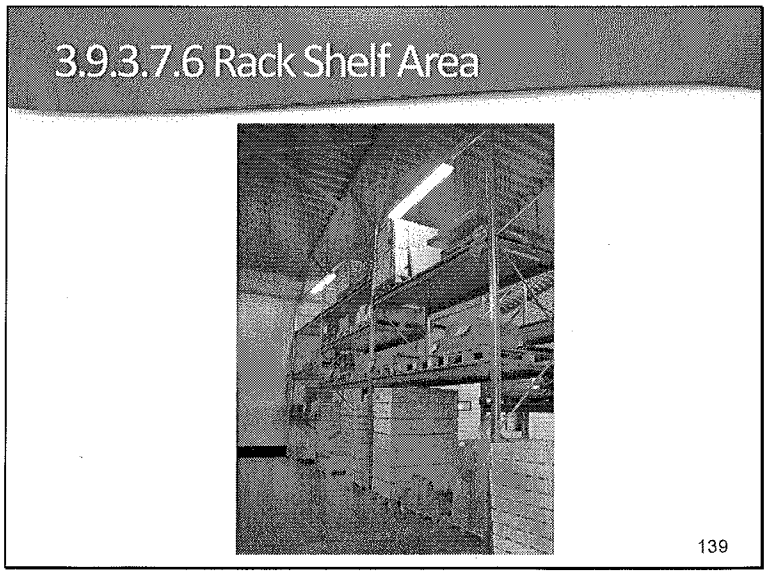
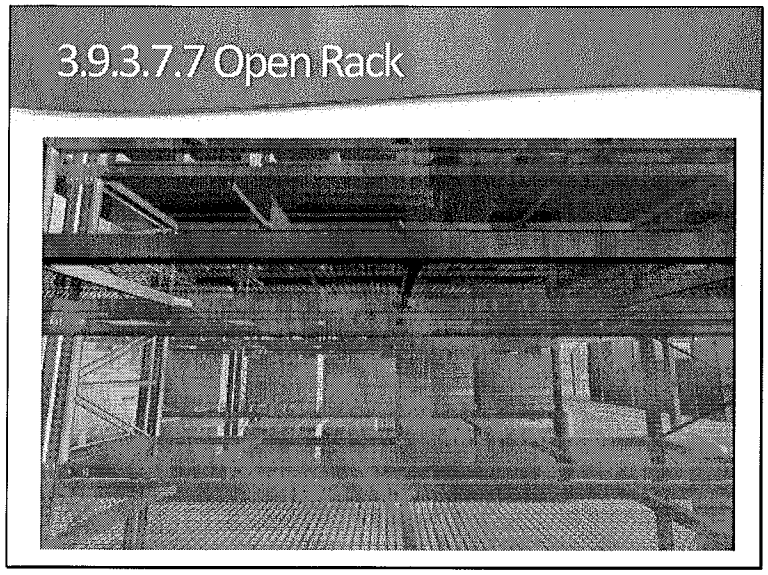


Page: 13-23

Module 3: Storage Fundamentals

Presentation	Notes



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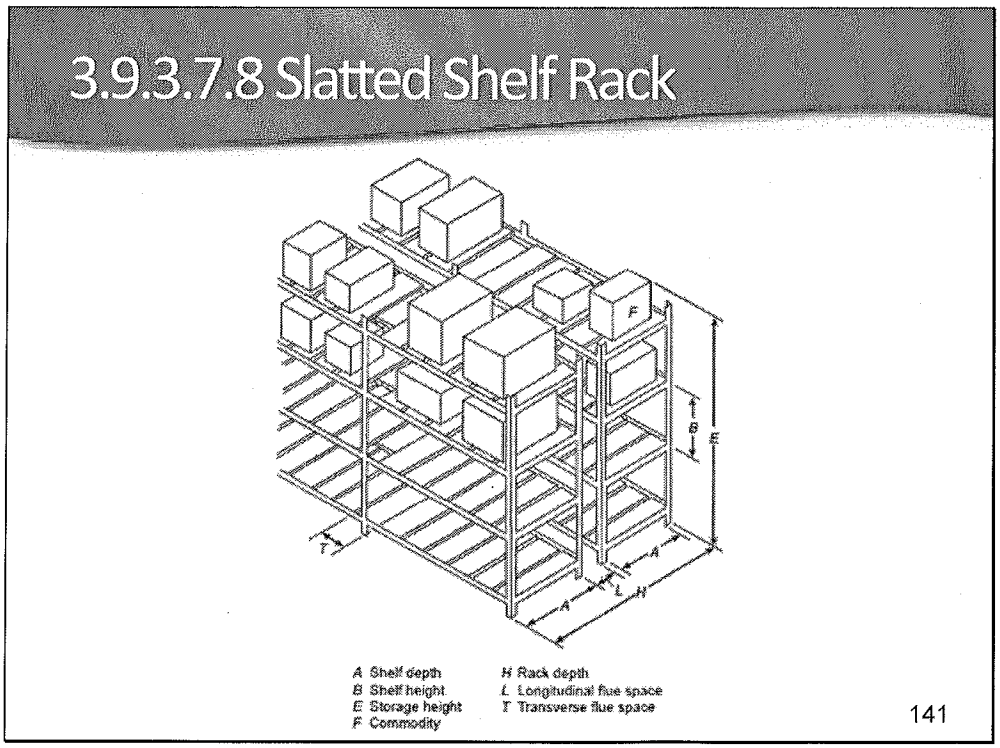
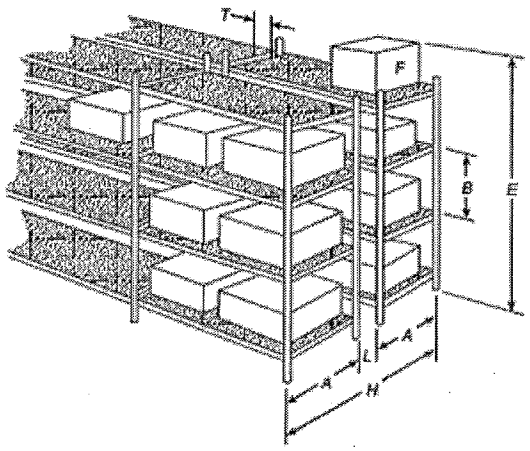


Page: 13-23

Module 3: Storage Fundamentals

Presentation	Notes

3.9.3.8 Solid Shelving

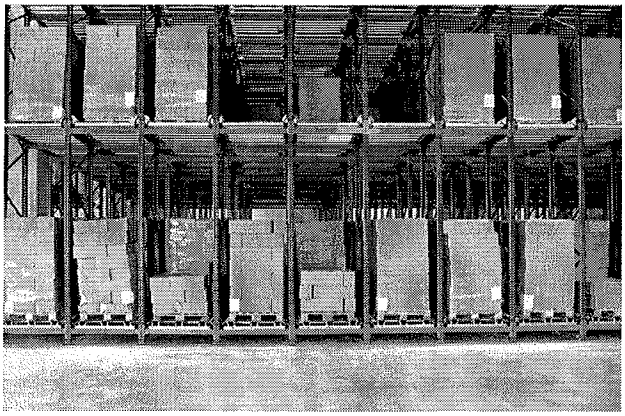


A Shelf depth
B Shelf height
E Storage height
F Commodity
H Rack depth
L Longitudinal flue space
T Transverse flue space

142

Page: 13-23

3.9.3.9 Transverse Flue Space

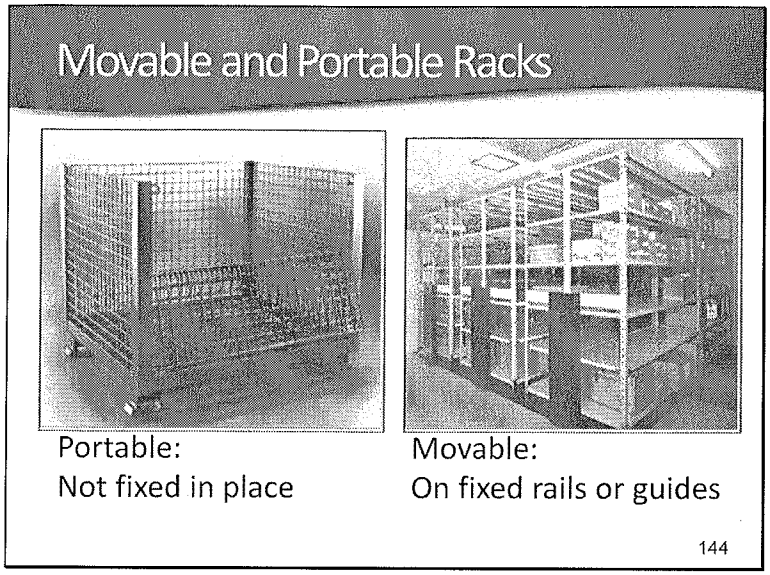


143

Page: 13-23

Module 3: Storage Fundamentals

Presentation	Notes



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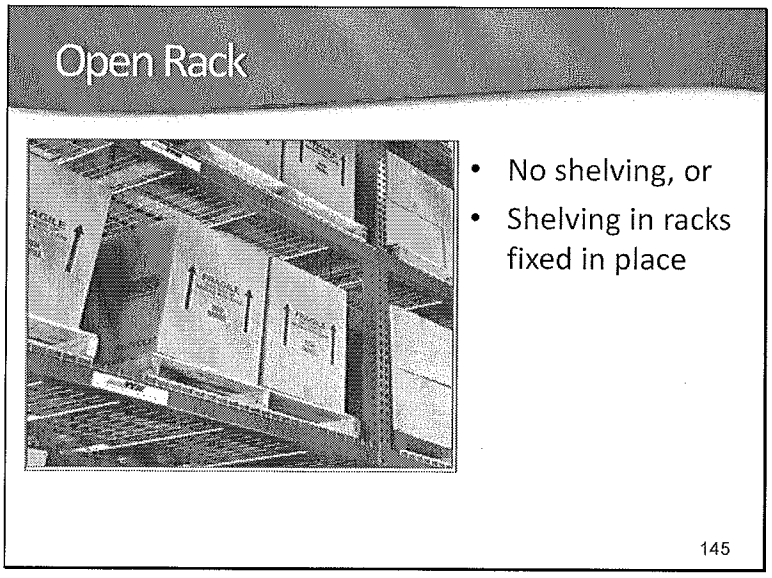
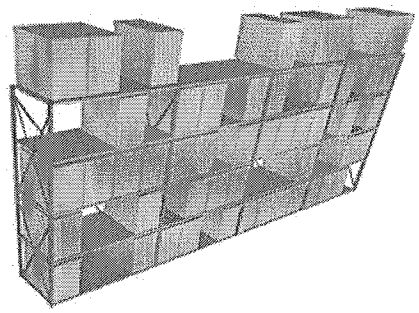


Page: 13-23 (3.9.3.7.7)

Module 3: Storage Fundamentals

Presentation	Notes

Solid Shelving – Open Racks

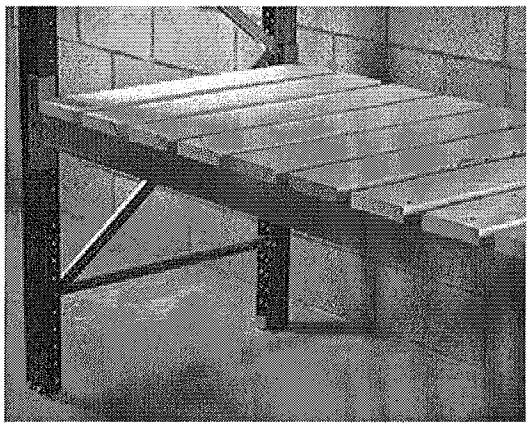


- Area equal to or less than 1.9 m^2
- Shelving material more than 50% open
- Flue spaces maintained

146

Page: 13-23 (3.9.3.8)

Slatted Shelves



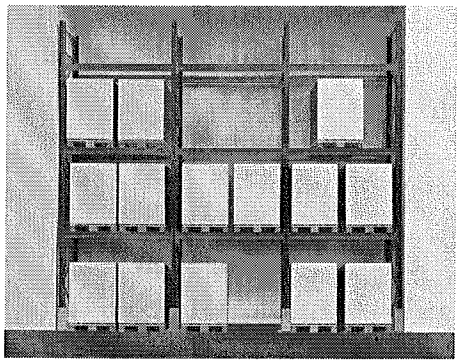
147

Module 3: Storage Fundamentals

Presentation	Notes

Rack Storage – Step 8

- Do I have miscellaneous storage?



148

Rack Storage – Step 9

- Determine design criteria and sprinkler technology
- Additional considerations
- Chapter 16, 17 or 20



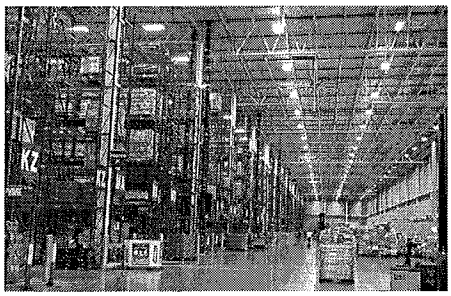
149

Module 3: Storage Fundamentals

Presentation	Notes

Additional Considerations

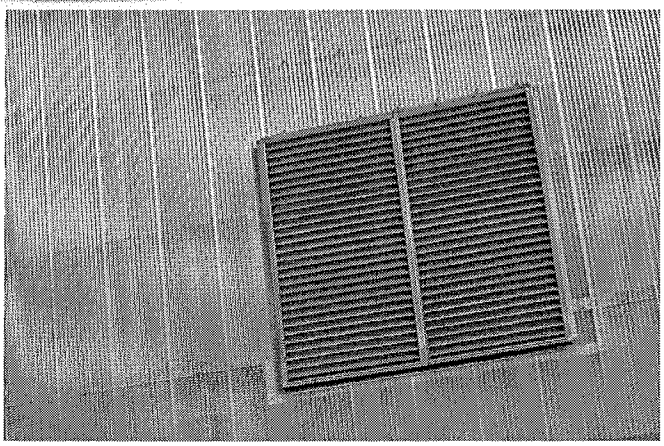
- Smoke venting and draft curtains
- Excessive clearances
- Roof slope
- Building height
- HVLS fans



Chapter 12

– Smoke vent will affect the sprinkler operation.

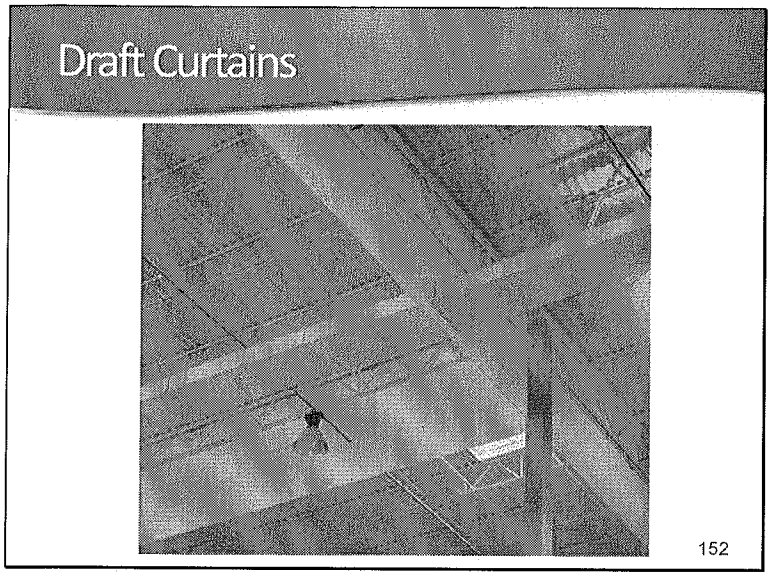
Roof Venting



Page: 13-126

Module 3: Storage Fundamentals

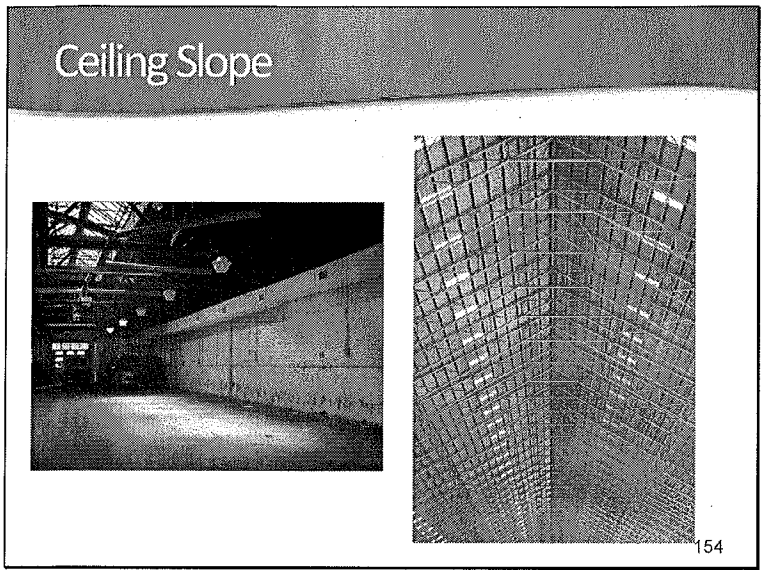
Presentation	Notes





Module 3: Storage Fundamentals

Presentation	Notes



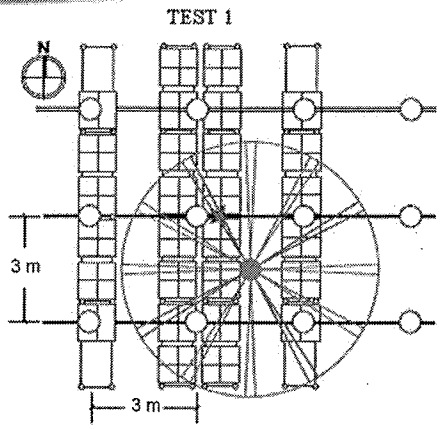


High volume Low Speed Fans

Module 3: Storage Fundamentals

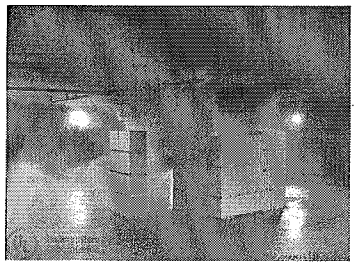
Presentation	Notes

HVLS Fans – Size and Location



156

HVLS Testing Results





157

Module 3: Storage Fundamentals

Presentation	Notes

Excessive Clearances – Racks

- Clearance > 6.1 m
- Class I-IV up to 7.6 m
  - Assume storage height creates 6.1 m clearance
  - QR in-racks below the top tier at flue intersections

158

Excessive Clearances – Racks

- Clearance ~~>~~ 3.1 m
- Class I-IV up over 7.6 m and plastics up to 7.6 m
  - Assume storage height creates 3.1 m clearance
  - QR in-racks below the top tier at flue intersections

Quick Response

159

Module 3: Storage Fundamentals

Presentation	Notes

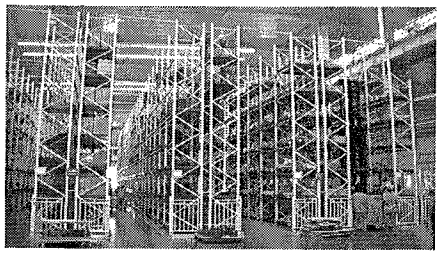
Excessive Clearances – Racks

- Clearance < 3.1 m
- Plastics over 7.6 m
  - QR in-racks below the top tier at flue intersections

160

Rack Specific – Additional Considerations

- Open top containers 16.1.7, 17.1.6
- Aisle widths (including narrow aisles)
- Movable racks



161

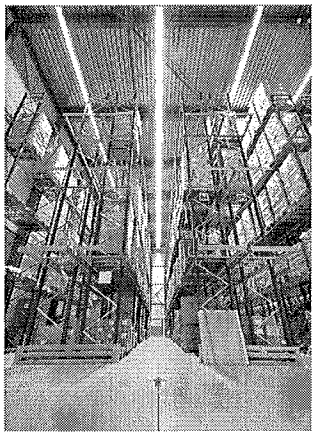
chapter 16.

Module 3: Storage Fundamentals

Presentation	Notes

Narrow Aisles

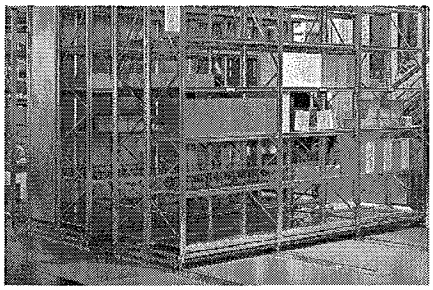
- Single- and double-row racks with aisle widths less than 1.07 m must be considered multiple-row racks



162

Page: 13-176 (17.1.2.2)

Movable Racks



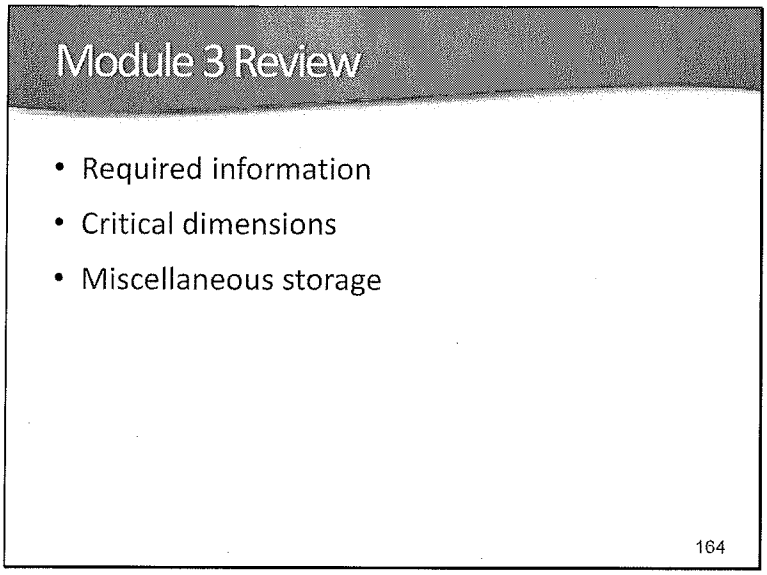
- Design as multiple-row racks

163

Page: 13-23 (3.9.3.7.2 and 3.9.3.7.4)

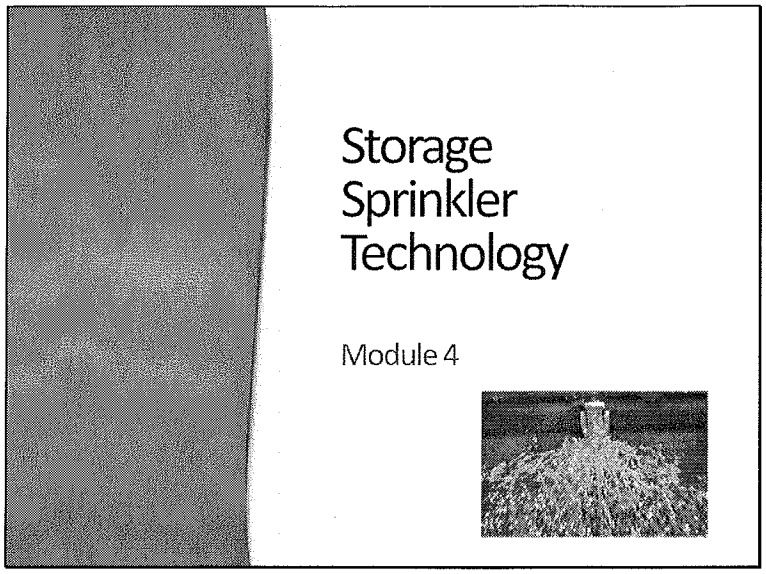
Module 3: Storage Fundamentals

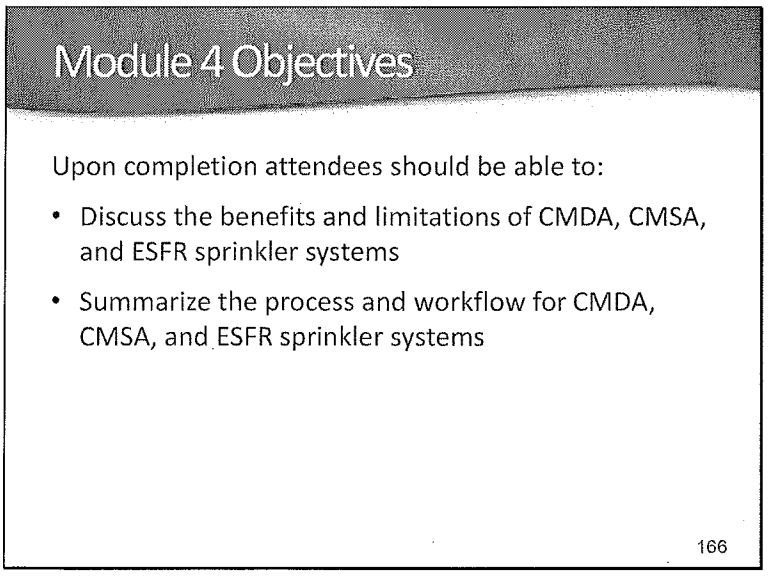
Presentation	Notes



Module 4: Storage Sprinkler Technology

Presentation	Notes





Module 4: Storage Sprinkler Technology

Presentation	Notes

Storage Sprinkler Technology

- Control mode density area (CMDA)
- Control mode specific application (CMSA)
- Early suppression fast-response (ESFR)
- In-rack sprinklers
- Face sprinklers

167

Control Mode Density Area

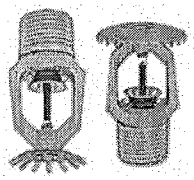
- Occupancy design approach
  - Defined coverage area
  - Defined delivered density
  - Density/area curves
  - Pendent/upright installations rules
  - Pendent/upright obstruction rules

168

Module 4: Storage Sprinkler Technology

Presentation	Notes

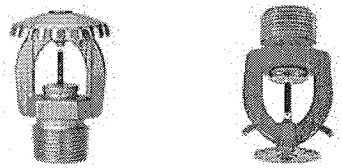
How did we get here?



- For control mode density area (CMDA) sprinklers, the standard spray K-115 pendent and upright automatic sprinklers were the largest K-factor for storage until 1992

169

Control Mode Density Area



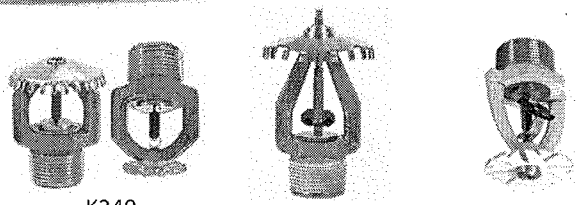
- In 1992 the first CMDA K-160 pendent and upright automatic sprinklers were introduced (formerly known as the ELO)

170

Module 4: Storage Sprinkler Technology

Presentation	Notes

Control Mode Density Area



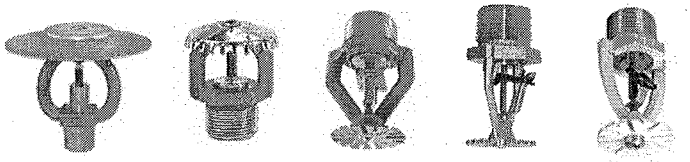
K240 | K-360 EC Upright | K-360 EC Pendent

- The K-240 and K-360 CMDA automatic sprinklers

171

Larger K, lower pressure req for same density.

Control Mode Specific Application



K-160 | K-240 | K-280 | K-360 | K- 360EC

extra large drop for storage

esfr primarily

CMSA automatic sprinklers

172

ESFR — designed for 4 operating sprinklers to extinguish fire.

Module 4: Storage Sprinkler Technology

Presentation | **Notes**

CMSA Spacing and Protection Area

TABLE 8.11.2.2.1 Protection Areas and Maximum Spacing for CMSA Sprinklers

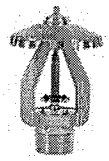
Construction Type	Protection Area ft^2	Protection Area m^2	Maximum Spacing ft	Maximum Spacing m
Noncombustible unobstructed	130	12.1	12	3.7
Noncombustible obstructed	130	12.1	12	3.7
Combustible unobstructed	130	12.1	12	3.7
Combustible obstructed	100	9.3	10	3.1
Rack storage combustible obstructed	100	9.3	10	3.1
Rack storage unobstructed and noncombustible obstructed	100	9.3	12	3.7

- Minimum protection area = 7.4 m^2

174

Page: 13-77

CMSA Maximum Spacing Rules



8.11.3.1

Maximum Spacing Rules



175

Page: 13-77

Module 4: Storage Sprinkler Technology

Presentation	Notes

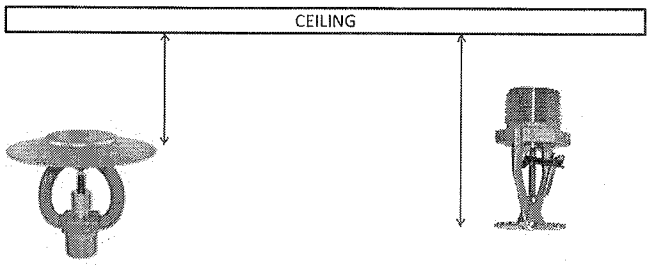
Additional CMSA Spacing Rules

- The minimum allowable area of ≥ 7.4 m^2
- Distance from wall ≤ ½ maximum spacing from Table 8.12.2.2.1
- Distance from wall > 102mm
- Minimum distance between sprinklers ≥ 2.4 m on center

176

Page: 13-81

CMSA Deflector Positioning Rules



177

Page: 13-81 (12.4.1)
Page: 13-77 (11.4.1.1)
Page: 13-77 (11.4.1.2)

Module 4: Storage Sprinkler Technology

Presentation **Notes**

CMSA Obstructions Rules

- Obstructions to sprinkler discharge pattern development
- Obstructions that prevent sprinkler discharge from reaching hazard

178

CMSA Obstructions Rules

Positioning of Sprinklers to Avoid Obstructions to Discharge (CMSA Sprinklers)

Distance from Sprinkler to Side of Obstruction *(A)*	Maximum Allowable Distance of Deflector Above Bottom of Obstruction *(B)* (mm)
Less than .30 m	0
.30 m to less than .45 m	38
.45 m to less than .61 m	76
.61 m to less than .76 m	140
.76 m to less than .91 m	203
.91 m to less than 1.07 m	254
1.07 m to less than 1.2 m	305
1.2 m to less than 1.3 m	381
1.3 m to less than 1.5 m	457
1.5 m to less than 1.6 m	558
1.6 m to less than 1.8 m	660
1.8 m	787

This table is an unofficial metric equivalent to Table 8.11.5.1.2 in NFPA 13, 2010 Edition. A metric version is not included in NFPA 13, 2010

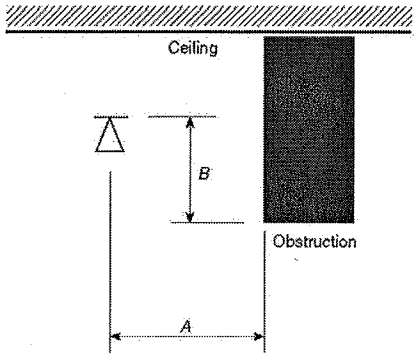


Figure 8.11.5.1.2 *Positioning of Sprinkler to Avoid Obstruction to discharge (CMSA Sprinklers)*

179

Module 4: Storage Sprinkler Technology

Presentation **Notes**

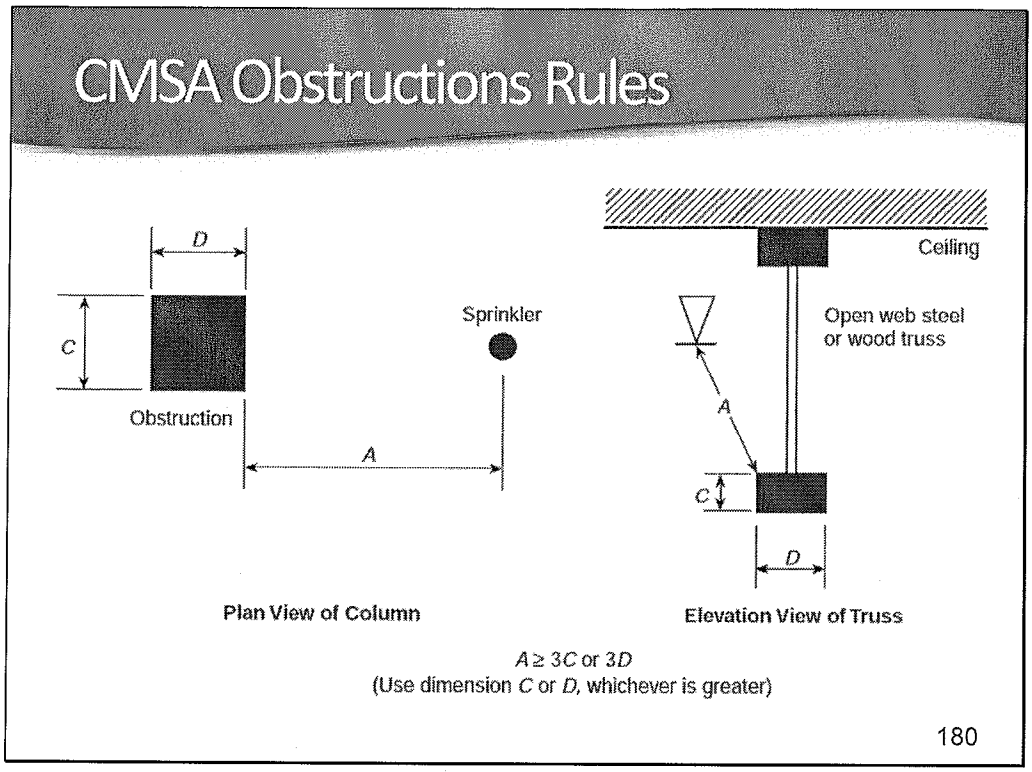
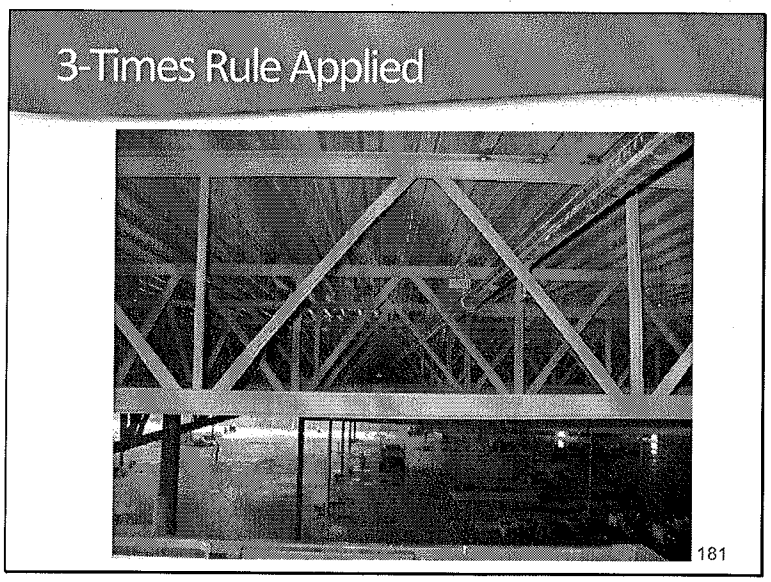


Photo from George Stanley



Module 4: Storage Sprinkler Technology

Presentation **Notes**

CMSA Obstructions Rules

Obstruction Entirely Below Sprinkler
(CMSA Sprinklers)

Minimum Distance to Side of Obstruction (m) (A)	Distance of Deflector Above Bottom of Obstruction *(B)(mm)*
Less than .15	38
.15 m to less than .30 m	76
.30 m to less than .45 m	101
.45 m to less than .61 m	127
.61 m to less than .76 m	140
.76 m to less than .91 m	152

This table is an unofficial metric equivalent to Table 8.11.5.1.2 in NFPA 13, 2010 Edition.
A metric version is not included in NFPA 13, 2010

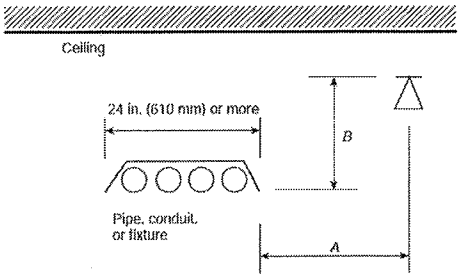
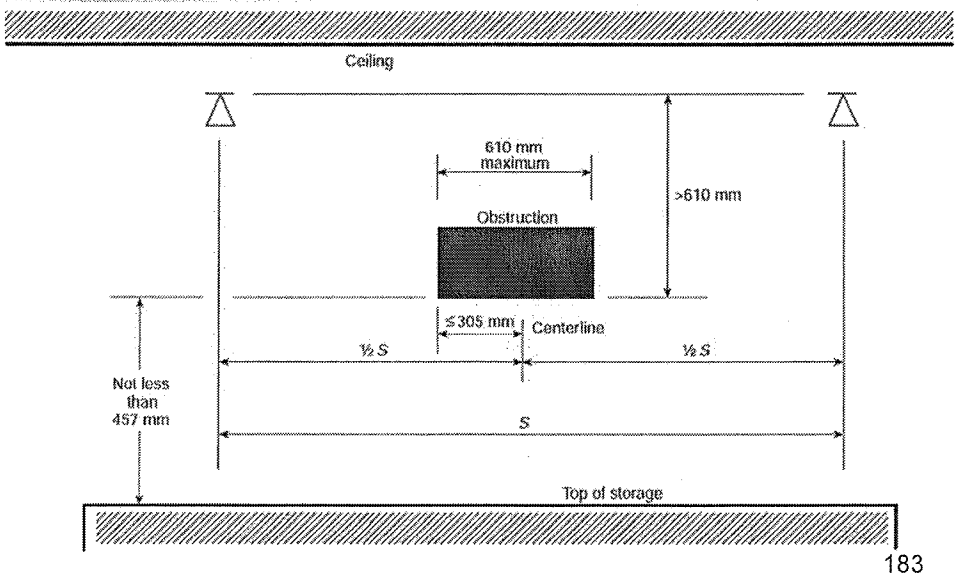


FIGURE 8.11.5.3.2 Obstruction Entirely Below Sprinkler (CMSA Sprinklers).

182

CMSA Obstructions Rules



183

Module 4: Storage Sprinkler Technology

Presentation **Notes**

CMSA Obstructions Rules

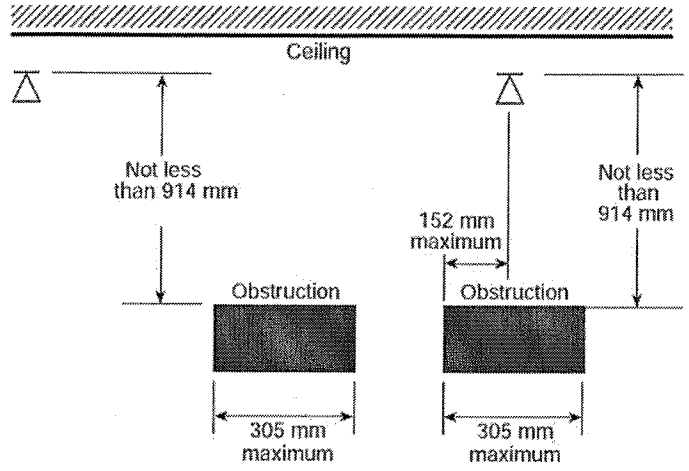
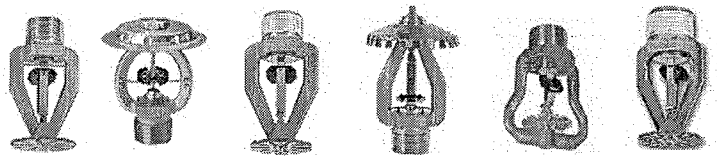


FIGURE 8.11.5.3.5 Obstruction More Than 914 mm Below Sprinklers (CMSA Sprinklers).

184

Page: 13-80

Early Suppression Fast-Response



K-200 K-200 K-240 K-240 K-320 K-360

Suppression mode automatic sprinklers

185

Module 4: Storage Sprinkler Technology

Presentation | **Notes**

ESFR Spacing Ceiling Up to 30 ft

TABLE 8.12.2.2.1 Protection Areas and Maximum Spacing of ESFR Sprinklers

	Ceiling/Roof Heights Up to 30 ft (9.1 m)			
	Protection Area		*Spacing*	
Construction Type	*ft²*	*m²*	*ft*	*m*
Noncombustible unobstructed	100	9.3	12	3.7
Noncombustible obstructed	100	9.3	12	3.7
Combustible unobstructed	100	9.3	12	3.7
Combustible obstructed	N/A		N/A	

187

Page: 13-81

ESFR Spacing Ceiling Over 30 ft

TABLE 8.12.2.2.1 Protection Areas and Maximum Spacing of ESFR Sprinklers

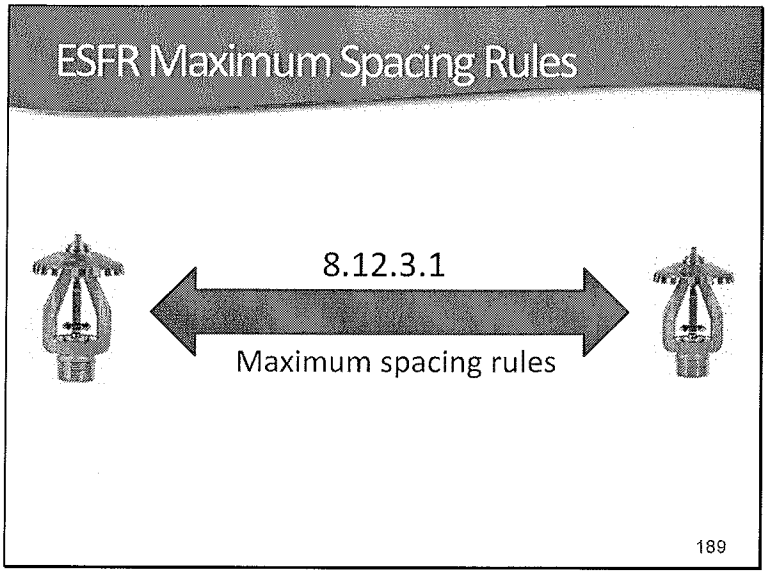
	Ceiling/Roof Heights Over 30 ft (9.1 m)			
	Protection Area		*Spacing*	
Construction Type	*ft²*	*m²*	*ft*	*m*
Noncombustible unobstructed	100	9.3	10	3.1
Noncombustible obstructed	100	9.3	10	3.1
Combustible unobstructed	100	9.3	10	3.1
Combustible obstructed	N/A		N/A	

188

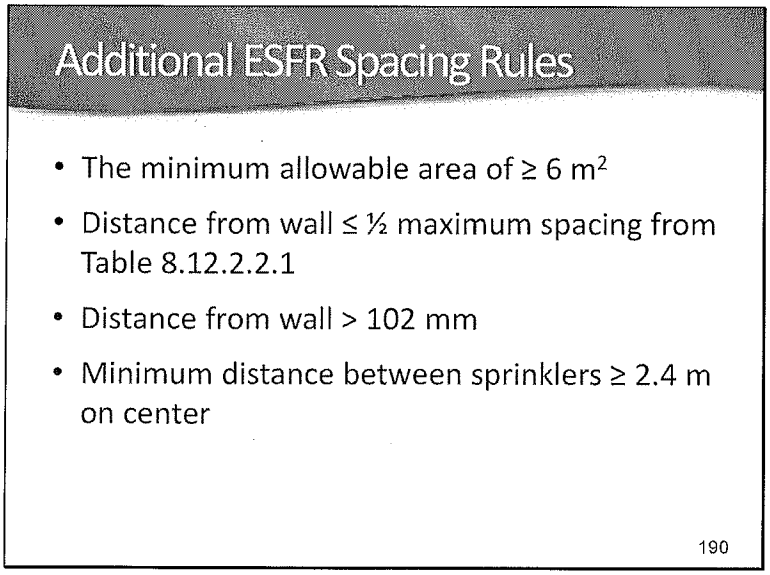
Page: 13-81

Module 4: Storage Sprinkler Technology

Presentation	Notes



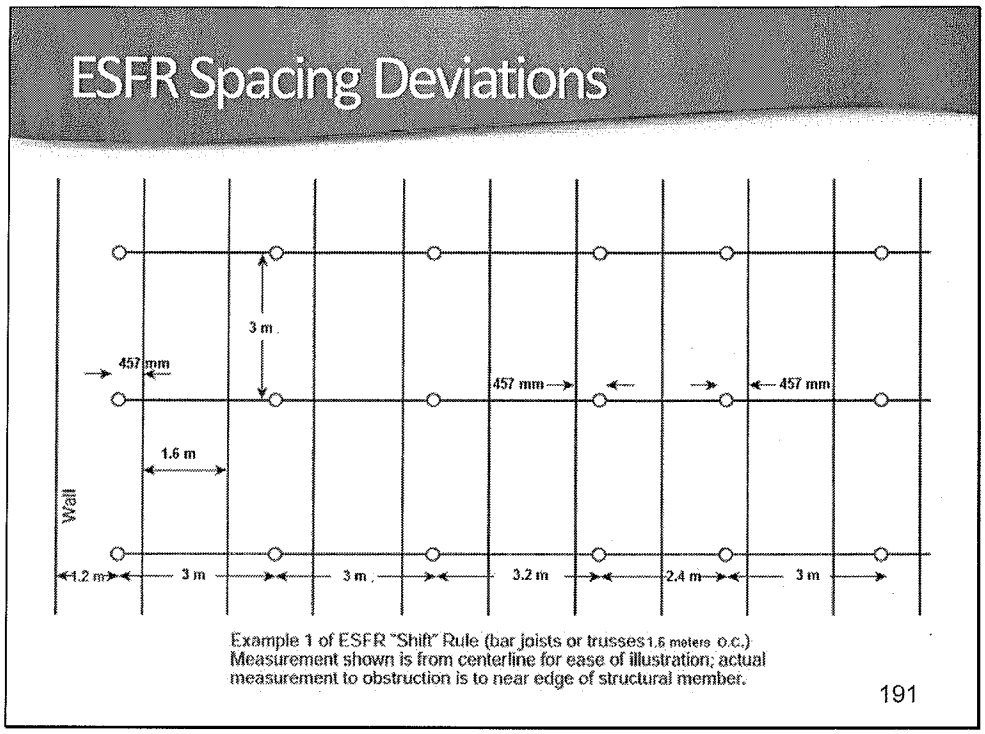
Page: 13-81



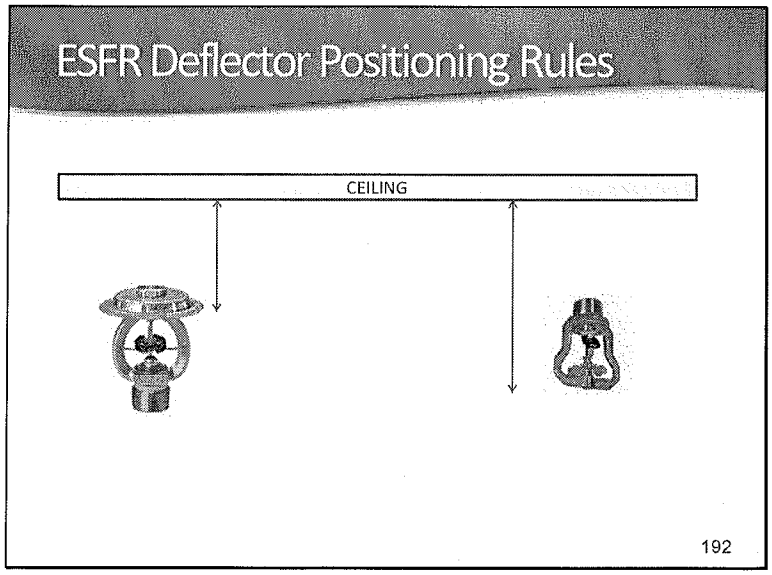
Page: 13-81

Module 4: Storage Sprinkler Technology

Presentation | **Notes**



Page: 13-80 (8.12.2.2.3)
Page: 13-300 (Figure A.8.12.2.2)

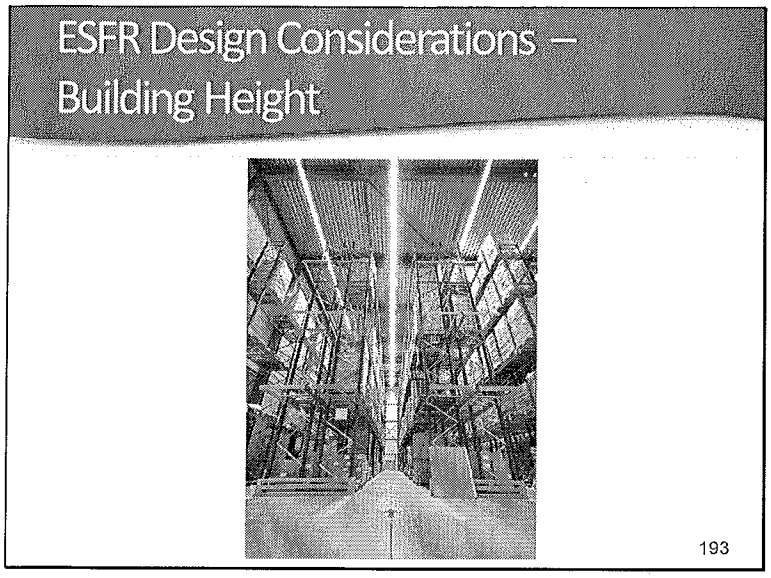


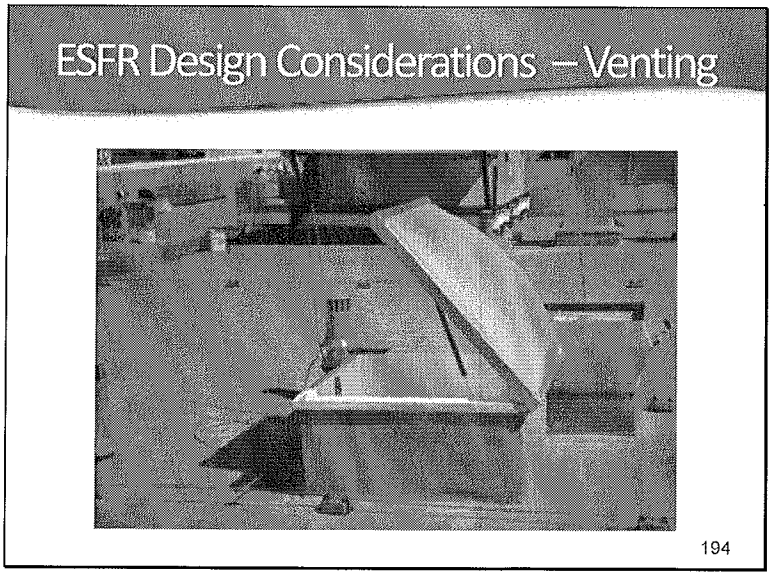
Page: 13-81

Clause 8.12.4.1.2

Module 4: Storage Sprinkler Technology

Presentation	Notes

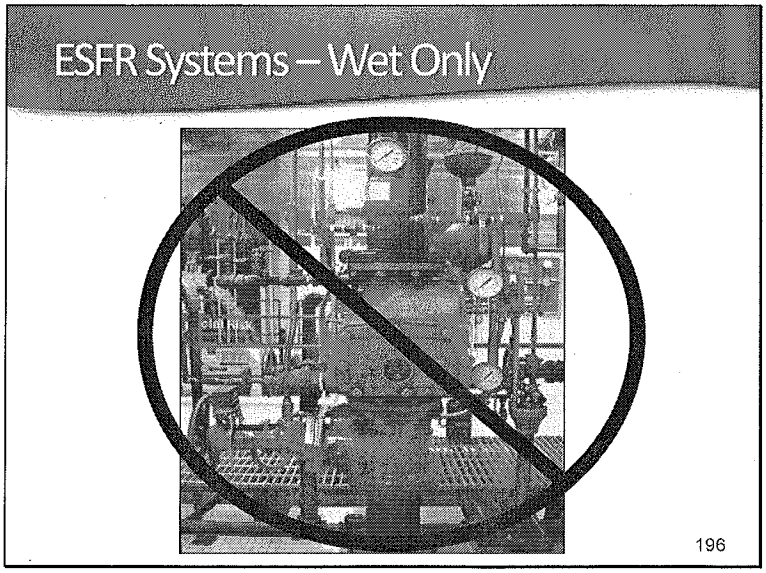




Module 4: Storage Sprinkler Technology

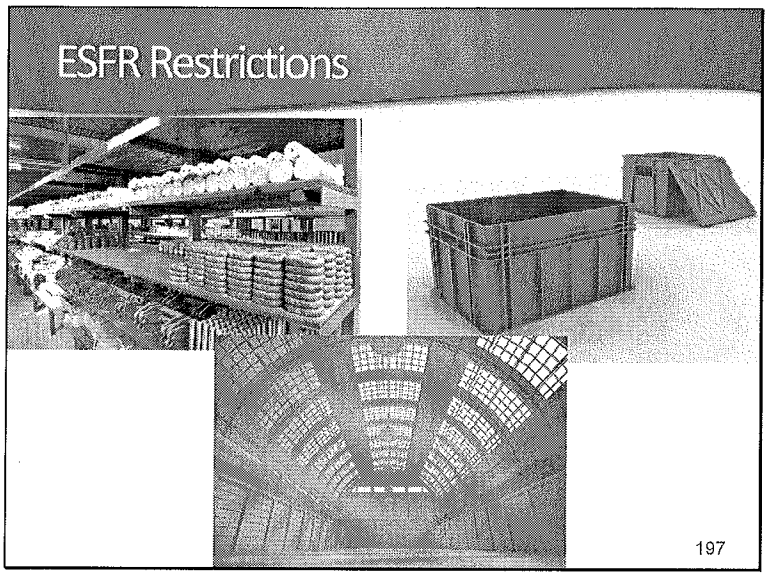
Presentation	Notes





Module 4: Storage Sprinkler Technology

Presentation	Notes



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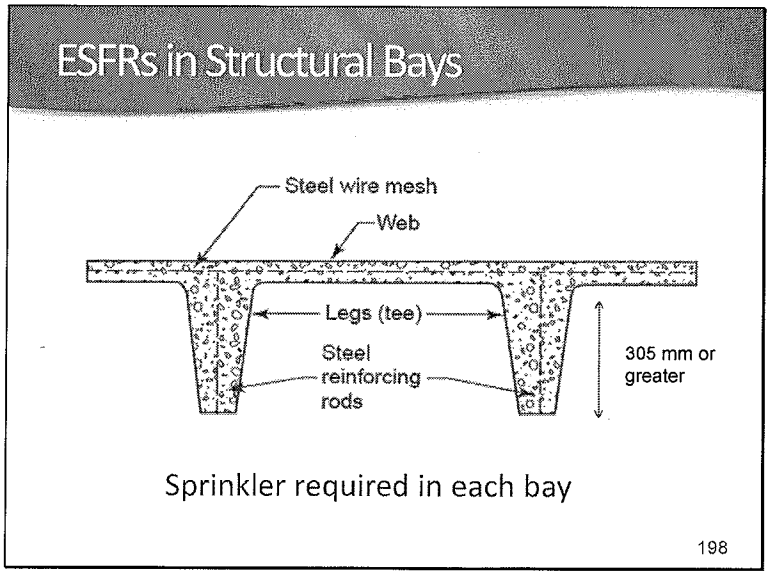


Page: 13-49

Module 4: Storage Sprinkler Technology

Presentation **Notes**

ESFR Separation Considerations

- ESFR adjacent to standard spray sprinklers
  - 0.6 m draft curtain
  - 1.2 m aisle centered below the draft curtain shall be maintained

199

ESFR Obstructions Rules

- Obstructions at or near ceiling
- Isolated obstructions below elevation of sprinklers
- Continuous obstructions below sprinklers

201

Module 4: Storage Sprinkler Technology

Presentation **Notes**

ESFR Obstructions at or Near Ceiling

Positioning of Sprinklers to Avoid Obstructions to Discharge (ESFR Sprinklers)

Distance from Sprinkler to Side of Obstruction (A)	Maximum Allowable Distance of Deflector Above Bottom of Obstruction (B)(mm)
Less than .30	0
.30 m to less than .45 m	38
.45 m to less than .61 m	76
.61 m to less than .76 m	140
.76 m to less than .91 m	203
.91 m to less than 1.07 m	254
1.07 m to less than 1.2 m	305
1.2 m to less than 1.3 m	381
1.3 m to less than 1.5 m	457
1.5 m to less than 1.6 m	558
1.6 m to less than 1.8 m	660
1.8	787

This table is an unofficial metric equivalent to Table 8.11.5.1.2 in NFPA 13, 2010 Edition. A metric version is not included in NFPA 13, 2010

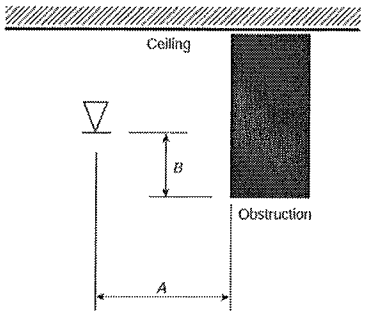
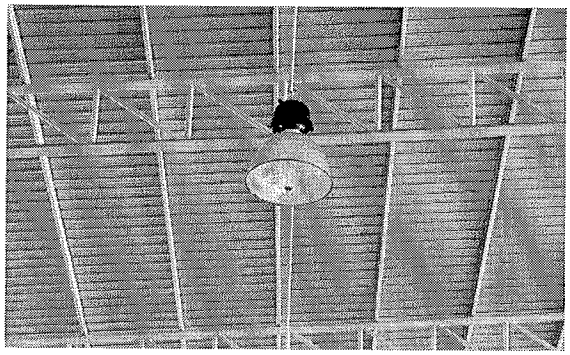


FIGURE 8.12.5.1.1 Positioning of Sprinkler to Avoid Obstruction to Discharge (ESFR Sprinklers).

202

Page: 13-82

Isolated ESFR Obstructions Below Elevation of Sprinklers

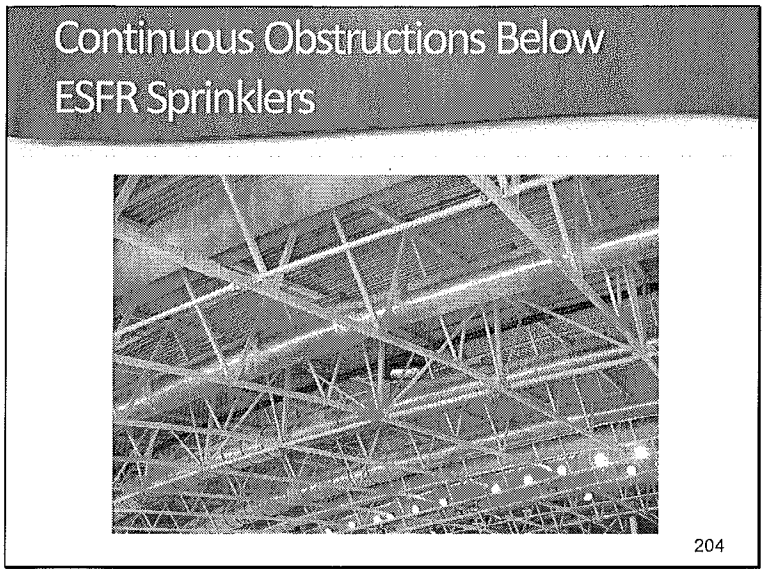


203

Page: 13-82

Module 4: Storage Sprinkler Technology

Presentation	Notes



Page: 13-82

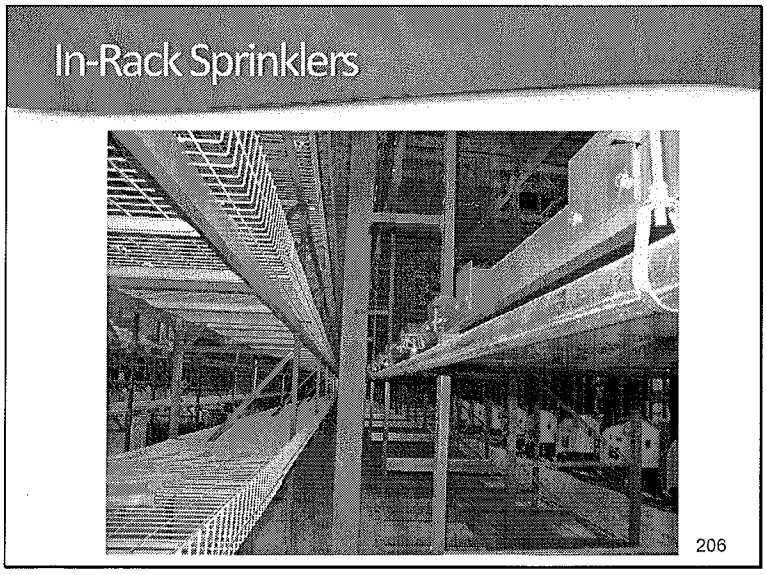


Photo from George Stanley

Module 4: Storage Sprinkler Technology

Presentation **Notes**

When In-Rack Sprinklers are Required – Chapter 12

- **12.1.3.4.1** For spray sprinkler criteria where the distance between ceiling height and top of storage exceeds the clearances identified in this section, the requirements of 12.1.3.4 shall apply.
- **12.1.3.4.3** Where the clearance exceeds 6.1 m (20 ft.) for Table 12.12.1.2(a) or Section 16.2, protection shall be based upon the storage height that would result in a 6.1 m (20 ft) distance between the ceiling and top of storage or providing one level of supplemental, quick-response in-rack sprinklers located directly below the top tier of storage and at every flue space intersection.
- **12.1.3.4.4** Where the clearance exceeds 3.1 m (10 ft) for Section 16.3 and Chapter 17, protection shall be based upon the storage height that would result in a 3.1 m (10 ft) distance between the ceiling and top of storage or providing one level of supplemental, quick-response in-rack sprinklers located directly below the top tier of storage and at every flue space intersection.

209

Page: 13-126

When In-Rack Sprinklers are Required – Chapter 13

TABLE 13.2.1 Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) in Height

Cartoned	Unexpanded and expanded		>10 to ≤12	>3.0 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 189, 379	500	1893	120
		Solid-piled, palletized, bin box, shelf, and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH2		0, 50, 100	0, 189, 379	500	1893	120
		Rack	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2	+ 1 level of in-rack	0, 50, 100	0, 189, 379	250	946	90

210

Page: 13-133

Module 4: Storage Sprinkler Technology

Presentation	Notes

When In-Rack Sprinklers are Required – Chapter 16

- **16.1.6.1** Where solid shelving in single-, double-, and multiple-row racks exceeds 1.86 m^2 but does not exceed 5.95 m^2 in area, sprinklers shall not be required below every shelf, but shall be installed at the ceiling and below shelves at intermediate levels not more than 2 m apart vertically.
- **16.1.6.2** Where solid shelving in single-, double-, and multiple-row racks exceeds 5.95 m^2 in area or where the levels of storage exceed 2 m, sprinklers shall be installed at the ceiling and below each level of shelving.

211

Page: 13-148

When In-Rack Sprinklers are Required – Chapter 17

- **17.1.5.1** Where solid shelving in single-, double-, and multiple-row racks exceeds 1.86 m^2 but does not exceed 5.95 m^2 in area, sprinklers shall not be required below every shelf, but shall be installed at the ceiling and below shelves at intermediate levels not more than 2 m apart vertically.
- **17.1.5.2** Where solid shelving in single-, double-, and multiple-row racks exceeds 5.95 m^2 in area or where the levels of storage exceed 2 m, sprinklers shall be installed at the ceiling and below each level of shelving.

212

Page: 13-176

Module 4: Storage Sprinkler Technology

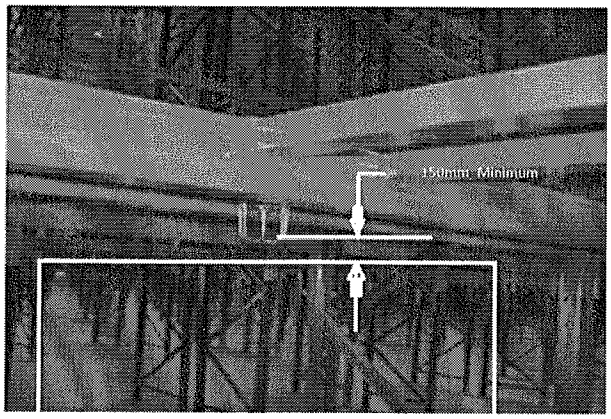
Presentation **Notes**

Where In-Racks Become Mandatory Based on Type of Sprinkler and Storage or Ceiling Height

Chapter	Commodity	Storage Height	Building Height	CMDA	CMSA	ESFR
16	Class IV	>6.7 m	NA	x		
	Class I - III	>7.6 m	NA	x		
	Class I - IV	>10.6	>12.1 m		x	
	Class I - IV	>12.1 m	>13.7 m			x
17	Group A plastic commodities in cartons, encapsulated or nonencapsulated	6.1 m	>7.6 m	x		
		>6.1 m	NA	x		
	Group A plastic Cartoned Unexpanded	>10.6	>12.1 m		x	
	Group A plastic Cartoned Unexpanded	>12.1 m	>13.7 m			x
	Group A plastic Exposed Unexpanded	>10.6	>12.1 m			x

213

In-Rack Minimum Clearance



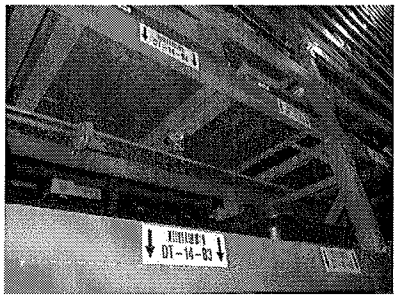
214

Module 4: Storage Sprinkler Technology

Presentation	Notes

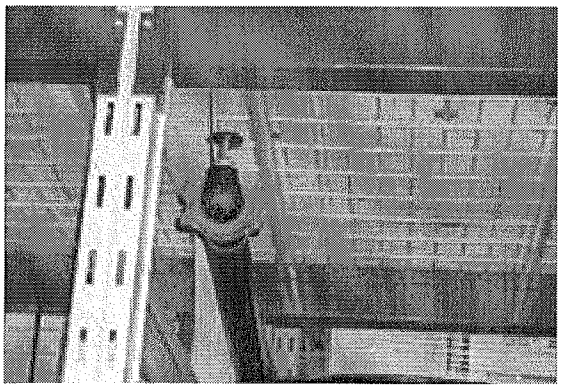
In-Rack Hydraulics

- Pipes shall be hydraulically sized
- In-rack demand added to ceiling demand
- Balanced to higher pressure



215

3.9.3.4* Face Sprinklers



216

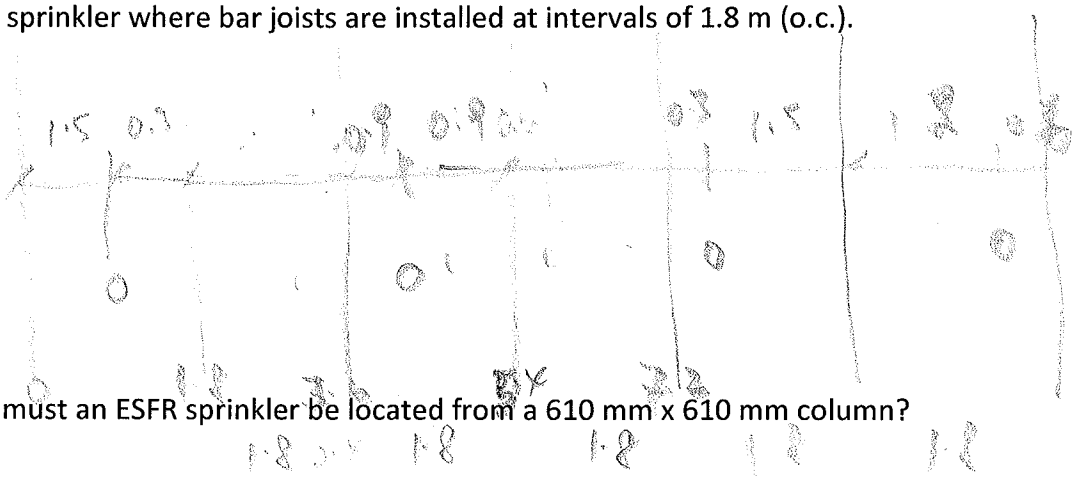
Page: 13-22

Module 4: Storage Sprinkler Technology

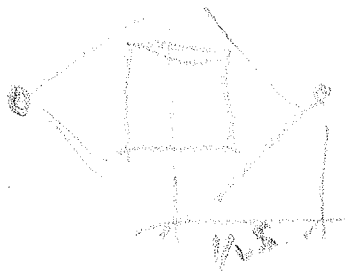
Activity 4.1

Instructions: Answer the following questions on ESFR sprinkler design.

1. Using the shift rule from 8.12.2.2.3 in NFPA 13, illustrate the modified spacing for a (3 m x 3 m) ESFR sprinkler where bar joists are installed at intervals of 1.8 m (o.c.).



2. How far must an ESFR sprinkler be located from a 610 mm x 610 mm column?

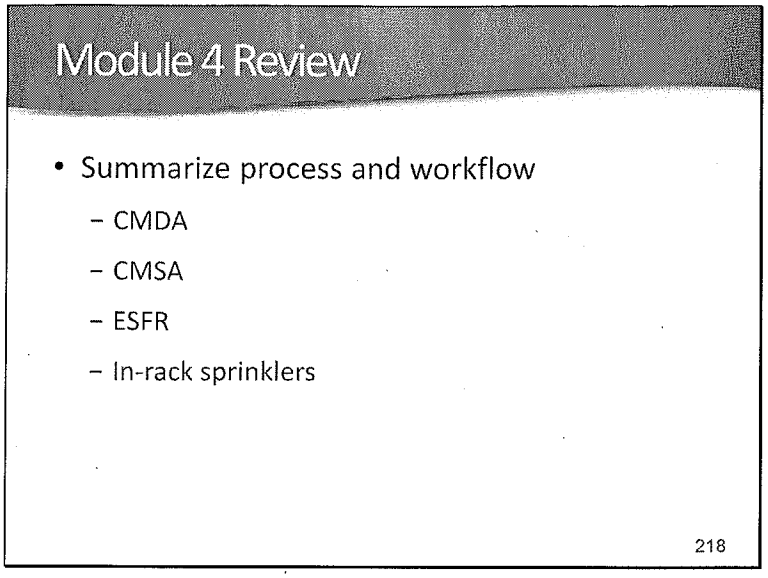


3. How high above a .09 m wide fluorescent light must an ESFR sprinkler be if the horizontal distance between the light and the sprinkler is 482.6 mm?



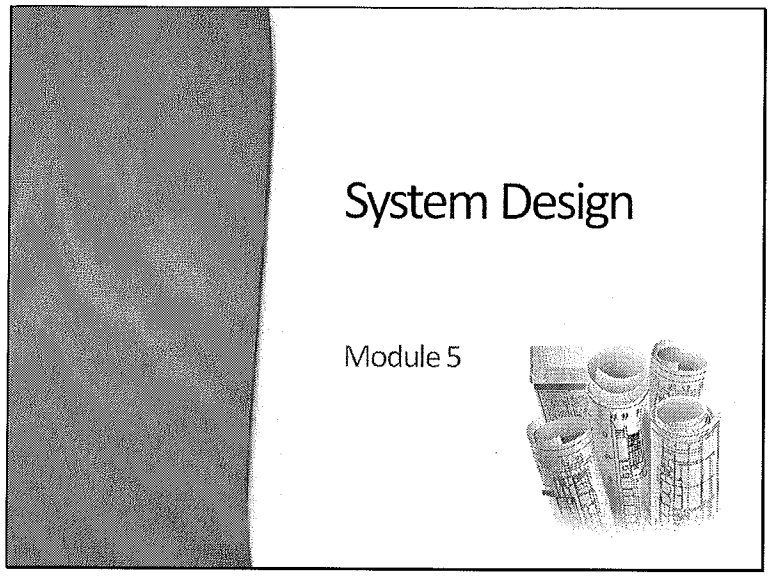
Module 4: Storage Sprinkler Technology

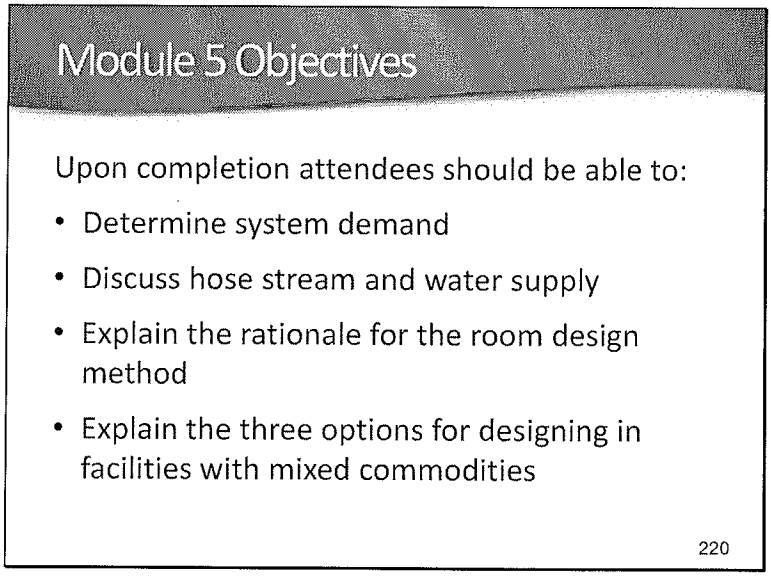
Presentation	Notes



Module 5: System Design

Presentation	Notes





Module 5: System Design

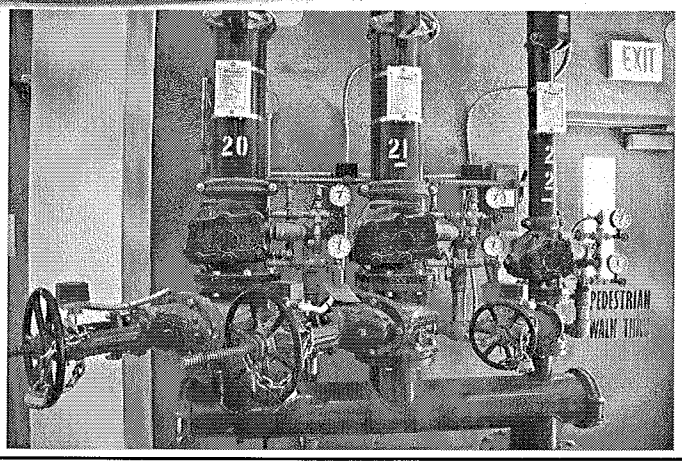
Presentation	Notes

Storage Sprinkler Design

- System requirements
- Wet
- Dry
- Preaction
- Adjacent hazards or design methods
- Hose stream and water supplies

221

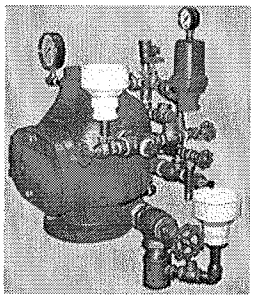
Wet Systems

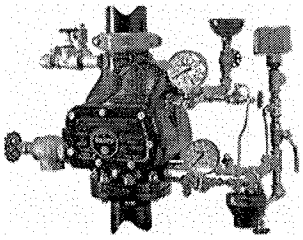


Module 5: System Design

Presentation	Notes

Dry Systems





223

NFPA 13 K-factor Requirements for Storage Protection

NFPA 13, 2013 Edition Density	K-factor
12.6.1: densities of 8.2 mm/min or less	80 & larger
12.6.2: densities of greater than 8.2 mm/min to 13.9 mm/min	115 & larger
12.6.3: densities greater than 13.9 mm/min	160 & larger

224

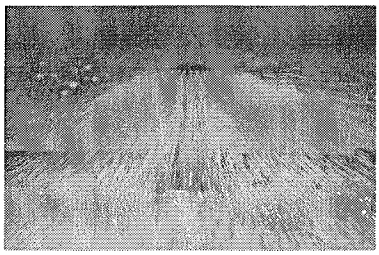
Page: 13-127

Module 5: System Design

Presentation **Notes**

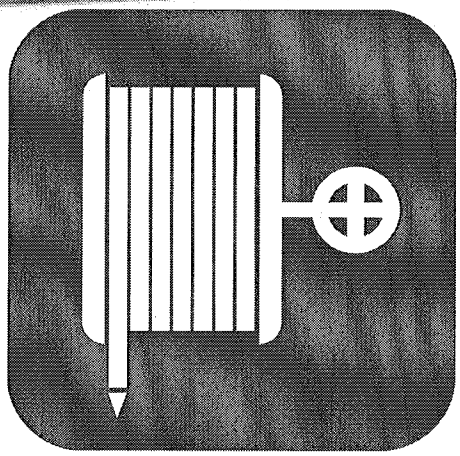
Determining System Demand

- Chapters 12–22
- Based on sprinkler technology selected
- Hose streams
- Room design method (rare)



225

Hose Stream Requirements

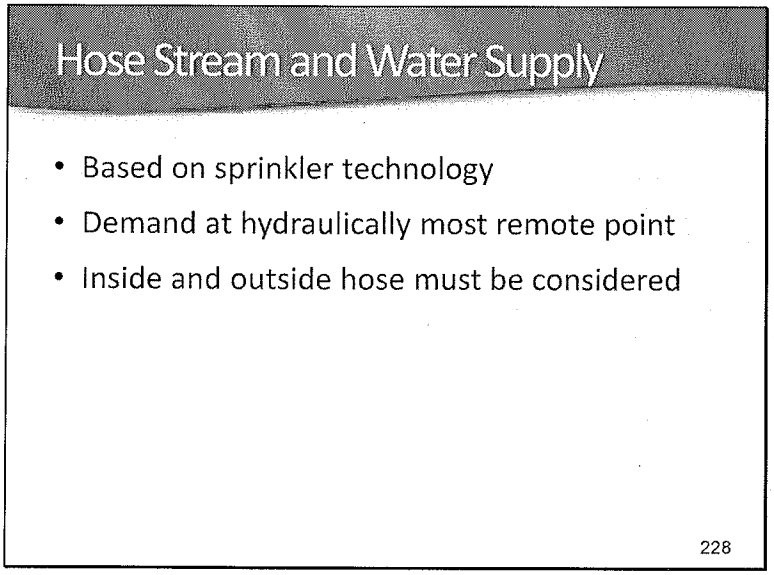


226

Module 5: System Design

Presentation	Notes





Page: 13-128

Module 5: System Design

Presentation **Notes**

Hose Stream and Water Supply CMDA

TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
Control mode density/area	Standard and extended-coverage	NA	Up to 1200 ft² (111 m²)	250	950	60
			Over 1200 ft² (111 m²) up to 1500 ft² (139 m²)	500	1900	90
			Over 1500 ft² (139 m²) up to 2600 ft² (240 m²)	500	1900	120
			Over 2600 ft² (240 m²)	500	1900	150

229

Page: 13-129

Hose Stream and Water Supply CMSA

TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
CMSA	Standard	Up to 12	NA	250	950	60
		Over 12 to 15	NA	500	1900	90
		Over 15 to 25	NA	500	1900	120
		Over 25	NA	500	1900	150
	Extended-coverage	Up to 6	NA	250	950	60
		Up to 8	144 ft² (13.4 m²) maximum	250	950	60
		Over 6 to 8	NA	500	1900	90
		Over 8 to 12	NA	500	1900	120
		Over 12	NA	500	1900	150

230

Page: 13-129

Module 5: System Design

Presentation **Notes**

Hose Stream and Water Supply ESFR

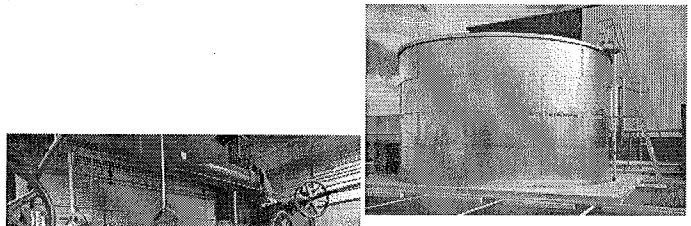
TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

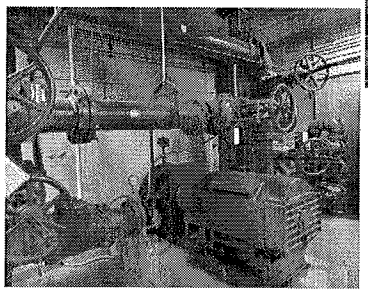
Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
ESFR	Standard	Up to 12	NA	250	950	60
		Over 12 to 15	NA	500	1900	90
		Over 15 to 25	NA	500	1900	120
		Over 25	NA	500	1900	150

231

Page: 13-129

Water Supply – Pumps and Tanks



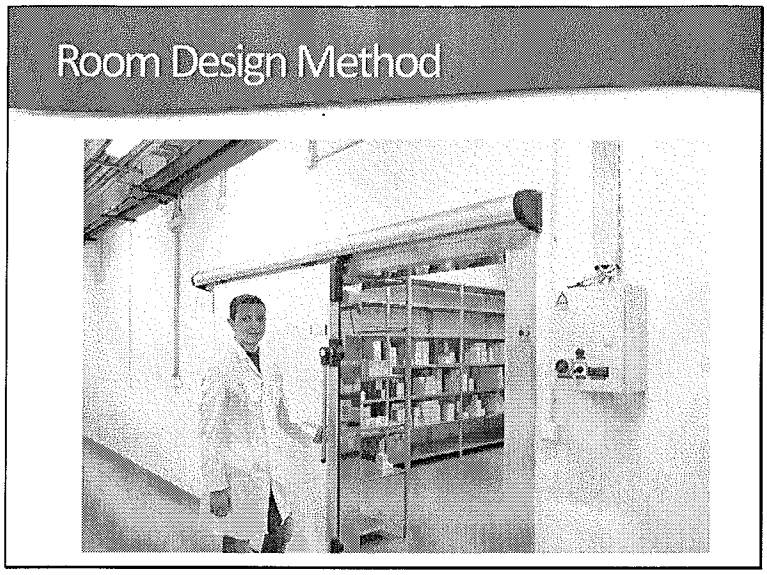


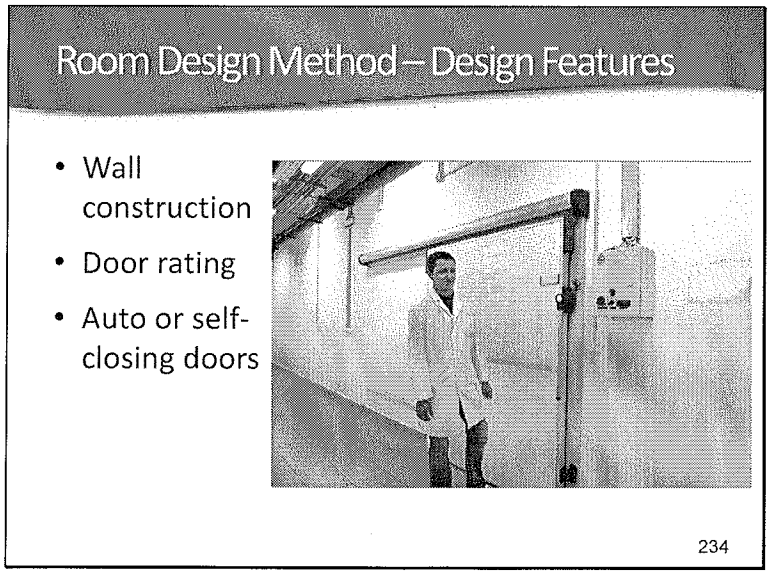
232

Page: 13-129

Module 5: System Design

Presentation	Notes





Page: 13-130

Module 5: System Design

Presentation **Notes**

Mixed Commodity Areas

- Option 1 – Worst case hazard
- Option 2 – Physical barrier
- Option 3 – 4.5 m extension of higher hazard area

235

Adjacent Hazards or Design Methods

- Option 1 – Worst case hazard throughout
  - Design flexibility
  - Operational flexibility
  - Increased delivered density

236

Page: 13-132 (12.3*)

Module 5: System Design

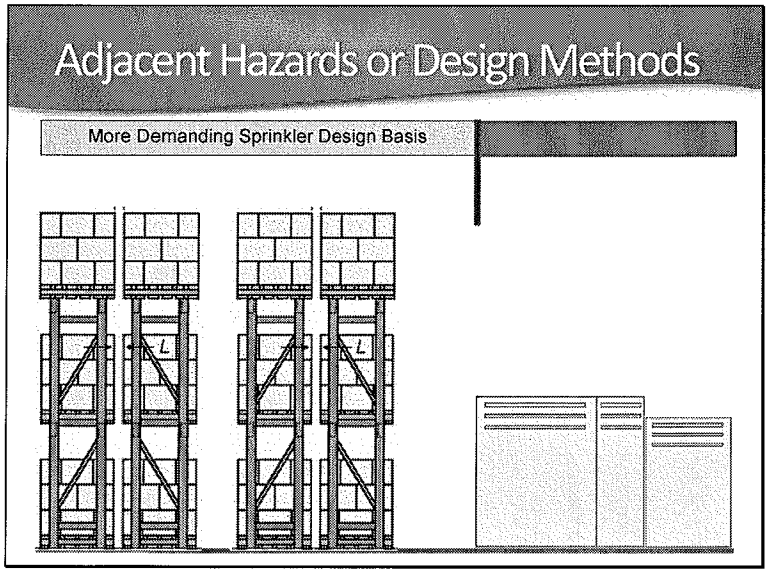
Presentation	Notes

Adjacent Hazards or Design Methods

- Option 2 – Physical barrier
  - Lower potential demand
  - Eliminate fire pump
  - Additional construction
  - Fire-stopping and penetrations
  - Operational limitations
    - Day-to-day
    - Building life cycle

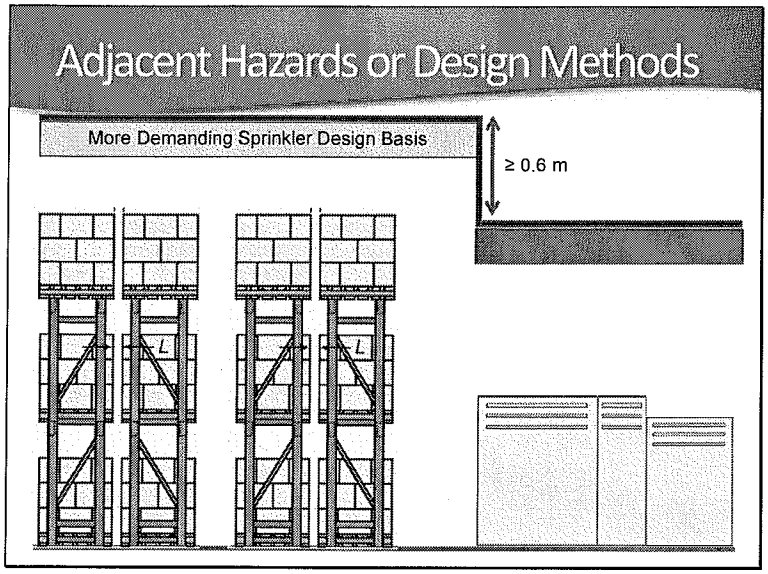
237

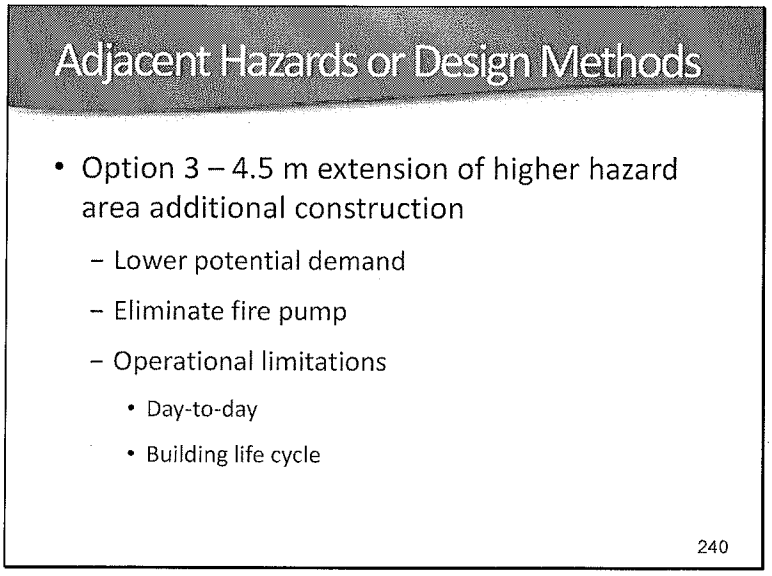
Adjacent Hazards or Design Methods



Module 5: System Design

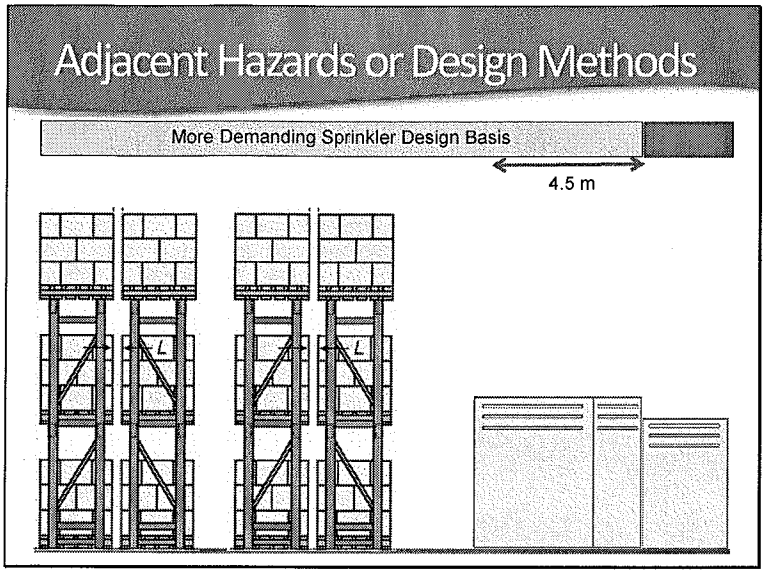
Presentation	Notes



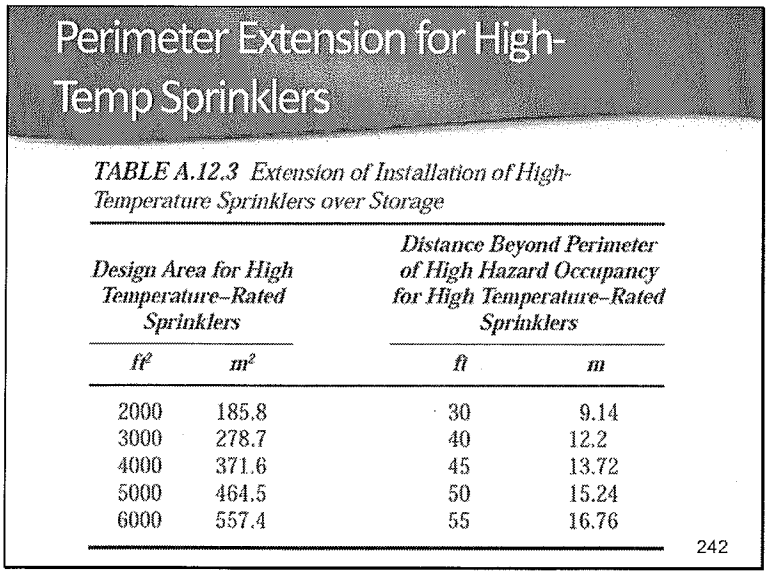


Module 5: System Design

Presentation	Notes



Page: 13-127 (12.3)



Page: 13-344

Module 5: System Design

Presentation	Notes

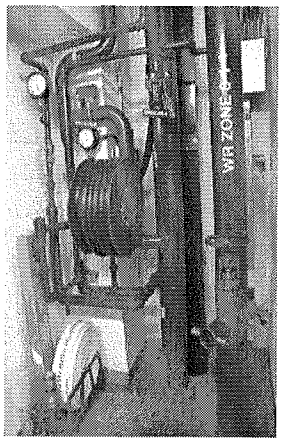
Storage Configurations Outside of NFPA 13

- **1.5 Equivalency.** Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.
- **1.5.1** Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.
- **1.5.2** The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

243

Page: 13-13

Hose Connections



244

Module 5: System Design

Activity 5.1

Instructions: Using the given scenario, determine the minimum density/area required for a rack storage area and a piled storage area.

Scenario: You've been contacted by a distributer of Sporting Goods equipment who is building a new warehouse facility 6,039 m^2 in area, plus a 372 m^2 office area. The warehouse is 9.1 m high with a 2 in 12 roof slope.

They plan to store a variety of goods in boxes, on wood pallets, non-encapsulated. 3,252 m^2 of the north side of the building will include single- and double-row pallet racks with 2.4 m aisles. The maximum storage height will be 6.7 m. The south side of the warehouse will include storage on the floor, palletized 5.5 m high maximum. The products are a combination of commodity classifications with the highest determined to be Class IV. High temperature K 160 sprinklers are used throughout.

Using CMDA sprinklers at the roof and no in-rack sprinklers, determine the minimum density/area required for each area.

Rack Storage Area:

Module 5: System Design

Piled Storage Area:

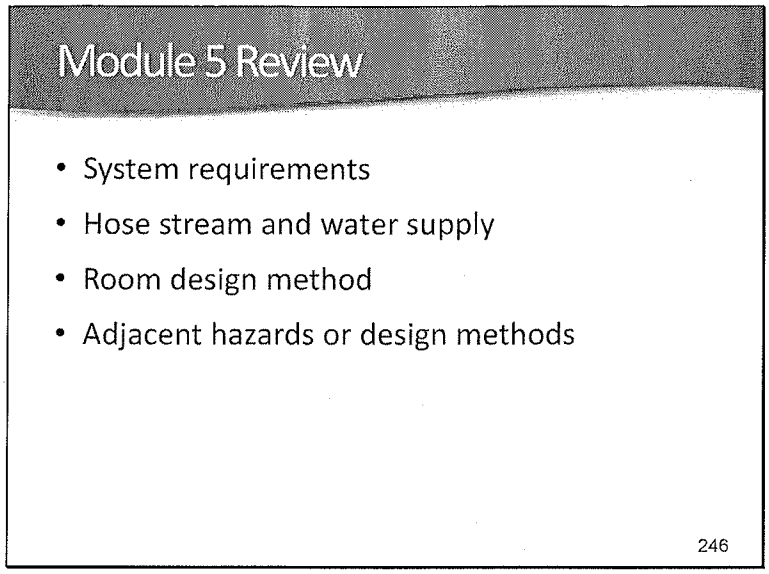
Additional Questions

1. What options do we have to separate the two areas?

2. Where would a draft curtain be placed relative to the two storage areas if this was the option used to separate the two areas?

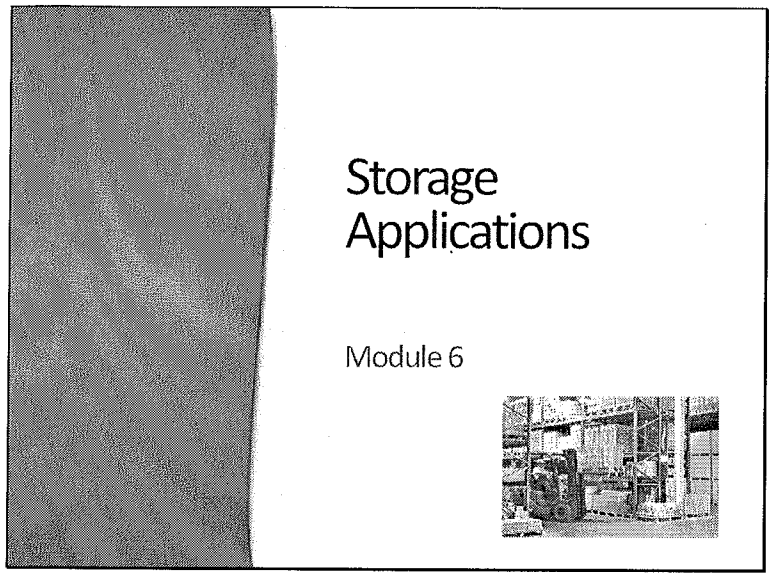
Module 5: System Design

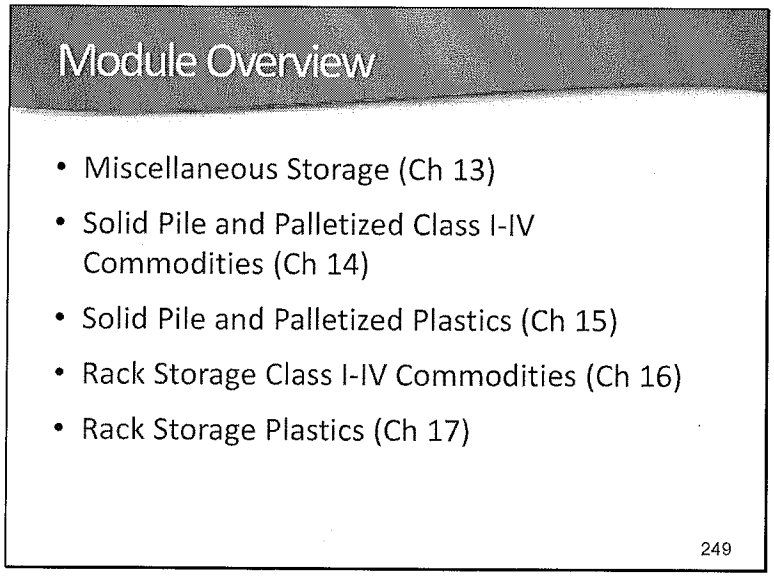
Presentation	Notes



Module 6: Storage Applications

Presentation	Notes





Module 6: Storage Applications

Presentation **Notes**

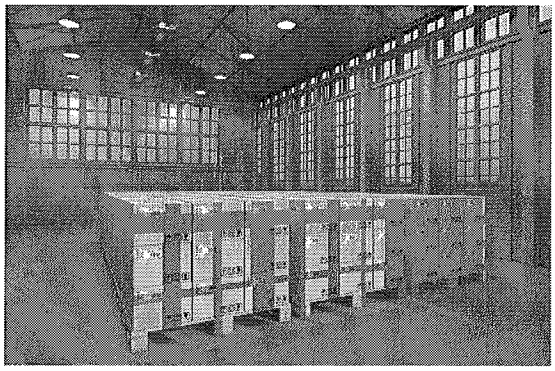
Module 6 Objectives

Upon completion attendees should be able to:

- Navigate through chapters 13 – 17 of NFPA 13
- Explain the structure of chapters 13-17 (including subsections) of NFPA 13
- Locate the appropriate chapter based on a given design approach
- Select an appropriate sprinkler technology based on a given design approach
- Explain in-rack rules
- Explain the significance of the notes associated with figures in chapters 13-17 of NFPA 13
- Review hydraulic design requirements

250

Chapter 13 – Miscellaneous Storage



251

Module 6: Storage Applications

Presentation **Notes**

Chapter 13 – Miscellaneous Storage

- Definition Limitations
- 13.2.1 Table 13.2.1 and Figure 13.2.1 shall apply to any of the following situations:

  (1) Miscellaneous storage of Class I through Class IV commodities up to 3.7 m in height

  (2) Miscellaneous storage of Group A plastics up to 3.7 m in height

  (3) Miscellaneous storage of rubber tires up to 3.7 m in height

  (4) Miscellaneous storage of rolled paper up to 3.7 m in height

  (5) Storage of Class I through Class IV commodities up to 3.7 m in height as directed by 14.2.3.1 and 16.2.1.2.1

  (6) Storage of Group A plastics up to 1.5 m in height as directed by 15.2.1 and 17.2.1.1

252

Page: 13-132

Table 13.2.1

TABLE 13.2.1 Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) in Height

Commodity	*Type of Storage*	*Storage Height*		*Maximum Ceiling Height*		*Design Curve Figure 13.2.1*	*Note*	*Inside Hose*		*Total Combined Inside and Outside Hose*		*Duration (minutes)*
		ft	*m*	*ft*	*m*			*gpm*	*L/min*	*gpm*	*L/min*	
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, rack, and back-to-back shelf storage	≤12	≤3.7	—	—	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		≤10	≤3.0	—	—	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.0 to ≤3.7	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.0	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2		0, 50, 100	0, 189, 379	250	946	90
	Rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120

Page: 13-133

Module 6: Storage Applications

Presentation	Notes

Figure 13.2.1

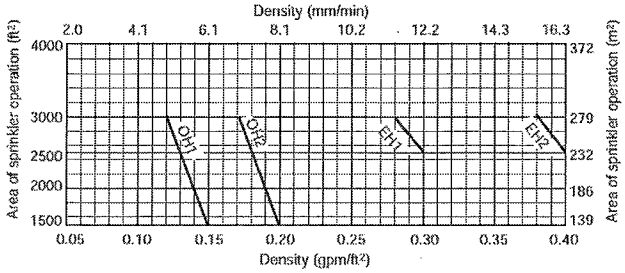


FIGURE 13.2.1 Miscellaneous Storage Up to 12 ft (3.7 m) in Height — Design Curves (see Table 13.2.1).

254

Page: 13-135

Not for hazard group classification but for design densities determination.

Misc Storage – In-Rack Sprinklers

- Minimum K-80
- Minimum 1 bar
- Simultaneous operation with ceiling sprinklers
- First tier or above ½ storage height

255

Module 6: Storage Applications

Presentation | **Notes**

Misc Storage – In-Rack Sprinkler Spacing

TABLE 13.3.4.2 In-Rack Sprinkler Spacing for Class I, II, III, and IV Commodities Stored in Single- or Double-Row Racks Up to 12 ft (3.7 m) in Height

			Commodity Class					
	Aisle Widths		I and II		III		IV	
Encapsulated	ft	m	ft	m	ft	m	ft	m
No	8	2.4	12	3.7	12	3.7	10	3.0
No	4	1.2	12	3.7	10	3.0	10	3.0
Yes	—	—	8	2.4	8	2.4	8	2.4

256

Page: 13-135

Misc Storage – In-Rack Sprinkler Locations

- Located in longitudinal flue at intersection with transverse flues
- Within 300 mm of rack centerline where no flue exists
- Additional sprinklers may be needed where transverse flue spacing exceeds maximum spacing allowance

257

Module 6: Storage Applications

Presentation	Notes

Little Known Fact – NFPA 13 Exposed Expanded Protection For Rack Storage

Commodity		Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Exposed	Unexpanded and expanded	Palletized, bin box, shelf, and rack back-to-back shelf storage	≤5	≤1.5	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
		Palletized, bin box, and shelf back-to-back shelf storage	>5 to ≤8	>1.5 to ≤2.4	28	—	EH2		0, 50, 100	0, 189, 379	500	1893	120
		Palletized, bin box, shelf, and rack back-to-back shelf storage	>5 to ≤10	>1.5 to ≤3.05	15	4.6	EH2		0, 50, 100	0, 189, 379	500	1893	120
	Unexpanded	Palletized, bin box, shelf, and rack back-to-back shelf storage	>5 to ≤10	>1.5 to ≤3.05	20	6.1	EH2		0, 50, 100	0, 189, 379	500	1893	120
	Expanded	Rack	>5 to ≤10	>1.5 to ≤3.05	20	6.1	OH2	+1 level of in-rack	0, 50, 100	0, 189, 379	250	946	90
	Unexpanded and expanded	Palletized, bin box, and shelf back-to-back shelf storage	>10 to ≤12	>3.05 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 189, 379	500	1893	120
		Rack	>10 to ≤12	>3.05 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 189, 379	500	1893	120
			>10 to ≤12	>3.05 to ≤3.7	32	—	OH2	+1 level of in-rack	0, 50, 100	0, 189, 379	250	946	90

258

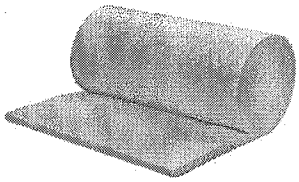
Page: 13-177 (17.2.1.1)

Module 6: Storage Applications

Presentation **Notes**

Miscellaneous Storage Example

- Rolled insulation ← class IV
- Cartoned
- Solid piled
- 3.2 m storage height
- 7.6 m ceiling



259

Chapter 13 – Miscellaneous Storage

TABLE 13.2.1 Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) in Height

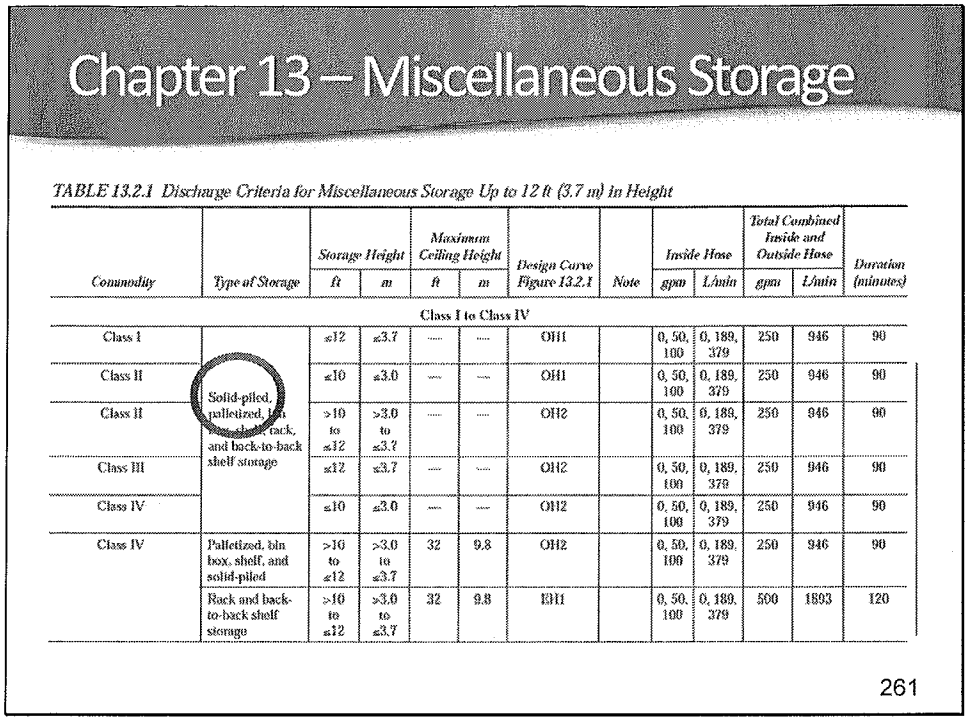
Commodity	Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, rack, and back-to-back shelf storage	≤12	≤3.7	—	—	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		≤10	≤3.0	—	—	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.0 to ≤3.7	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.0	—	—	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2		0, 50, 100	0, 189, 379	250	946	90
	Rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120

260

Page: 13-133

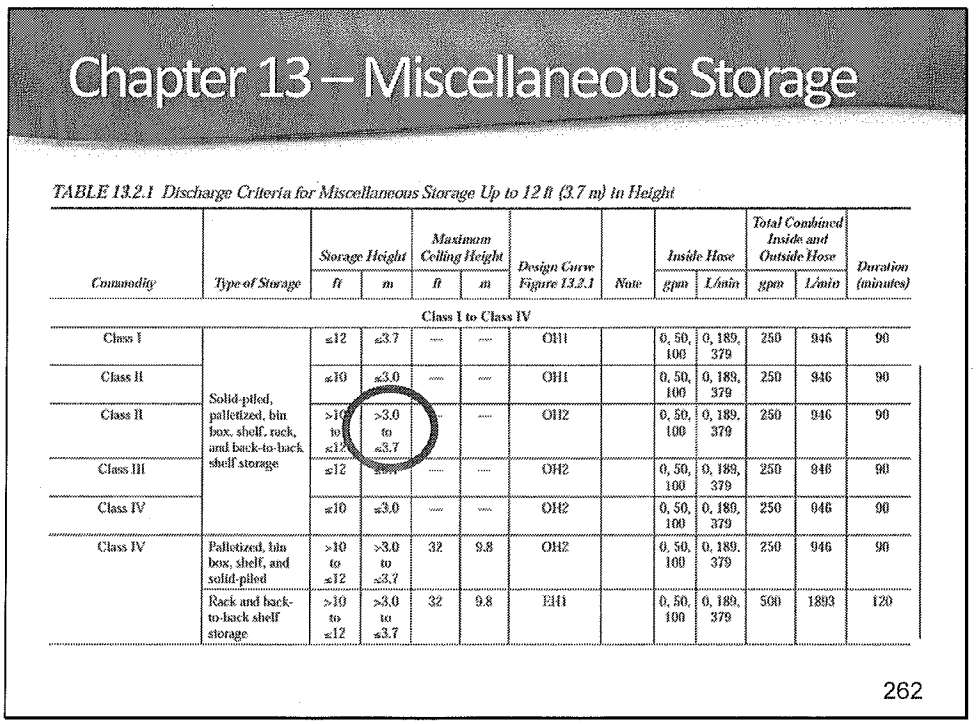
Module 6: Storage Applications

Presentation **Notes**



Commodity	Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, rack, and back-to-back shelf storage	≤12	≤3.7	----	----	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		≤10	≤3.0	----	----	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.0 to ≤3.7	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.0	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2		0, 50, 100	0, 189, 379	250	946	90
	Rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120

Page: 13-133



Commodity	Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, rack, and back-to-back shelf storage	≤12	≤3.7	----	----	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		≤10	≤3.0	----	----	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.0 to ≤3.7	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.0	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2		0, 50, 100	0, 189, 379	250	946	90
	Rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120

Page: 13-133

Module 6: Storage Applications

Presentation **Notes**

Chapter 13 – Miscellaneous Storage

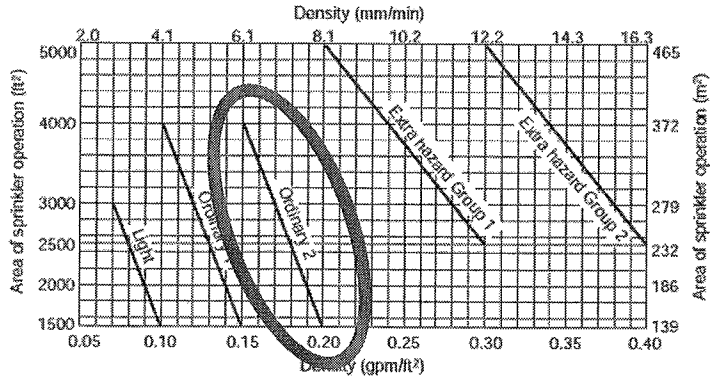
TABLE 13.2.1 Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) In Height

Commodity	Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, rack, and back-to-back shelf storage	≤12	≤3.7	.....	.....	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		≤10	≤3.0	.....	.....	OH1		0, 50, 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.0 to ≤3.7	.....	.....	OH2		0, 50, 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	.....	.....	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.0	.....	.....	OH2		0, 50, 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	9.8	OH2		0, 50, 100	0, 189, 379	250	946	90
	Rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120

263

Page: 13-133

Chapter 13 – Miscellaneous Storage



264

Page: 13-135

Module 6: Storage Applications

Presentation | **Notes**

What if the storage height was 4.2 meters?

265

Page: 13-136

If the Storage Height Is 4.2 m – Use Ch 14

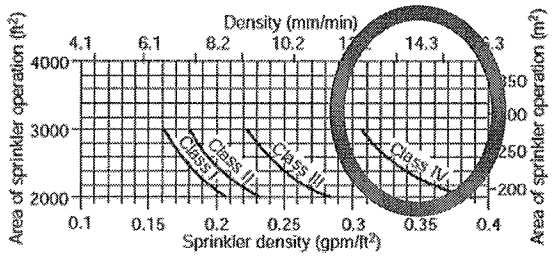


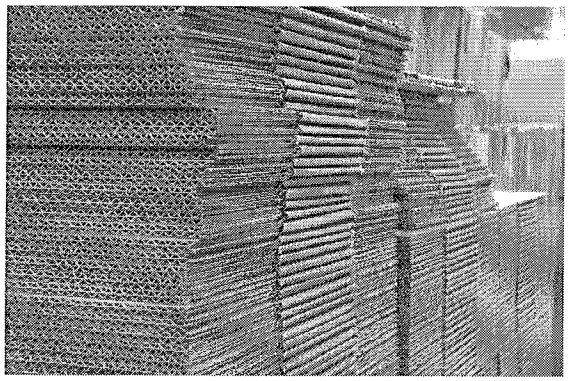
FIGURE 14.2.4.1 Sprinkler System Design Curves for 20 ft (6.1 m) High Storage — Ordinary Temperature-Rated Sprinklers.

266

Module 6: Storage Applications

Presentation	Notes

Chapter 14 – Protection for Palletized, Solid-Piled, Bin Box, Shelf, or Back-to-Back Shelf Storage of Class I through Class IV Commodities

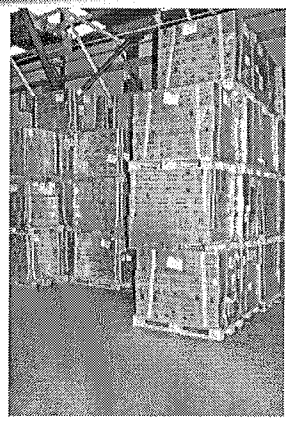


267

Chapter 14 Piled and Palletized Storage – General Topics

- CMDA
- CMSA
- ESFR
- Hose stream
- Water supply
- Limitations
  - Wood joist
  - Encapsulation

moved to Chapt. 12



268

Module 6: Storage Applications

Presentation **Notes**

Chapter 14—Protection of Class I to IV Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, Shelf Storage, or Back to Back Shelf Storage

- Sprinkler Type
  - **CMDA – Section 14.2**
  - CMSA – Section 14.3
  - ESFR – Section 14.4
- CMDA
  - Encapsulated up to 4.6m
  - Nonencapsulated
    - Shelf to 4.6m
    - All other up to 9.1m
  - Storage up to 3.7m – Chapter 13
  - Storage over 3.7m Section 14.2.4

12.6* Storage Applications.

12.6.1 For storage applications with densities of 8.2 mm/min or less, standard-response sprinklers with a K-factor of K-80 or larger shall be permitted.

12.6.2 For general storage applications, rack storage, rubber tire storage, roll paper storage, and baled cotton storage being protected with upright and pendent spray sprinklers with required densities of greater than 8.2 mm/min to 13.9 mm/min, standard-response sprinklers with a nominal K-factor of K-115 or larger shall be used.

12.6.3 For general storage applications, rack storage, rubber tire storage, roll paper storage, and baled cotton storage being protected with upright and pendent spray sprinklers with required densities greater than 13.9 mm/min, standard-response spray sprinklers with a K-factor of K-161 or larger that are listed for storage applications shall be used.

12.6.9 Ordinary- and intermediate-temperature sprinklers with K-factors of K-161 or larger, where listed for storage, shall be permitted to use the densities for high temperature sprinklers.

269

CMDA Design Curves for Protection of Class I to IV Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, Shelf Storage, or Back to Back Shelf Storage

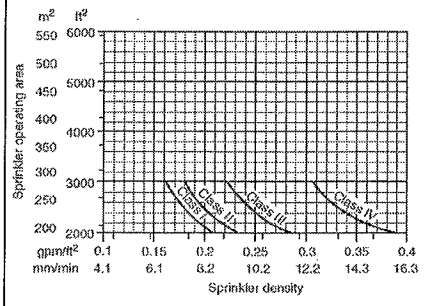


FIGURE 14.2.4.1 Sprinkler System Design Curves, 20 ft (6.1 m) High Storage — Ordinary Temperature-Rated Sprinklers.

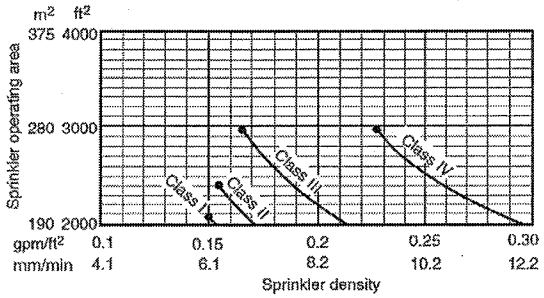


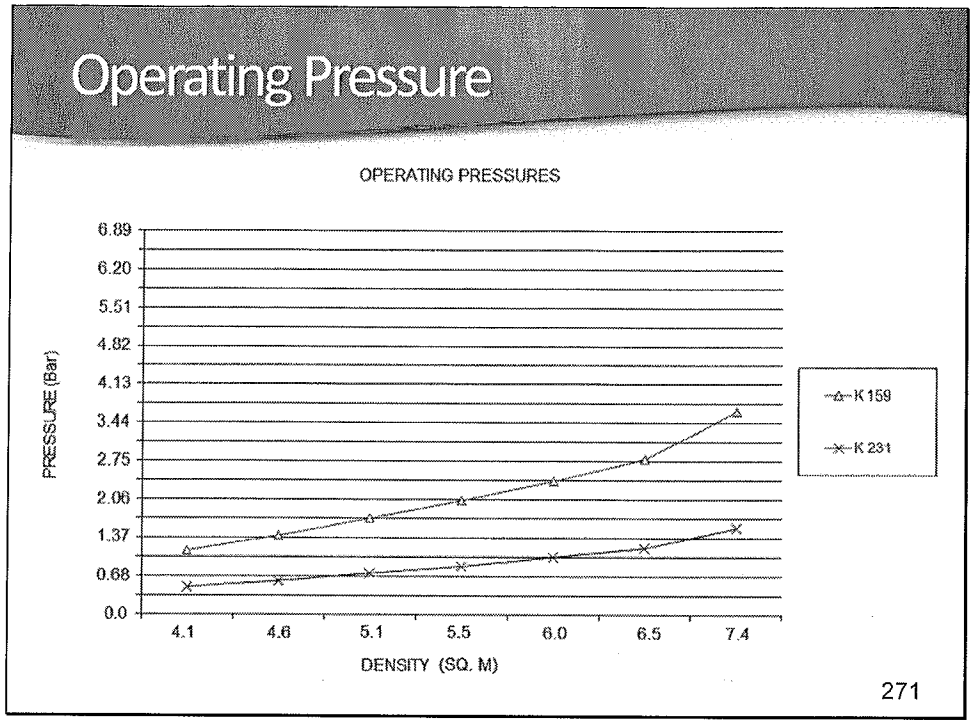
FIGURE 14.2.4.2 Sprinkler System Design Curves, 20 ft (6.1 m) High Storage — High Temperature-Rated Sprinklers.

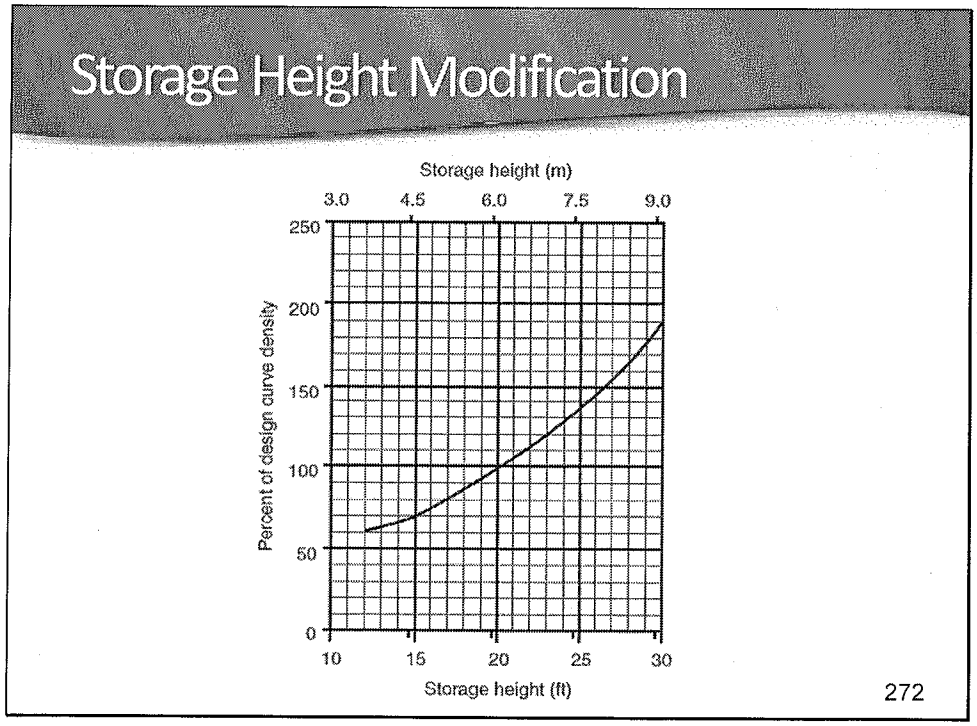
270

Page: 13-136

Module 6: Storage Applications

Presentation **Notes**





Page: 13-136

Module 6: Storage Applications

Presentation	Notes

Chapter 14 -Minimum Density and Area Check

- 14.2.4.5 For storage greater than 3.7 m, the design density shall not be less than 6.1 mm/min, and the design area shall not be less than 186 m^2 for wet systems or 242 m^2 for dry systems for any commodity, class, or group.

273

Page: 13-136

Chapter 14 – OH2 Comparison

- 14.2.4.6 For storage greater than 3.7 m, the sprinkler design density for any given area of operation for a Class III or Class IV commodity, calculated in accordance with 14.2.4, shall not be less than the density for the corresponding area of operation for ordinary hazard Group 2.

274

Page: 13-136

Module 6: Storage Applications

Presentation	Notes

Chapter 14 – Encapsulation Limitations



275

Page: 13-137 (14.2.5)

Hose Demand and Water Supply for CMDA Approach

TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
Control mode density/area	Standard and extended-coverage	NA	Up to 1200 ft² (111 m²)	250	950	60
			Over 1200 ft² (111 m²) up to 1500 ft² (139 m²)	500	1900	90
			Over 1500 ft² (139 m²) up to 2600 ft² (240 m²)	500	1900	120
			Over 2600 ft² (240 m²)	500	1900	150

276

Page: 13-129

Module 6: Storage Applications

Presentation **Notes**

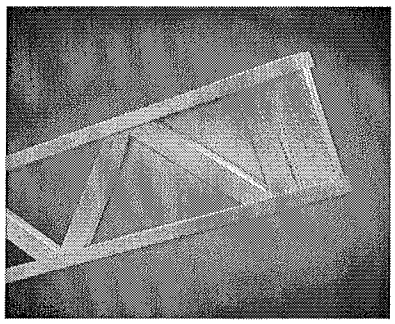
Chapter 14 Protection of Class I to IV Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, Shelf Storage, or Back-to-Back Shelf Storage

TABLE 14.3.1 CMSA Sprinkler Design Criteria for Palletized and Solid-Piled Storage of Class I Through Class IV Commodities (Encapsulated and Nonencapsulated)

Configuration	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure psi	Minimum Operating Pressure bar
	Class I or II	25	7.6	30	9.1	11.2 (160) Upright	Wet	15	25	1.7
							Dry	25	25	1.7
						16.8 (240) Upright	Wet	15	10	0.7
							Dry	25	15	1.0
						19.6 (280) Pendent	Wet	15	16	1.1
				35	10.6	11.2 (160) Upright	Wet	15	25	1.7
							Dry	25	25	1.7
						16.8 (240) Upright	Wet	15	15	1.0
							Dry	25	15	1.0
		30	9.1	35	10.6	19.6 (280) Pendent	Wet	15	25	1.7
		35	10.6	40	12.1	19.6 (280) Pendent	Wet	15	30	2.1

Page: 13-137

Chapter 14 – CMSA and Wood Joists



- 14.3.3.1 and 14.3.3.2

278

Page: 13-139

Module 6: Storage Applications

Presentation **Notes**

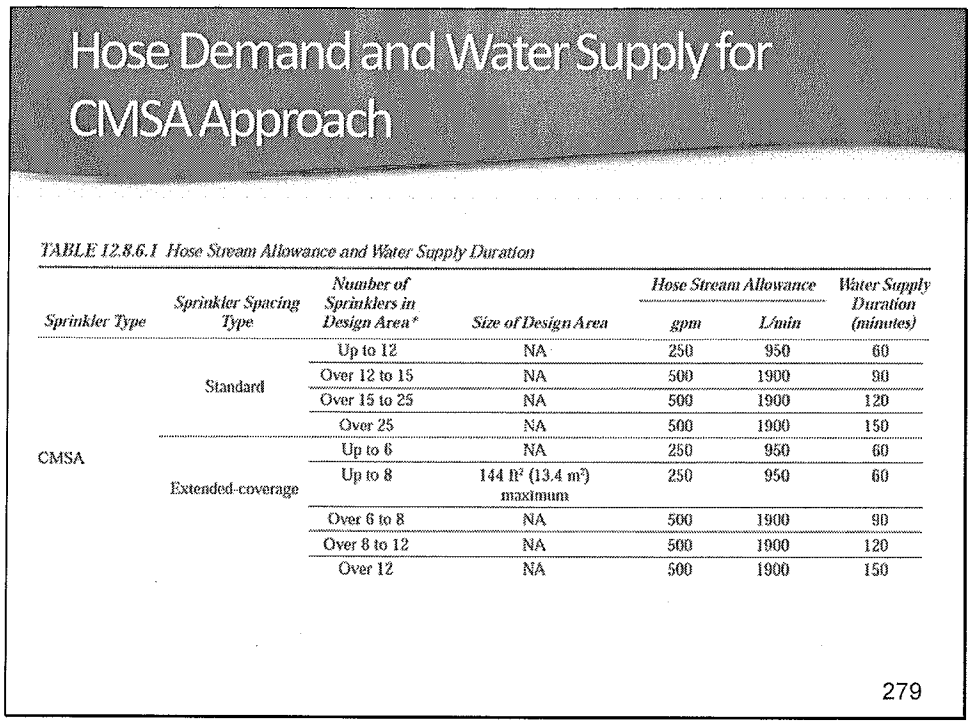


TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
CMSA	Standard	Up to 12	NA	250	950	60
		Over 12 to 15	NA	500	1900	90
		Over 15 to 25	NA	500	1900	120
		Over 25	NA	500	1900	150
	Extended-coverage	Up to 6	NA	250	950	60
		Up to 8	144 ft² (13.4 m²) maximum	250	950	60
		Over 6 to 8	NA	500	1900	90
		Over 8 to 12	NA	500	1900	120
		Over 12	NA	500	1900	150

Page: 13-129

Module 6: Storage Applications

Presentation **Notes**

Chapter 14 Protection of Class I to IV Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, Shelf Storage, or Back-to-Back Shelf Storage

- Sprinkler Type
  - CMDA – Section 14.2
  - CMSA – Section 14.3
  - **ESFR – Section 14.4**
- ESFR
  - Table 14.4

Table 14.4.1 ESFR Protection of Palletized and Solid-Piled Storage of Class I Through Class IV Co

Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar
	20	6.1	25	7.6	14.0 (200)	Upright/ Pendent	50	3.4
					16.8 (240)	Upright/ Pendent	35	2.4
					22.4 (320)	Pendent	25	1.7
					25.2 (360)	Pendent	15	1.0
	25	7.6	30	9.1	14.0 (200)	Upright/ Pendent	50	3.4
					16.8 (240)	Upright/ Pendent	35	2.4
					22.4 (320)	Pendent	25	1.7
					25.2 (360)	Pendent	15	1.0
			32	9.8	14.0 (200)	Upright/ Pendent	60	4.1
					16.8 (240)	Pendent	42	2.9
Class I, II, III, or IV, encapsulated (no open-top containers or solid shelves)	30	9.1	35	10.7	14.0 (200)	Upright/ Pendent	75	5.2
					16.8 (240)	Upright/ Pendent	52	3.6
					22.4 (320)	Pendent	35	2.4
					25.2 (360)	Pendent	20	1.4

Page: 13-140

Module 6: Storage Applications

Presentation | **Notes**

Chapter 14 ESFR – Number of Design Sprinklers

- Not addressed in table like CMSA
- Not area approach like CMDA
- Always 12 sprinklers (14.4.3)
  - 4 sprinklers on 3 hydraulically most remote branch lines

281

Page: 13-139

Hose Demand and Water Supply for ESFR Approach

TABLE 12.8.6.1 Hose Stream Allowance and Water Supply Duration

Sprinkler Type	*Sprinkler Spacing Type*	*Number of Sprinklers in Design Area**	*Size of Design Area*	*Hose Stream Allowance*		*Water Supply Duration (minutes)*
				gpm	*L/min*	
ESFR	Standard	Up to 12	NA	250	950	60
		Over 12 to 15	NA	500	1900	90
		Over 15 to 25	NA	500	1900	120
		Over 25	NA	500	1900	150

NA: Not applicable.

*For CSMA and ESFR sprinklers the additional sprinklers included in the design area for obstructions do not need to be considered in determining the total number of sprinklers in this column.

282

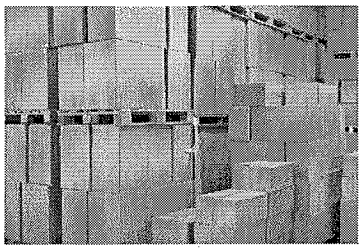
Page: 13-129

Module 6: Storage Applications

Presentation | **Notes**

Chapter 14 Example

- 9.1 m storage height
- 10.6 m ceiling
- Class IV palletized storage
- Wet system



283

Chapter 14 Example – CMDA Approach

- Figure 14.2.4.2 –12.2 mm/min X 190% (Figure 14.2.4.3) = 23.2 mm/min over 186 m^2
- Table 12.8.6.1 - Hose allowance is 1900 L/min for 150 minutes

Sprinkler Demand LPM		Hose Demand LPM		Total Flow LPM		Duration Minutes		Total Liters
4,315	+	1,900	=	6,215	x	150	=	932,250

284

Page: 13-136 (Figure 14.2.4.2)
Page: 13-129 (Table 12.8.6.1)

Module 6: Storage Applications

Presentation	Notes

Chapter 14 Example – CMSA Approach

- Table 14.3.1 – K280 pendent 15 sprinklers @ 1.7 bar = 15 x 371 Lpm = 5564 L/min
- Table 12.8.6.1 - Hose allowance is 1900 L/min for 90 minutes

Sprinkler Demand LPM		Hose Demand LPM		Total Flow LPM		Duration Minutes		Total Liters
~~5,476~~ 5564	+	1,900	=	7,376	x	90	=	663,840

285

Page: 13-137 (Table 14.3.1)
Page: 13-129 (Table 12.8.6.1)

Chapter 14 Example – ESFR Approach

- Table 14.4.1 – K360 pendent 12 sprinklers @ 1.4 bar = 12 x 427.7 L/min = 5133 L/min
- Table 12.8.6.1 – Hose allowance is 946 L/min for 60 minutes

Sprinkler Demand LPM		Hose Demand LPM		Total Flow LPM		Duration Minutes		Total Liters
5,133	+	946	=	6,079	x	60	=	364,740

286

Page: 13-140 (Table 14.4.1)
Page: 13-129 (Table 12.8.6.1)

Module 6: Storage Applications

Presentation **Notes**

Chapter 14 Example–9.1 m Class IV Palletized Storage under a 10.6 m Ceiling– Wet System –Summary

Sprinkler Type	Total Flow Lpm	Total Liters
CMDA K-160 or greater	6,215	932,250
CMSA K-280 pendent	7,376	663,840
ESFR K-360 ESFR	6,079	364,740

287

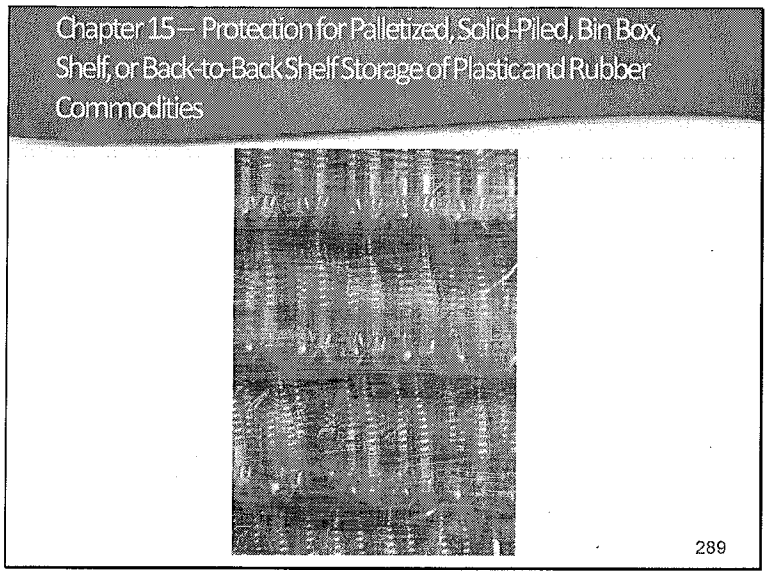
Example–9.1m Class IV Palletized Storage under a 10.6m Ceiling – Wet System

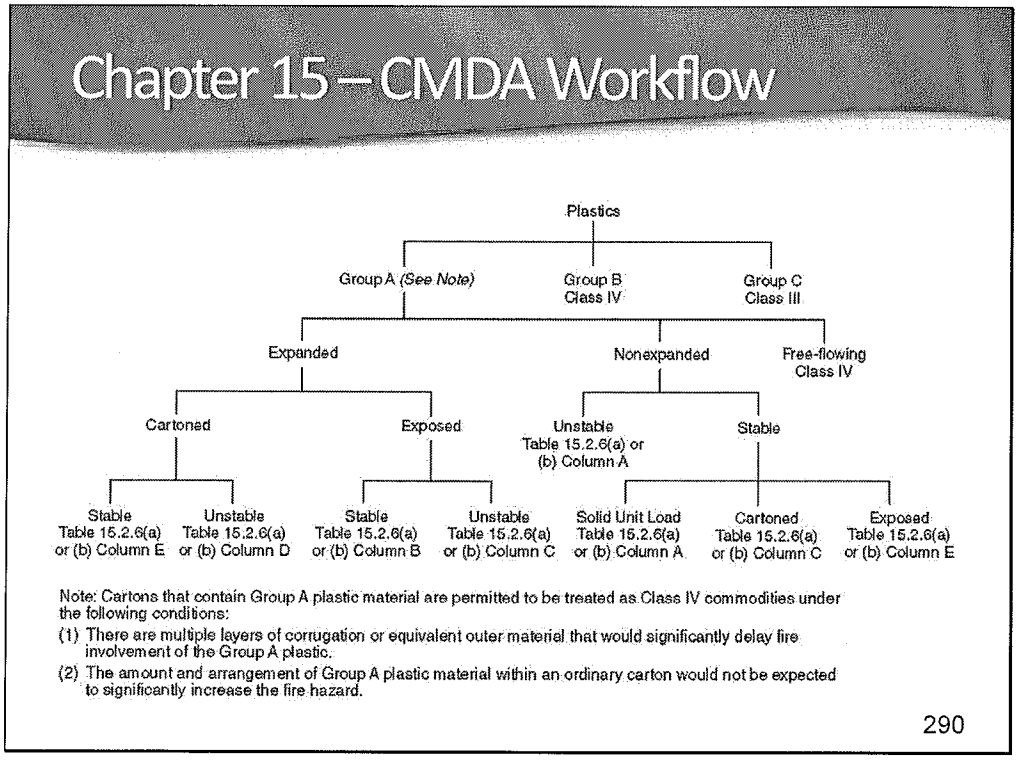
30 ft (9.1m) Class IV Palletized Storage under a 10.6m Ceiling – Wet System			
	NFPA 13		
	CMDA K-160 or greater	CMSA K-280 pendent	ESFR K-360 ESFR
Sprinkler demand Lpm	4315	5476	5133
Hose demand Lpm	1900	1900	946
Total flow Lpm	6215	7376	6079
Duration minutes	150	90	60
Total liters	932,250	663,840	364,740

288

Module 6: Storage Applications

Presentation	Notes





Page: 13-141

Module 6: Storage Applications

Presentation **Notes**

Chapter 15 – Back-to-Back Shelf Limitation for CMDA

Table 15.2.2 Back-to-Back Shelf Storage of Cartoned Unexpanded Group A Plastics

Storage Height		Ceiling Height		Protection
ft	m	ft	m	
Over 5 up to 8	1.5/2.4	Up to 14	4.3	Ordinary Hazard Group 2
Up to 12	3.7	Up to 15	4.6	0.45 gpm/ft² over 2500 ft² 18.3 mm/min/232 m²
Up to 12	3.7	Up to 30	9.1	0.6 gpm/ft² over 2500 ft² 24.5 mm/min/232 m²
Up to 15	4.6	Up to 30	9.1	0.7 gpm/ft² over 2500 ft² 28.5 mm/min/232 m²

291

Page: 13-141

Chapter 15 – CMDA Approach

Table 15.2.6(b) Design Densities for Palletized, Solid-Piled, Bin Box, or Shelf Storage of Plastic and Rubber Commodities (S.I. Units)

Maximum Storage Height (m)	Roof/Ceiling Height (m)	Density (mm/min)				
		A	B	C	D	E
>1.5 to ≤3.6	Up to 4.6	8.2	EH2	12.2	EH1	EH2
	>4.6 to 6.1	12.2	24.4	20.4	EH2	EH2
	>6.1 to 9.8	16.3	32.6	24.4	18.3	28.5
4.6	Up to 6.1	12.2	24.4	20.4	16.3	18.3
	>6.1 to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 10.7	18.3	36.7	28.5	22.4	34.6
6.1	Up to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8
7.6	Up to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8

292

Page: 13-142

Module 6: Storage Applications

Presentation	Notes

Chapter 15 – CMDA Approach Design Area

(1) The area shall be a minimum of 232 m^2.

(2) When selecting a point from the EH1 or EH2 density/area curves of Figure 13.2.1, the following area reductions shall be permitted

(a) For K-115 sprinklers used with Curve EH1, the design area shall be permitted to be reduced by 25 percent, but not below 186 m^2, where high temperature sprinklers are used.

(b) For K-160 or larger sprinklers, the design area shall be permitted to be reduced by 25 percent, but not below 186 m^2, regardless of temperature rating.

(3) For closed arrays, the area shall be permitted to be reduced to 186 m^2.

293

Chapter 15 - CMDA Interpolation

- Example:
  - 5.5 m of storage
  - 10.6 m building
  - Cartoned, stable pile

294

Module 6: Storage Applications

Presentation **Notes**

CMDA Interpolation – Step 1

Identify Density Column

A: (1) Nonexpanded, unstable

(2) Nonexpanded, stable, solid unit load

B: Expanded, exposed, stable

C: (1) Expanded, exposed, unstable

(2) Nonexpanded, stable, cartoned

D: Expanded, cartoned, unstable

E: (1) Expanded, cartoned, stable

(2) Nonexpanded, stable, exposed

Table 15.2.6(b) Design Densities for Palletized, Solid-Piled, Bin Box, or Shelf Storage of Plastic and Rubber Commodities (S.I. Units)

Maximum Storage Height (m)	Roof/Ceiling Height (m)	Density (mm/min) A	B	C	D	E
>1.5 to ≤3.6	Up to 4.6	8.2	EH2	12.2	EH1	EH2
	>4.6 to 6.1	12.2	24.4	20.4	EH2	EH2
	>6.1 to 9.8	16.3	32.6	24.4	18.3	28.5
4.6	Up to 6.1	12.2	24.4	20.4	16.3	18.3
	>6.1 to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 10.7	18.3	36.7	28.5	22.4	34.6
6.1	Up to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8
7.6	Up to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8

295

Page: 13-142

CMDA Interpolation – Step 2

Identify Applicable Rows
Based on Storage Height

Table 15.2.6(b) Design Densities for Palletized, Solid-Piled, Bin Box, or Shelf Storage of Plastic and Rubber Commodities (S.I. Units)

Maximum Storage Height (m)	Roof/Ceiling Height (m)	Density (mm/min) A	B	C	D	E
>1.5 to ≤3.6	Up to 4.6	8.2	EH2	12.2	EH1	EH2
	>4.6 to 6.1	12.2	24.4	20.4	EH2	EH2
	>6.1 to 9.8	16.3	32.6	24.4	18.3	28.5
4.6	Up to 6.1	12.2	24.4	20.4	16.3	18.3
	>6.1 to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 10.7	18.3	36.7	28.5	22.4	34.6
6.1	Up to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8
7.6	Up to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8

Page: 13-143

Module 6: Storage Applications

Presentation **Notes**

CMDA Interpolation – Step 3

Identify Applicable Rows
Based on Ceiling Height

Table 15.2.6(b) Design Densities for Palletized, Solid-Piled, Bin Box, or Shelf Storage of Plastic and Rubber Commodities (S.I. Units)

Maximum Storage Height (m)	Roof/Ceiling Height (m)	Density (mm/min)				
		A	B	C	D	E
>1.5 to ≤3.6	Up to 4.6	8.2	EH2	12.2	EH1	EH2
	>4.6 to 6.1	12.2	24.4	20.4	EH2	EH2
	>6.1 to 9.8	16.3	32.6	24.4	18.3	28.5
4.6	Up to 6.1	12.2	24.4	20.4	16.3	18.3
	>6.1 to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 10.7	18.3	36.7	28.5	22.4	34.6
6.1	Up to 7.6	16.3	32.6	24.4	18.3	28.5
	>7.6 to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8
7.6	Up to 9.1	18.3	36.7	28.5	22.4	34.6
	>9.1 to 10.7	24.4	49.0	34.6	28.5	44.8

Page: 13-143

CMDA Interpolation – Steps 4-5-6

4) Identify the densities for the appropriate rows in the table:
   6.1 m of storage = 44.8 mm/min
   4.6 m of storage = 34.6 mm/min

5) Calculate the difference in density between the bounding rows
   44.8 mm/min - 34.6 mm/min = 10.2 mm/min

6) Calculate the "density per unit (m) of storage height"
   10.2 mm/min / 1.5 m = 6.8 mm/min per meter of storage

298

Module 6: Storage Applications

Presentation	Notes

CMDA Interpolation – Step 7

7) 5.5 m is 0.91 m at 6.8 mm/min greater than 34.6 mm/min for 4.6 m

Therefore, 34.6 mm/min + 6.1 mm/min = 40.7 mm/min

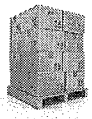
5.5 m density = 40.7 mm/min

299

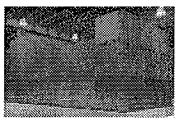
Chapter 15 – CMSA Design Approach

Acceptable Approaches

- Solid pile



- Palletized

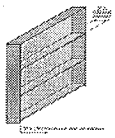


Must Use CMDA

- Bin box



- Shelf storage



300

Module 6: Storage Applications

Presentation **Notes**

Chapter 15 – CMSA Design Approach

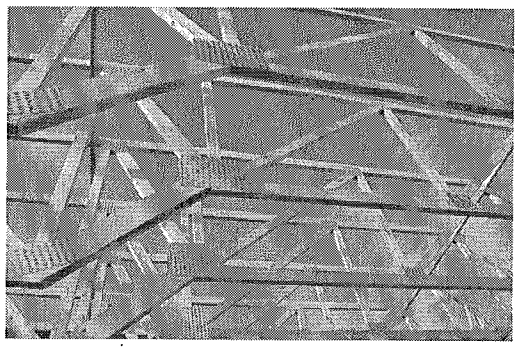
TABLE 15.3.1 CMSA Sprinkler Design Criteria for Palletized and Solid-Piled Storage of Plastic and Rubber Commodities

Storage Arrangement	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure psi	Minimum Operating Pressure bar
Palletized	Cartoned unexpanded plastics	20	6.1	30	9.1	11.2 (160) Upright	Wet	25	25	1.7
						16.8 (240) Upright	Wet	15	22	1.5
						19.6 (280) Pendent	Wet	15	16	1.1
		25	7.6	30	9.1	16.8 (240) Upright	Wet	15	22	1.5
						19.6 (280) Pendent	Wet	15	16	1.1
		30	9.1	35	10.7	19.6 (280) Pendent	Wet	15	25	1.7
		35	10.6	40	12.1	19.6 (280) Pendent	Wet	15	30	2.1

301

Page: 13-144

Chapter 15 – CMSA and Wood Joists



- 15.3.3.1 and 15.3.3.2

302

Page: 13-143

Module 6: Storage Applications

Presentation | **Notes**

Chapter 15 – ESFR Design Approach

TABLE 15.4.1 ESFR Protection of Palletized and Solid-Piled Storage of Plastic and Rubber Commodities

Storage Arrangement	Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar
Palletized and solid-piled storage(no open-top containers)	Cartoned unexpanded plastic	20	6.1	25	7.6	14.0 (200)	Upright/pendent	50	3.4
						16.8 (240)	Upright/pendent	35	2.4
						22.4 (320)	Pendent	25	1.7
						25.2 (360)	Pendent	15	1.0
				30	9.1	14.0 (200)	Upright/pendent	50	3.4
						16.8 (240)	Upright/pendent	35	2.4
						22.4 (320)	Pendent	25	1.7
						25.2 (360)	Pendent	15	1.0
				35	10.7	14.0 (200)	Upright/pendent	75	5.2
						16.8 (240)	Upright/pendent	52	3.6
						22.4 (320)	Pendent	35	2.4
						25.2 (360)	Pendent	20	1.4

Page: 13-143

Chapter 15 ESFR – Number of Design Sprinklers

- Not addressed in table like CMSA
- Not area approach like CMDA
- Consistent with Chapter 14
- Always 12 sprinklers
  - 4 sprinklers on 3 hydraulically most remote branch lines

304

Module 6: Storage Applications

Activity 6.1

Instructions: Answer the questions for each scenario given.

Scenario 1: A distributor of flooring products is storing 305 mm x 305 mm vinyl floor tiles stacked in cardboard boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 7.9 meters above the floor. The building deck is 9.7 meters above the floor. The contractor installing the sprinkler system is going to use high-temperature, standard spray upright sprinklers at the ceiling

a. What is the commodity?

b. How is it stored?

c. How high?

d. What is the correct figure and density/area to use?

e. Do any adjustments need to be made?

f. What is the final density/area?

g. What is the acceptable K-factor?

Module 6: Storage Applications

Scenario 2: A bakery is storing hamburger and hot dog buns in plastic bags in paperboard cartons on cardboard trays. The packages are stored in the back of the store on 660.4 mm deep metal shelves. The top of the storage is 4.2 meters above the floor. The ceiling is 5.1 meters above the floor. The designer of the sprinkler system needs to know the correct density and area to use if they chose K-160 sprinklers.

a. What is the commodity?

b. How is it stored?

c. How high?

d. What is the correct figure and density/area to use?

e. Do any adjustments need to be made?

f. What is the final density/area?

Module 6: Storage Applications

Scenario 3: Metal junction boxes for electrical installations are being stored in cardboard boxes. The boxes are placed directly on top of one another until they reach a height of 4.8 meters above the floor. The roof deck is 6.1 meters above the floor.

a. What is the commodity?

class 1

b. How is it stored?

high piled

c. How high?

4.8m

d. What is the correct figure and density/area to use?

ordinary temp ⇒ 0.2 gpm/ft²
high temp ⇒ 0.15 gpm/ft² (6.1 mm/min) @ 190m²

e. Do any adjustments need to be made?

~~NO~~ 75%

f. What is the final density/area?

~~as in (d).~~ 4.6mm/min @ 190m².

g. What is the acceptable K-factor?

K80

$Q = K\sqrt{P}$

$K = Q/\sqrt{P} =$

~~Q = SA = 190 x 6.1 = 1,159 ℓ/min~~

Module 6: Storage Applications

Scenario 4: A manufacturer stores empty plastic bottles in boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 5.7 meters above the floor. The roof deck is 7 meters above the floor. The sprinkler system designer would like to use K-160 sprinklers.

a. What is the commodity?

b. How is it stored?

c. How high?

d. What is the correct figure and density/area to use?

e. Do any adjustments need to be made?

f. What is the final density/area?

Module 6: Storage Applications

Scenario 5: A manufacturer stores empty plastic bottles in boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 5.7 meters above the floor. The roof deck is 7 meters above the floor. The sprinkler system designer would like to use K-320 ESFR pendent sprinklers.

a. What is the commodity?

b. How is it stored?

c. How high?

d. What is the roof height?

e. What is the correct table to use?

f. What is the final pressure and number of sprinklers?

Module 6: Storage Applications

Scenario 6: A company that makes and ships materials for hobby enthusiasts stores small blocks of Styrofoam to be placed in their packaging. The blocks are placed directly on top of each other to a height of 2.1 meters above the floor. The sprinkler system designer would like to use K-160 sprinklers.

a. What is the commodity?

Group A Plastics.

b. How is it stored?

Pile of

c. How high?

2.1m

d. What is the roof height?

Assume less than 4.6m.

e. What is the correct column to use?

E for expanded, cartoned, stable.

(Ett2)

f. Are any adjustments needed?

Yes for K160

g. What is the final density/area?

min $232m^2$ ⇒ 16.3 mm/min @ $232 m^2$

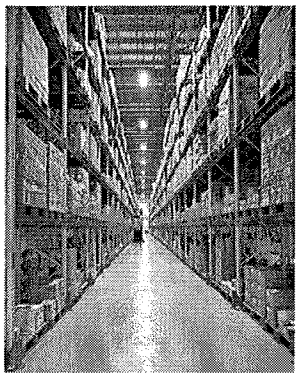
$0.75 \times 232 = 174 m^2$ ∴ 16.3 mm/min @ $\frac{18.6m}{min}^2$

Module 6: Storage Applications

Presentation **Notes**

Rack Storage – Chapters 16 and 17





306

Impact of In-Rack Sprinklers

A metric conversion of Table C.9 Summary of Relationship Between Sprinkler Discharge Density and the Extent of Fire Damage and Sprinkler Operation

	Fire Damage in Test Array		
Density (mm/min)	%	m^2	Sprinkler Operation (74° C) Area (m^2)
12.2 (ceiling only)	22	36.7	418 - 446
15.2 (ceiling only)	17	28.4	167.2
18.3 (ceiling only)	9	15	65
8.1 (ceiling only)	28-36	46.8 - 60.2	1217 - 1300.6
8.1 (Sprinklers at ceiling and in racks)	8	13.3	381
12.2 (Sprinklers at ceiling and in racks)	7	11.7	65

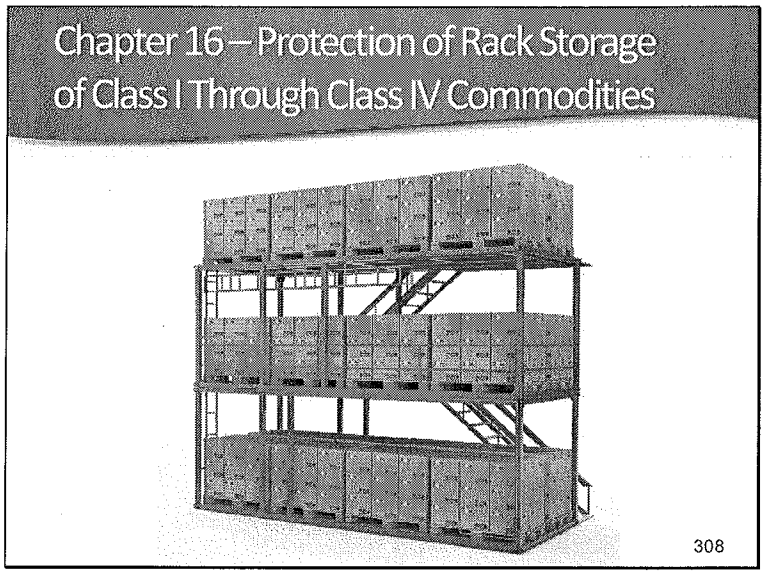
This table does not exist in metric form. It was converted for use in this seminar

307

Page: 13-409

Module 6: Storage Applications

Presentation | **Notes**



Page: 13-148

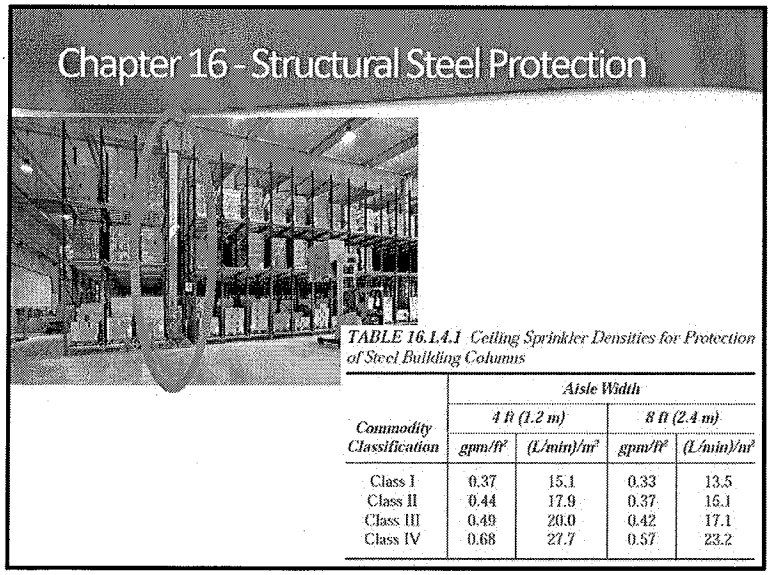
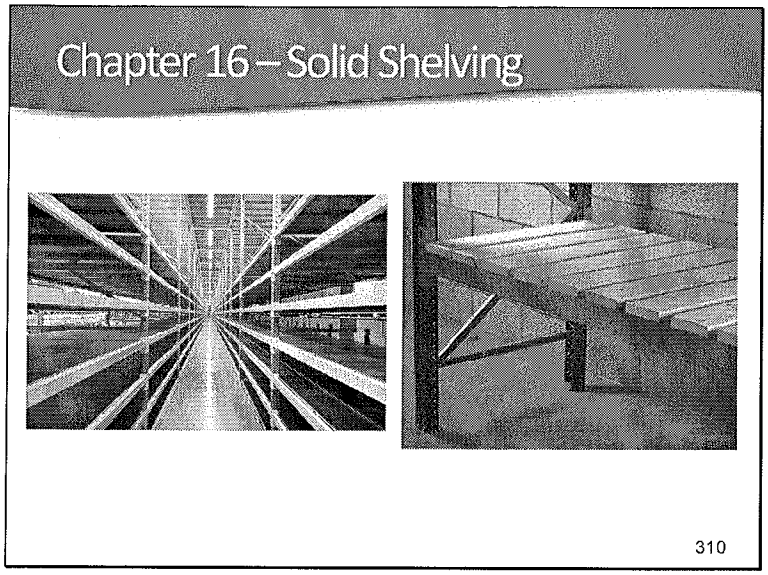


TABLE 16.1.4.1 Ceiling Sprinkler Densities for Protection of Steel Building Columns

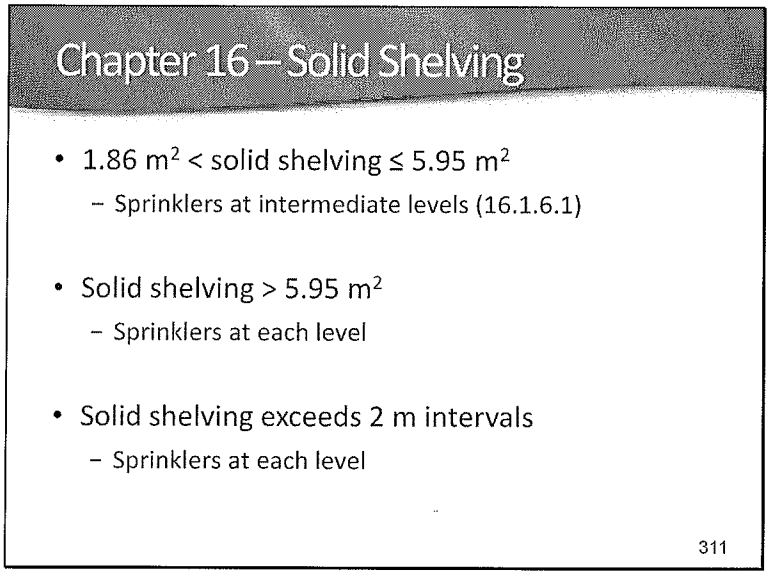
Commodity Classification	Aisle Width: 4 ft (1.2 m) gpm/ft²	4 ft (1.2 m) (L/min)/m²	8 ft (2.4 m) gpm/ft²	8 ft (2.4 m) (L/min)/m²
Class I	0.37	15.1	0.33	13.5
Class II	0.44	17.9	0.37	15.1
Class III	0.49	20.0	0.42	17.1
Class IV	0.68	27.7	0.57	23.2

Module 6: Storage Applications

Presentation	Notes

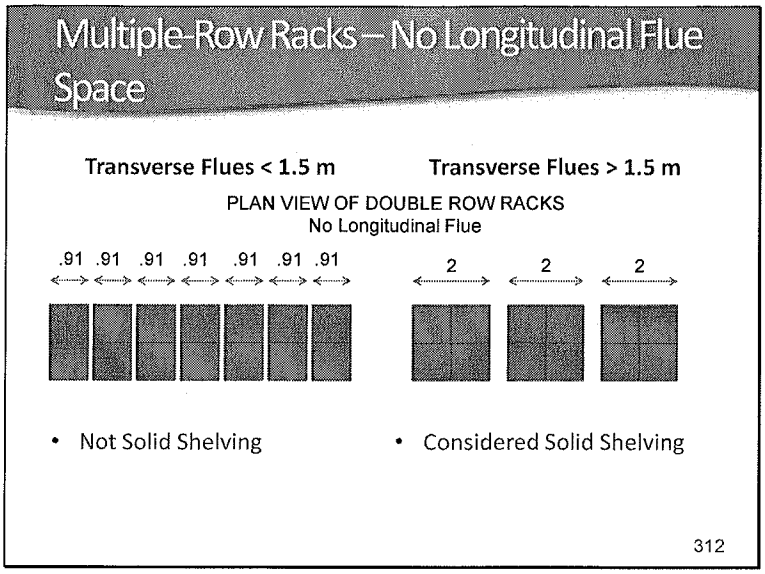


Page: 13-148

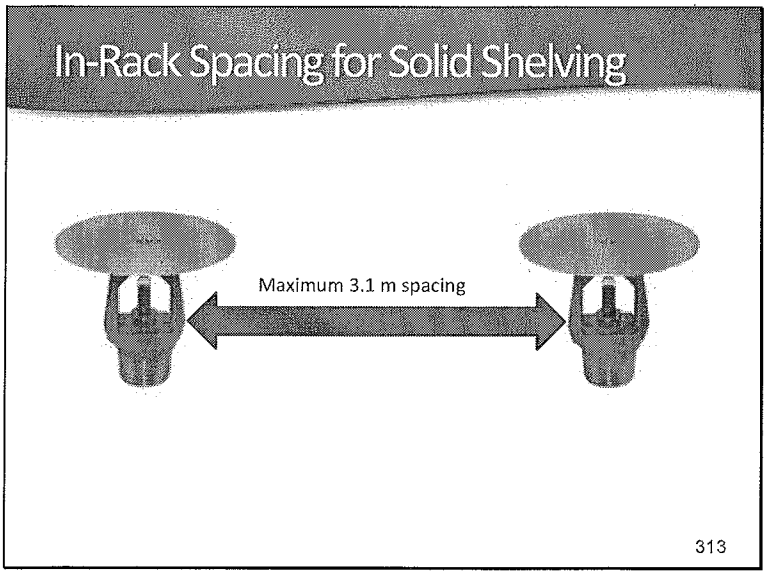


Module 6: Storage Applications

Presentation	Notes



Page: 13-148 (16.1.6.3)



Page: 13-148

Module 6: Storage Applications

Presentation | **Notes**

Solid Shelving – In-Rack Discharge Criteria

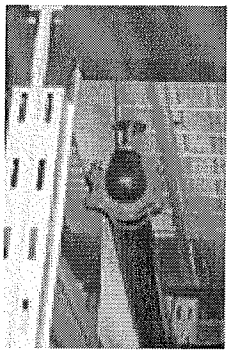
- Minimum flow of 114 L/min as follows:

Commodity	Number of Levels of In-Rack Sprinklers	Numbers of Sprinklers to be Calculated
Class I, II, or III	1	6
Class IV	1	8
Class I, II, or III	2+ levels	10 (5 on each of top 2 levels)
Class IV	2+ levels	14 (7 on each of top 2 levels)

314

Page: 13-148 (16.1.6.5)

Solid Shelving – Face Sprinklers



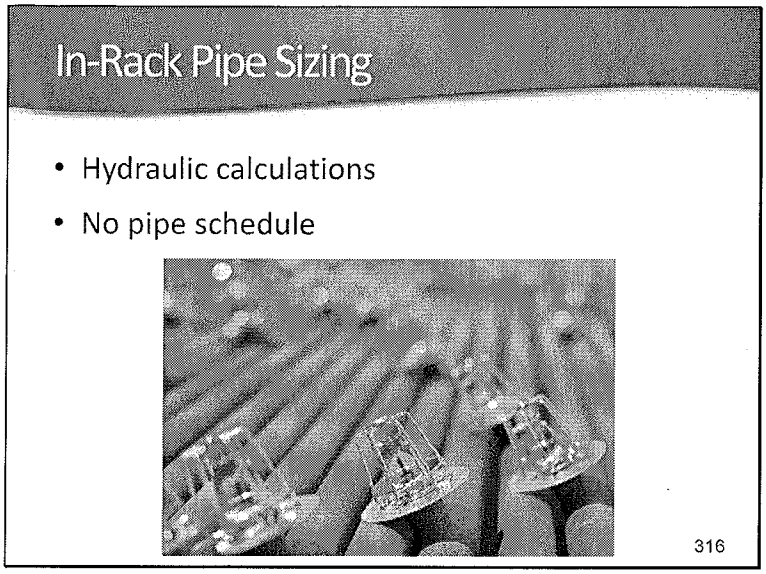
- Face sprinklers at each solid shelf
- At rack uprights
- 8 sprinklers at 227 L/min

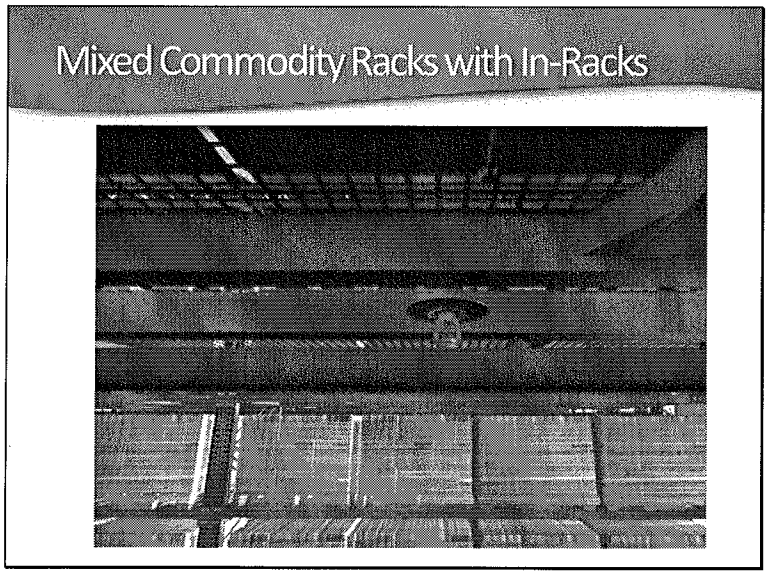
315

Page: 13-149 (16.1.6.6)

Module 6: Storage Applications

Presentation	Notes





Page: 13-149 (16.1.8.2)

Module 6: Storage Applications

Presentation	Notes

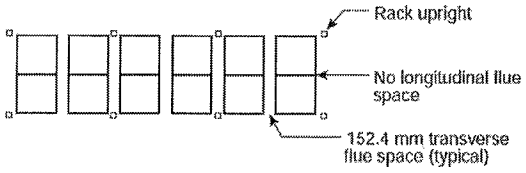
Horizontal Barriers

- Sheet metal or wood (or similar material)
- Extend the full length and depth of the rack
- Fitted within 51 mm horizontally around rack uprights

318

Flue Space Requirements for Storage Up to and Including 7.6 m

- No solid shelving – longitudinal flue not required
- 152.4 mm transverse flue required at unit loads and uprights



319

Page: 13-149 (16.1.10.1 and 16.1.10.2)

Module 6: Storage Applications

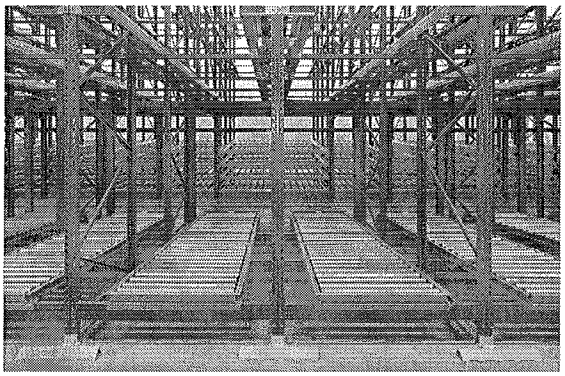
Presentation	Notes

Flue Space Requirements for Storage Over 7.6 m

- Nominal 152.4 mm transverse flue spaces between loads and at rack uprights shall be maintained in single-row, double-row, and multiple-row racks
- Nominal 152.4 mm longitudinal flue spaces shall be provided in double-row racks

320

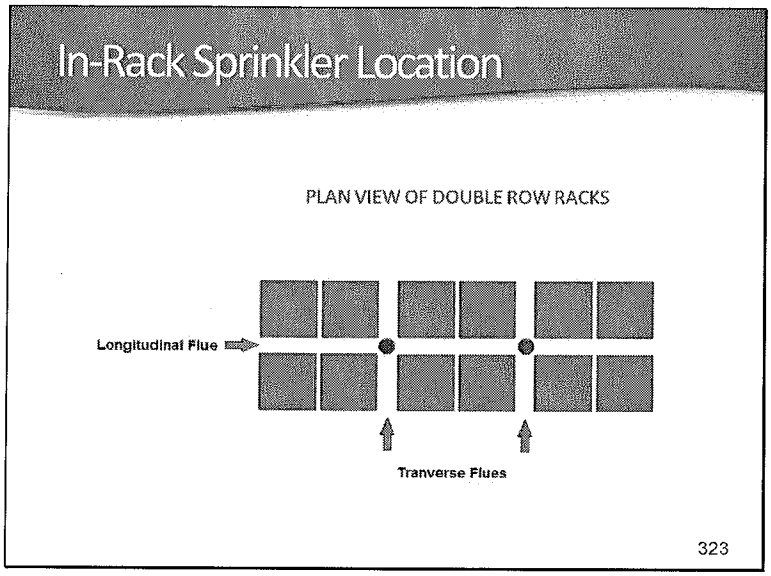
Flue Space Requirements for Storage Over 7.6 m



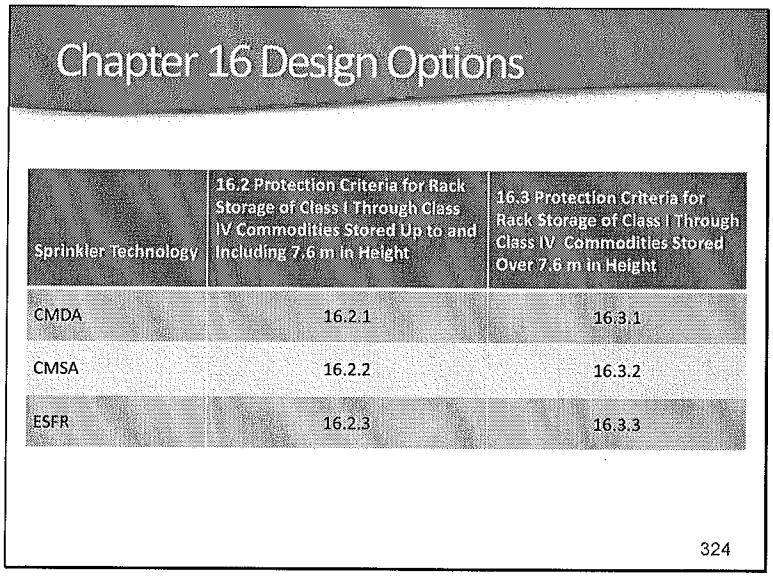
321

Module 6: Storage Applications

Presentation	Notes



Page: 13-149 (16.1.11.2.2 and 16.1.11.2.3)



Page: 13-149 (16.2.1)
Page: 13-158 (16.2.2)
Page: 13-160 (16.2.3)

Module 6: Storage Applications

Presentation	Notes

CMDA Design Approaches for Storage ≤ 7.6 m

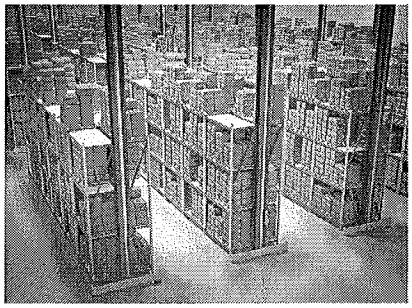
- Determine commodity
- Determine storage height
- Determine rack type(single/double or multiple row)
- Encapsulation
- Identify appropriate section (16.2.1.3.2 or 16.2.1.3.3), table, and design curve

325

Page: 13-149 (16.2.1.3.2)
Page: 13-150 (16.2.1.3.3)

Chapter 16 CMDA Example

- Class I commodity
- Storage 5.5 m
- Double row rack
- Non-encapsulated
- 2.4 m aisles



326

Page: 13-149 (16.2.1.3.2)

Module 6: Storage Applications

Presentation **Notes**

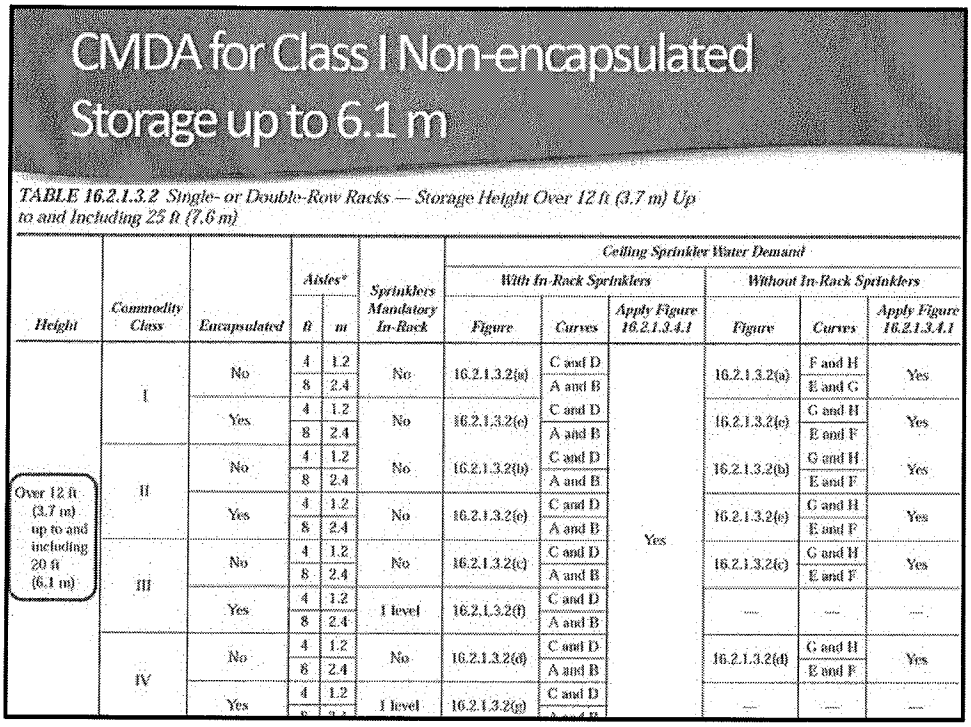


TABLE 16.2.1.3.2 Single- or Double-Row Racks — Storage Height Over 12 ft (3.7 m) Up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	With In-Rack Sprinklers: Curves	With In-Rack Sprinklers: Apply Figure 16.2.1.3.4.1	Without In-Rack Sprinklers: Figure	Without In-Rack Sprinklers: Curves	Without In-Rack Sprinklers: Apply Figure 16.2.1.3.4.1
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4	1.2	No	16.2.1.3.2(a)	C and D	Yes	16.2.1.3.2(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
	II	No	4	1.2	No	16.2.1.3.2(b)	C and D		16.2.1.3.2(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D		16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	III	No	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	16.2.1.3.2(d)	C and D		16.2.1.3.2(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(g)	C and D		—	—	—

Page: 13-150

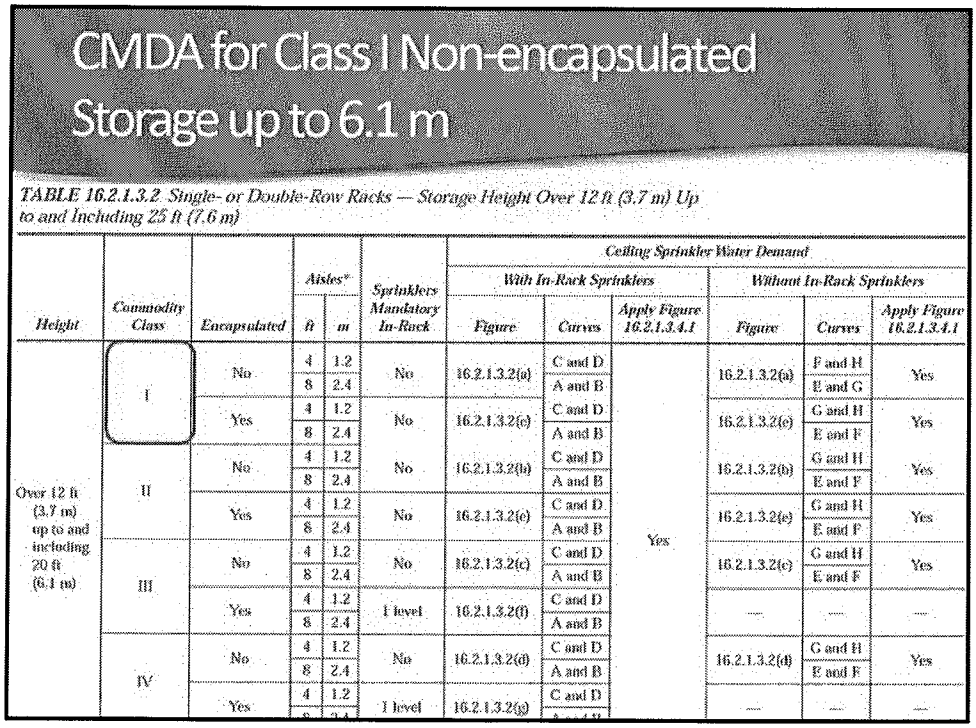


TABLE 16.2.1.3.2 Single- or Double-Row Racks — Storage Height Over 12 ft (3.7 m) Up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	With In-Rack Sprinklers: Curves	With In-Rack Sprinklers: Apply Figure 16.2.1.3.4.1	Without In-Rack Sprinklers: Figure	Without In-Rack Sprinklers: Curves	Without In-Rack Sprinklers: Apply Figure 16.2.1.3.4.1
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4	1.2	No	16.2.1.3.2(a)	C and D	Yes	16.2.1.3.2(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
	II	No	4	1.2	No	16.2.1.3.2(b)	C and D		16.2.1.3.2(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D		16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	III	No	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	16.2.1.3.2(d)	C and D		16.2.1.3.2(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(g)	C and D		—	—	—

Page: 13-150

Module 6: Storage Applications

Presentation **Notes**

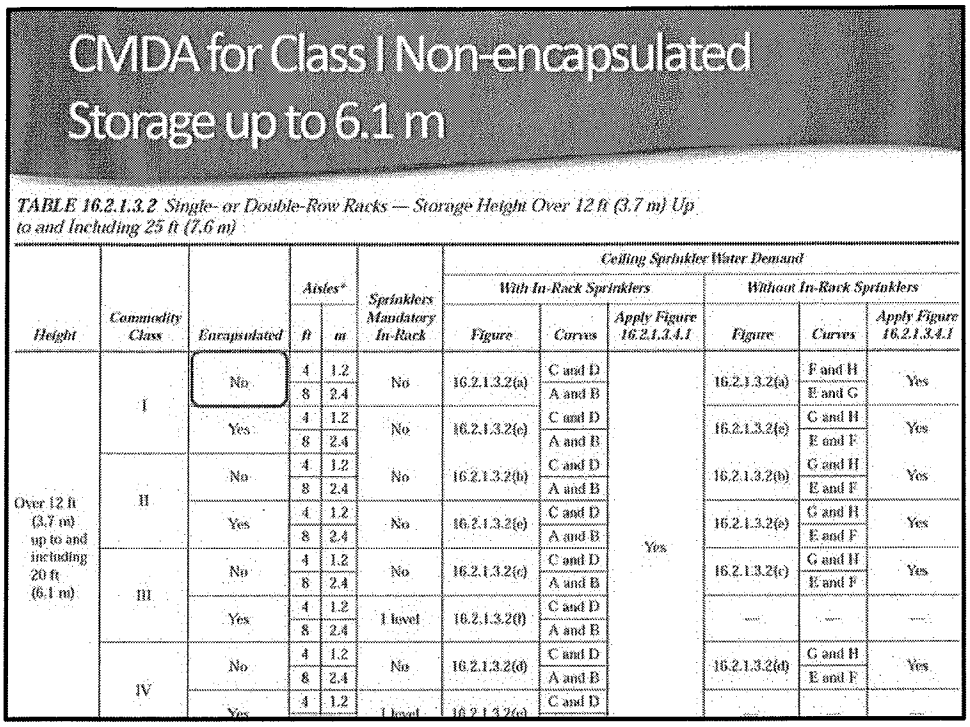


TABLE 16.2.1.3.2 Single- or Double-Row Racks — Storage Height Over 12 ft (3.7 m) Up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	Curves	Apply Figure 16.2.1.3.4.1	Without In-Rack Sprinklers: Figure	Curves	Apply Figure 16.2.1.3.4.1
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4	1.2	No	16.2.1.3.2(a)	C and D	Yes	16.2.1.3.2(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D		16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	II	No	4	1.2	No	16.2.1.3.2(b)	C and D		16.2.1.3.2(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D		16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	III	No	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	16.2.1.3.2(d)	C and D		16.2.1.3.2(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(g)	C and D		—	—	—

Page: 13-150

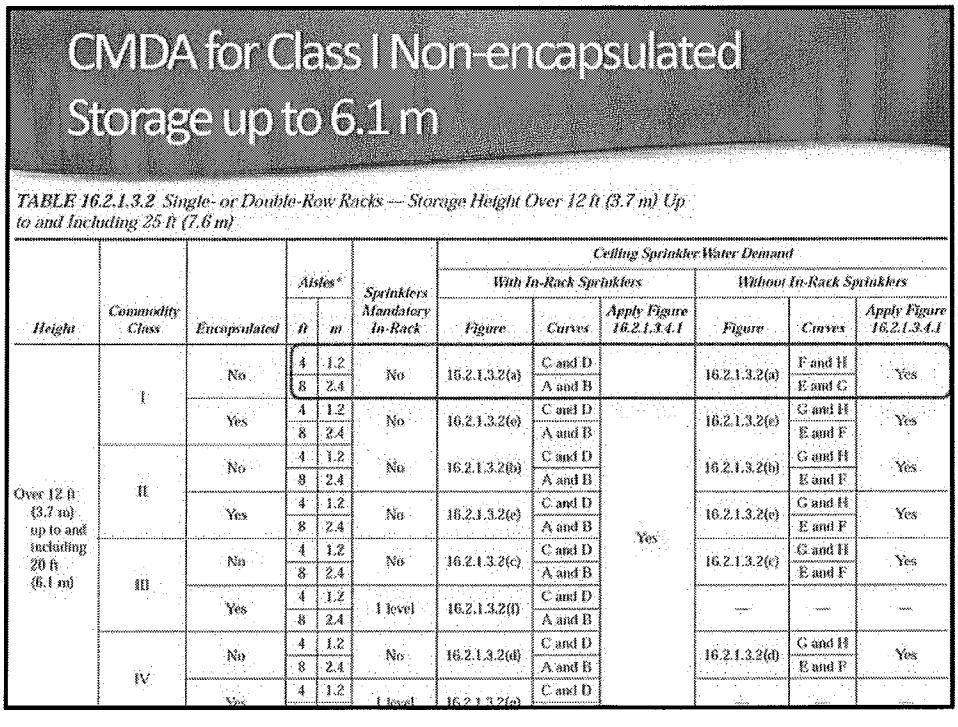


TABLE 16.2.1.3.2 Single- or Double-Row Racks — Storage Height Over 12 ft (3.7 m) Up to and Including 25 ft (7.6 m)

Height	Commodity Class	Encapsulated	Aisles* ft	Aisles* m	Sprinklers Mandatory In-Rack	Ceiling Sprinkler Water Demand: With In-Rack Sprinklers: Figure	Curves	Apply Figure 16.2.1.3.4.1	Without In-Rack Sprinklers: Figure	Curves	Apply Figure 16.2.1.3.4.1
Over 12 ft (3.7 m) up to and including 20 ft (6.1 m)	I	No	4	1.2	No	16.2.1.3.2(a)	C and D		16.2.1.3.2(a)	F and H	Yes
			8	2.4			A and B			E and G	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D	Yes	16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	II	No	4	1.2	No	16.2.1.3.2(b)	C and D		16.2.1.3.2(b)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	No	16.2.1.3.2(e)	C and D		16.2.1.3.2(e)	G and H	Yes
			8	2.4			A and B			E and F	
	III	No	4	1.2	No	16.2.1.3.2(c)	C and D		16.2.1.3.2(c)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(f)	C and D		—	—	—
			8	2.4			A and B				
	IV	No	4	1.2	No	16.2.1.3.2(d)	C and D		16.2.1.3.2(d)	G and H	Yes
			8	2.4			A and B			E and F	
		Yes	4	1.2	1 level	16.2.1.3.2(g)	C and D		—	—	—

Page: 13-150

Module 6: Storage Applications

Presentation | **Notes**

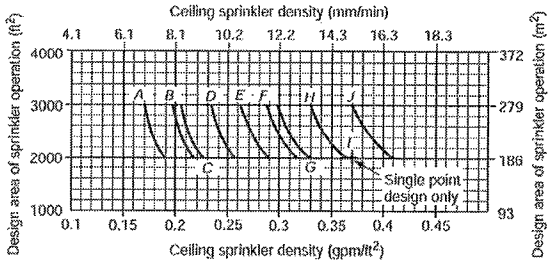
Design Decisions

- Use curve 16.2.1.3.2(a)
  - In-racks not mandatory
    - Ceiling only
    - In-rack and ceiling system
  - Ordinary or high-temperature sprinklers

331

Page: 13-151 (Figure 16.2.1.3.2(a)

CMDA for Class I Non-encapsulated Storage up to 6.1 m



Curve	Legend
A	Single- or double-row racks with 8 ft (2.44 m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	Single- or double-row racks with 8 ft (2.44 m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	Single- or double-row racks with 4 ft (1.22 m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	Single- or double-row racks with 4 ft (1.22 m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	Single- or double-row racks with 8 ft (2.44 m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 4 ft (1.22 m) aisles and high-temperature ceiling sprinklers
G	Single- or double-row racks with 8 ft (2.44 m) aisles and ordinary-temperature ceiling sprinklers
H	Single- or double-row racks with 4 ft (1.22 m) aisles and ordinary-temperature ceiling sprinklers
I	Multiple-row racks with 8 ft (2.44 m) or wider aisles and high-temperature ceiling sprinklers
J	Multiple-row racks with 8 ft (2.44 m) or wider aisles and ordinary-temperature ceiling sprinklers

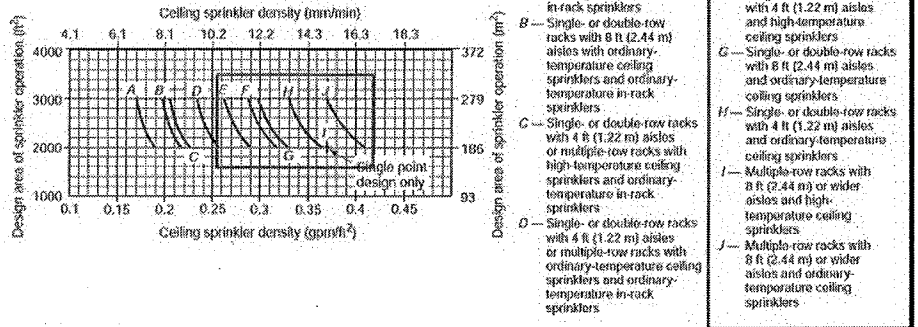
FIGURE 16.2.1.3.2(a) Sprinkler System Design Curves — 20 ft (6.1 m) High Rack Storage — Class I Nonencapsulated Commodities — Conventional Pallets.

Page: 13-151

Module 6: Storage Applications

Presentation	Notes

CMDA Option Without In-racks



Curve	Legend
A	Single- or double-row racks with 8 ft (2.44 m) aisles with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
B	Single- or double-row racks with 8 ft (2.44 m) aisles with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
C	Single- or double-row racks with 4 ft (1.22 m) aisles or multiple-row racks with high-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
D	Single- or double-row racks with 4 ft (1.22 m) aisles or multiple-row racks with ordinary-temperature ceiling sprinklers and ordinary-temperature in-rack sprinklers
E	Single- or double-row racks with 8 ft (2.44 m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 4 ft (1.22 m) aisles and high-temperature ceiling sprinklers
G	Single- or double-row racks with 8 ft (2.44 m) aisles and ordinary-temperature ceiling sprinklers
H	Single- or double-row racks with 4 ft (1.22 m) aisles and ordinary-temperature ceiling sprinklers
I	Multiple-row racks with 8 ft (2.44 m) or wider aisles and high-temperature ceiling sprinklers
J	Multiple-row racks with 8 ft (2.44 m) or wider aisles and ordinary-temperature ceiling sprinklers

FIGURE 16.2.1.3.2(a) Sprinkler System Design Curves — 20 ft (6.1 m) High Rack Storage — Class I Nonencapsulated Commodities — Conventional Pallets.

333

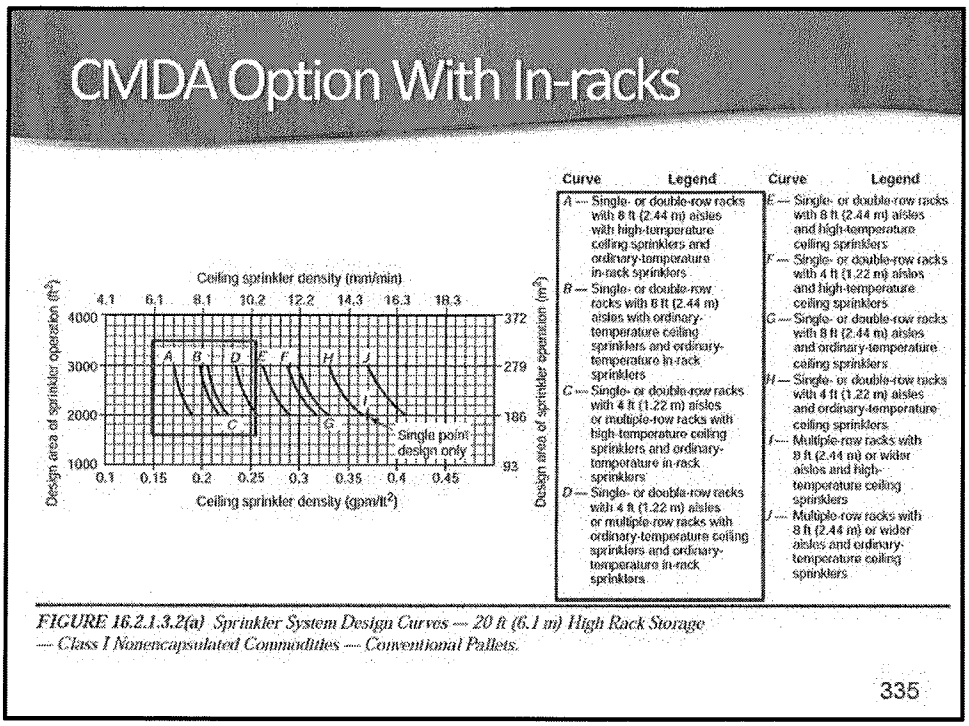
CMDA Option Without In-racks

- Density options dependent upon
  - Temperature rating
  - Aisle width
  - Rack arrangement

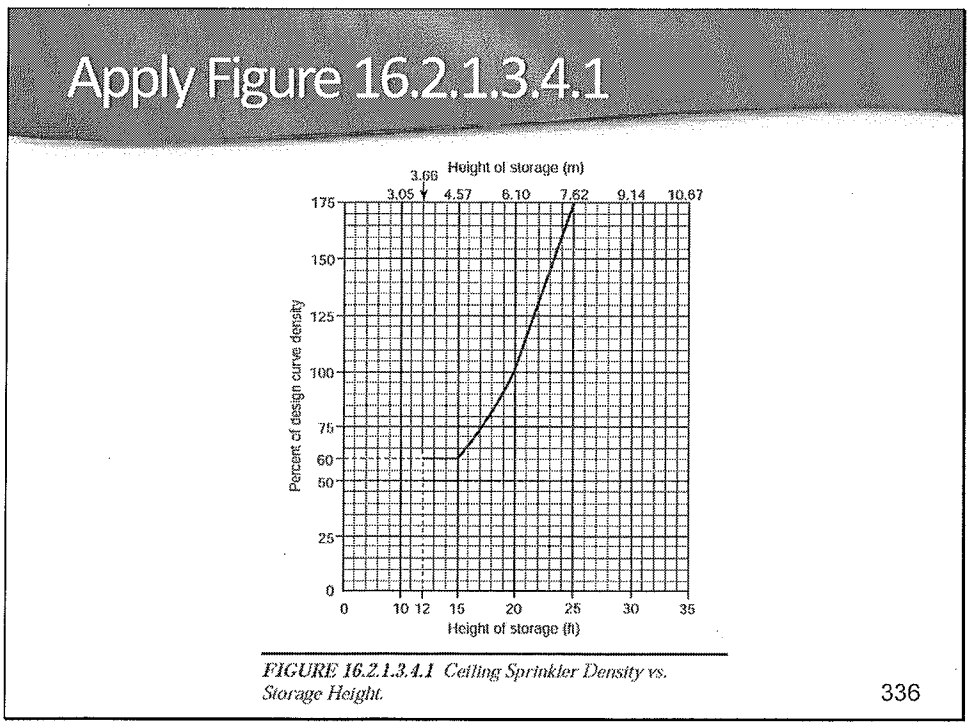
Curve	Legend
E	Single- or double-row racks with 8 ft (2.44 m) aisles and high-temperature ceiling sprinklers
F	Single- or double-row racks with 4 ft (1.22 m) aisles and high-temperature ceiling sprinklers
G	Single- or double-row racks with 8 ft (2.44 m) aisles and ordinary-temperature ceiling sprinklers
H	Single- or double-row racks with 4 ft (1.22 m) aisles and ordinary-temperature ceiling sprinklers
I	Multiple-row racks with 8 ft (2.44 m) or wider aisles and high-temperature ceiling sprinklers
J	Multiple-row racks with 8 ft (2.44 m) or wider aisles and ordinary-temperature ceiling sprinklers

Module 6: Storage Applications

Presentation **Notes**



Page: 13-151



Page: 13-157

Module 6: Storage Applications

Presentation **Notes**

Density Adjustment for In-Racks

TABLE 16.2.1.3.4.3 Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

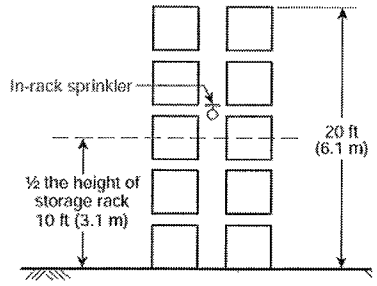
Storage Height	*In-Rack Sprinklers*	*Apply Figure 16.2.1.3.4.1 for Storage Height Adjustment*	*Permitted Ceiling Sprinklers Density Adjustments Where In-Rack Sprinklers Are Installed*
Over 12 ft (3.7 m) through 25 ft (7.6 m)	None	Yes	None
Over 12 ft (3.7 m) through 20 ft (6.1 m)	Minimum required	Yes	None
	More than minimum, but not in every tier	Yes	Reduce density 20% from that of minimum in-rack sprinklers
	In every tier	Yes	Reduce density 40% from that of minimum in-rack sprinklers
Over 20 ft (6.1 m) through 24 ft (7.5 m)	Minimum required	No	None
	More than minimum, but not in every tier	No	Reduce density 20% from that of minimum in-rack sprinklers
	In every tier	No	Reduce density 40% from that of minimum in-rack sprinklers

337

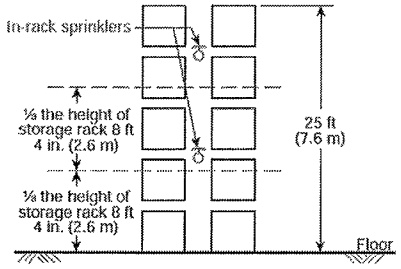
Page: 13-157

CMDA In-Rack Design Requirements for Storage up to 7.6 m

Positioning of One Level of In-Rack Sprinklers



Positioning of Two Levels of In-Rack Sprinklers



338

Page: 13-157 (16.2.1.4.1.4 and 16.2.1.4.1.5)

Module 6: Storage Applications

Presentation | **Notes**

CMDA In-Rack Design Requirements for Storage up to 7.6 m

TABLE 16.2.1.4.2.1 In-Rack Sprinkler Spacing for Class I, II, III, and IV Commodities Stored in Single- or Double-Row Racks Up to 25 ft (7.6 m) in Height Protected by Control Mode Density/Area Sprinklers at the Ceiling

			Commodity Class					
	Aisle Widths		I and II		III		IV	
Encapsulated	ft	m	ft	m	ft	m	ft	m
No	8	2.4	12	3.7	12	3.7	10	3.0
No	4	1.2	12	3.7	10	3.0	10	3.0
Yes	—	—	8	2.4	8	2.4	8	2.4

339

Page: 13-158

CMDA In-Rack Design Requirements for Storage up to 7.6 m

TABLE 16.2.1.4.2.2 In-Rack Sprinkler Spacing for Class I, II, III, and IV Commodities Stored in Multi-Row Racks Up to 25 ft (7.6 m) in Height Protected by Control Mode Density/Area Sprinklers at the Ceiling

Commodity Class							
I, II, III				IV			
Spacing		Area		Spacing		Area	
ft	m	ft²	m²	ft	m	ft²	m²
12	3.7	100	9.3	8	2.4	80	7.4

340

Page: 13-158

Module 6: Storage Applications

Presentation | **Notes**

CMDA In-Rack Discharge Criteria

Commodity	Number of Levels of In-Rack Sprinklers	Numbers of Sprinklers to be Calculated
Class I, II, or III	1	6
Class IV	1	8
Class I, II, or III	2+ levels	10 (5 on each of top 2 levels)
Class IV	2+ levels	14 (7 on each of top 2 levels)

341

Page: 13-158 (16.2.1.4.3.1 and 16.2.1.4.4)

CMSA Design Approaches for Storage ≤ 7.6 m

TABLE 16.2.2.1 CMSA Sprinkler Design Criteria for Rack Storage of Class I Through Class IV Commodities (Encapsulated and Nonencapsulated) Stored Up to and Including 25 ft (7.6 m) in Height

Storage Arrangement	*Commodity Class*	*Maximum Storage Height*		*Maximum Ceiling/Roof Height*		*K-Factor/ Orientation*	*Type of System*	*Number of Design Sprinklers*	*Minimum Operating Pressure*	
		ft	*m*	*ft*	*m*				*psi*	*bar*
Single-, double-, and multiple-row racks without solid shelves (no open-top containers)	Class I or II	20	6.1	30	9.1	11.2 (160) Upright	Wet	15	25	1.7
							Dry	25	25	1.7
						16.8 (240) Upright	Wet	15	10	0.7
							Dry	25	15	1.0
						19.6 (280) Pendent	Wet	15	16	1.1
		25	7.6	30	9.1	11.2 (160) Upright	Wet	20	25	1.7
							Dry	30	25	1.7
						16.8 (240) Upright	Wet	15	10	0.7
							Dry	30	15	1.0
						19.6 (280) Pendent	Wet	15	16	1.1

342

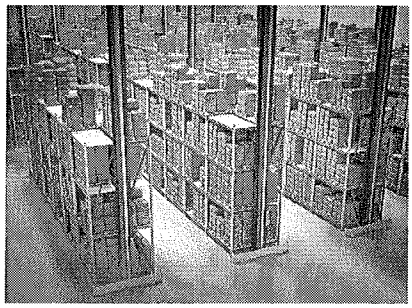
Page: 13-159

Module 6: Storage Applications

Presentation **Notes**

Chapter 16 CMSA Example

- Class I commodity
- Storage 5.5 m
- Double row rack
- Non-encapsulated
- 2.4 m aisles



343

CMSA Design Approaches for Storage ≤ 7.6 m

TABLE 16.2.2.1 CMSA Sprinkler Design Criteria for Rack Storage of Class I Through Class IV Commodities (Encapsulated and Nonencapsulated) Stored Up to and Including 25 ft (7.6 m) in Height

Storage Arrangement	Commodity Class	Maximum Storage Height		Maximum Ceiling/Roof Height		K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure	
		ft	m	ft	m				psi	bar
Single-, double-, and multiple-row racks without solid shelves (no open-top containers)	Class I or II	20	6.1	30	9.1	11.2 (160) Upright	Wet	15	25	1.7
							Dry	25	25	1.7
						16.8 (240) Upright	Wet	15	10	0.7
							Dry	25	15	1.0
						19.6 (280) Pendent	Wet	15	16	1.1
		25	7.6	30	9.1	11.2 (160) Upright	Wet	20	25	1.7
							Dry	30	25	1.7
						16.8 (240) Upright	Wet	15	10	0.7
							Dry	30	15	1.0
						19.6 (280) Pendent	Wet	15	16	1.1

344

Page: 13-159

Module 6: Storage Applications

Presentation	Notes

CMSA Design Approach with Solid Shelves

- Use Table 16.2.2.1 and 16.1.6
- Requires in-racks
  - 152.4 mm clearance from storage
  - At transverse and longitudinal intersection
  - Max spacing 2.4 m
  - 8 sprinkler calculation
  - Minimum 1 bar

345

Page: 13-159 (Table 16.2.2.1)
Page: 13-148 (16.1.6)

ESFR Approaches for Storage ≤ 7.6 m

TABLE 16.2.3.1 ESFR Sprinkler Protection of Rack Storage Without Solid Shelves of Class I Through Class IV Commodities Stored Up to and Including 25 ft (7.6 m) in Height

Storage Arrangement	*Commodity*	*Maximum Storage Height*		*Maximum Ceiling/Roof Height*		*Nominal K-Factor*	*Orientation*	*Minimum Operating Pressure*		*In-Rack Sprinkler Requirements*
		ft	*m*	*ft*	*m*			*psi*	*bar*	
Single-row, double-row, and multiple-row racks (no open-top containers)	Class I, II, III, or IV, encapsulated or unencapsulated	20	6.1	25	7.6	14.0 (200)	Upright/ pendent	50	3.4	No
						16.8 (240)	Upright/ pendent	35	2.4	No
						22.4 (320)	pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No
				30	9.1	14.0 (200)	Upright/ pendent	50	3.4	No
						16.8 (240)	Upright/ pendent	35	2.4	No
						22.4 (320)	Pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No

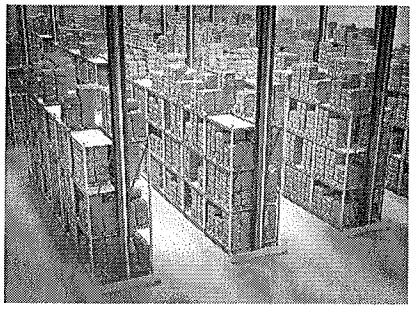
Page: 13-161

Module 6: Storage Applications

Presentation **Notes**

Chapter 16 ESFR Example

- Class I commodity
- Storage 5.5 m
- Double row rack
- Non-encapsulated
- 2.4 m aisles



347

ESFR Approaches for Storage ≤ 7.6 m

TABLE 16.2.3.1 ESFR Sprinkler Protection of Rack Storage Without Solid Shelves of Class I Through Class IV Commodities Stored Up to and Including 25 ft (7.6 m) in Height

Storage Arrangement	Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar	In-Rack Sprinkler Requirements
Single-row, double-row, and multiple-row racks (no open-top containers)	Class I, II, III, or IV, encapsulated or unencapsulated	20	6.1	25	7.6	14.0 (200)	Upright/ pendent	50	3.4	No
						16.8 (240)	Upright/ pendent	35	2.4	No
						22.4 (320)	pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No
				30	9.1	14.0 (200)	Upright/ pendent	50	3.4	No
						16.8 (240)	Upright/ pendent	35	2.4	No
						22.4 (320)	Pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No

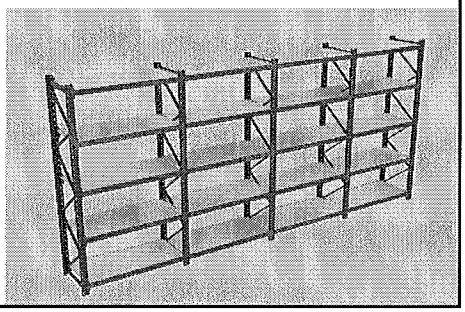
Page: 13-161

Module 6: Storage Applications

Presentation	Notes

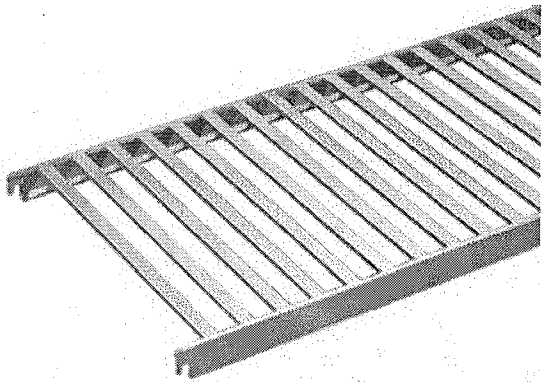
ESFR Design Approach with Solid Shelves

- Use Table 16.2.3.1 and 16.1.6
- Requires in-racks
  - Located at the first tier level at or above one-half of the storage height.
  - K-115 or K-160
  - 152.4 mm clearance
  - 1.5 m max spacing
  - 8 sprinkler calc
  - Minimum 1 bar
  - 227 L/min



Page: 13-161 (16.2.3.1)
Page: 13-148 (16.1.6)
Page: 13-162 (16.2.3.6.6)

ESFR Slatted Shelf Design



350

Page: 13-162 (16.2.4.1.2)

Module 6: Storage Applications

Presentation | **Notes**

CMDA Design Approaches for Storage > 7.6 m

- Determine commodity
- Determine storage height
- Determine rack type (single/double or multiple row)
- Determine clearance to ceiling
- Will require in-racks

351

Page: 13-163 (16.3.1)

CMDA Approach for Single- and Double-Row Racks

TABLE 16.3.1.1 Single- or Double-Row Racks Without Solid Shelves of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height with Aisles 4 ft (1.2 m) or More in Width

Commodity Class	In-Rack Sprinklers Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[a,b,c]		Figure	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance to Ceiling Up to 10 ft (3.1 m)[g]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[d]	Face[e,f]				ft²	m²	gpm/ft²	mm/min	gpm/ft²	mm/min
I	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m) under horizontal barriers	None	16.3.4.1.1.1(a)	30 ft (9.1 m)	No			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)	16.3.4.1.1.1(b)	Higher than 25 ft (7.6 m)	Yes	2000	186	0.25	10.2	0.35	14.3

352

Page: 13-164

Module 6: Storage Applications

Presentation | **Notes**

Chapter 16 CMDA Example

- Class I commodity
- Storage 9.1 m
- Double row rack
- Non-encapsulated
- 2.4 m aisles



353

CMDA Approach for Single- and Double-Row Racks

TABLE 16.3.1.1 Single- or Double-Row Racks Without Solid Shelves of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height with Aisles 4 ft (1.2 m) or More in Width

Commodity Class	In-Rack Sprinklers Approximate Vertical Spacing at Tier Nearest the Vertical Distance and Maximum Horizontal Spacing[b,c]		Figure	Maximum Storage Height	Stagger	Ceiling Sprinkler Operating Area		Ceiling Sprinkler Density Clearance to Ceiling Up to 10 ft (3.1 m)[d]			
								Ordinary Temperature		High Temperature	
	Longitudinal Flue[a]	Face[a,f]				ft²	m²	gpm/ft²	mm/min	gpm/ft²	mm/min
I	Vertical 20 ft (6.1 m) Horizontal 10 ft (3.1 m) under horizontal barriers	None	16.3.4.1.1.1(a)	30 ft (9.1 m)	No			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)	16.3.4.1.1.1(b)	Higher than 25 ft (7.6 m)	Yes	2000	186	0.25	10.2	0.35	14.3

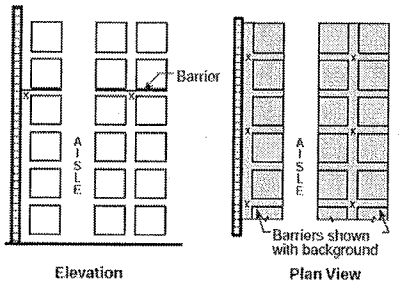
354

Page: 13-164

Module 6: Storage Applications

Presentation | **Notes**

CMDA Approach for Single- and Double-Row Racks



Notes:
1. Symbol x indicates in-rack sprinklers.
2. Each square represents a storage cube measuring 4 ft to 5 ft (1.2 m to 1.5 m) on a side. Actual load heights can vary from approximately 18 in. (0.5 m) up to 10 ft (3.1 m). Therefore, there could be as few as one load or as many as six or seven loads between in-rack sprinklers that are spaced 10 ft (3.1 m) apart vertically.

FIGURE 16.3.1.3.1.1(A)(a) In-Rack Sprinkler Arrangement. Class I Commodities, Storage Height 25 ft to Maximum 30 ft (7.6 m to Maximum 9.1 m).

355

Page: 13-165

CMDA Approach for Multiple-Row Racks

TABLE 16.3.1.2 Multiple-Row Racks of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height

Commodity Class	Encapsulated	In-Rack Sprinklers[a,b,c] Maximum Vertical Spacing ft	m	Maximum Horizontal Spacing in A Flue ft	m	Maximum Horizontal Spacing across Flue ft	m	Height Limit (ft)	Stagger	Figure	Maximum Spacing from Top of Storage to Highest In-Rack Sprinklers ft	m	Ceiling Sprinkler Operating Area ft²	m²	Ceiling Sprinklers Density Clearance to Ceiling Up to 10 ft 165° Rating gpm/ft²	mm/min	286° Rating gpm/ft²	mm/min
I	No	20	6.1	12	3.7	10	3.1	None	Between adjacent flues	16.3.4.1.3.1(a)	10	3.1	2000	186	0.25	10.2	0.35	14.3
	Yes														0.31		0.44	
I, II, and III	No	15	4.6	10	3.1	10	3.1			16.3.4.1.3.1(b)	10	3.1			0.30	12.2	0.40	16.3
	Yes														0.37		0.50	20.4
I, II, III, and IV	No	10	3.1	10	3.1	10	3.1			16.3.4.1.3.1(c)	5	1.5			0.35	14.3	0.45	18.3
	Yes														0.44		0.56	

356

Page: 13-165

Module 6: Storage Applications

Presentation **Notes**

CMSA Design Approaches for Storage > 7.6 m

TABLE 16.3.2.1 CMSA Sprinkler Design Criteria for Rack Storage of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height (Encapsulated and Nonencapsulated)

Storage Arrangement	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure psi	Minimum Operating Pressure bar
Single-, double-, and multiple-row racks without solid shelves (no open-top containers)	Class I or II	30	9.1	35	10.6	11.2 (160) Upright	Wet	20 + 1 level of in-rack	25	1.7
							Dry	30 + 1 level of in-rack	25	1.7
						16.8 (240) Upright	Wet	20 + 1 level of in-rack	15	1.0
							Dry	30 + 1 level of in-rack	15	1.0
						19.6 (280) Pendent	Wet	15	25	1.7
		35	10.6	40	12.1	11.2 (160) Upright	Dry*	36	55	3.8
						16.8 (240) Upright	Dry*	36	22	1.5
						19.6 (280) Pendent	Wet	15	30	2.1

CMSA for Storage > 7.6 m - In-Rack Requirements

- 152.4 mm clearance from storage
- At transverse and longitudinal intersection
- Max spacing 1.5 m
- 8 sprinkler calculations
- Minimum 1 bar

358

Module 6: Storage Applications

Presentation **Notes**

ESFR Sprinklers for Rack Storage of Class I Through Class IV Commodities Stored Over 7.6 m

TABLE 16.3.3.1 ESFR Sprinkler Protection of Rack Storage Without Solid Shelves of Class I Through Class IV Commodities Stored Over 25 ft (7.6 m) in Height

Storage Arrangement	Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar	In-Rack Sprinkler Requirements	Hose Stream Allowance gpm	Hose Stream Allowance L/min	Water Supply Duration (hours)
Single-, double-, and multiple-row rack (no open-top containers)	Class I, II, III, or IV, encapsulated or nonencapsulated	30	9.1	35	10.7	14.0 (200)	Upright/pendent	75	5.2	No			
						16.8 (240)	Upright/pendent	52	3.6	No			
						22.4 (320)	Pendent	35	2.4	No			
						25.2 (360)	Pendent	20	1.4	No			
				40	12.2	14.0 (200)	Pendent	75	5.2	No			
						16.8 (240)	Pendent	52	3.6	No			
						22.4 (320)	Pendent	40	2.8	No			
						25.2 (360)	Pendent	25	1.7	No			

Page: 13-175

ESFR for Storage > 7.6 m - In-Rack Requirements

- 152.4 mm clearance from storage
- At transverse and longitudinal intersection
- Max spacing 1.5 m
- 8 sprinkler calculation at 227 L/min per sprinkler
- Minimum 1 bar

360

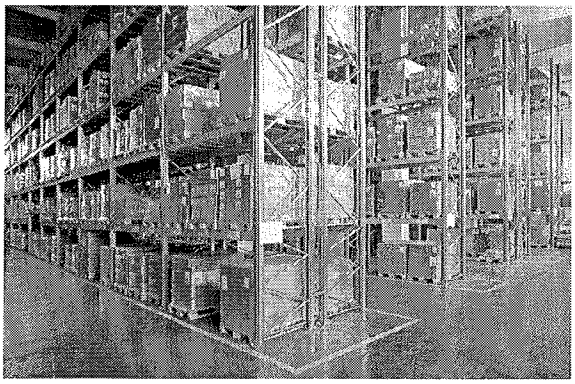
Module 6: Storage Applications

Presentation | **Notes**

Example - 7.6m Class IV Double Rack Storage w/1.2 m Aisle under a 9.1m Ceiling – Wet System

	NFPA 13		
	CMDA K160 or Greater W/ 1 level of In-Rack	CMSA - K280 Pend	ESFR - K360 ESFR
Sprinkler demand Lpm	3578	4405	4432
Hose demand Lpm	1900	1900	946
Total flow Lpm	5503	6305	5379
Duration minutes	120	90	60
Total liters	660,407	570,929	322,709

Chapter 17 – Protection of Rack Storage of Plastic and Rubber Commodities



362

Module 6: Storage Applications

Presentation **Notes**

Chapter 17 - Scope

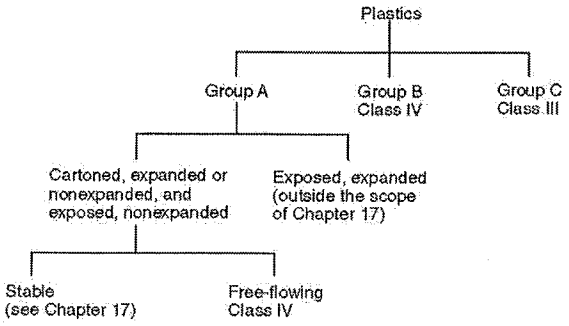


Figure 17.1.2.1 *Decision Tree*

363

Page: 13-176

Chapter 17 -Structural Steel Protection

TABLE 17.1.4.1 Ceiling Sprinkler Densities for Protection of Steel Building Columns

	Aisle Width			
	4 ft (1.2 m)		8 ft (2.4 m)	
Commodity Classification	*gpm/ft²*	*(L/min)/m²*	*gpm/ft²*	*(L/min)/m²*
Plastics	0.68	27.7	0.57	23.2

364

Page: 13-176

Module 6: Storage Applications

Presentation	Notes

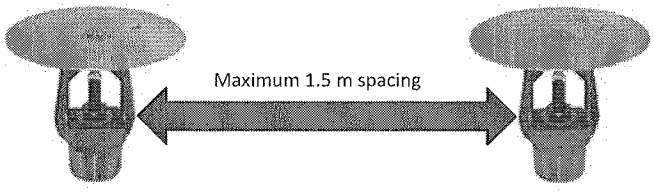
Chapter 17 - Solid Shelving

- 1.86 m^2 < solid shelving ≤ 5.95 m^2
  - Sprinklers at intermediate levels
- Solid shelving > 5.95 m^2
  - Sprinklers at each level
- Solid shelving exceeds 2 m intervals
  - Sprinklers at each level

365

Page: 13-176 (17.1.5.2)

In-Rack Spacing



366

Page: 13-176

Module 6: Storage Applications

Presentation	Notes

Chapter 17 – In-Rack Hydraulics Options

- Add face sprinklers
  - Not added to ceiling
  - 8 sprinklers at 227 L/min
  - Calculate in-racks only
- In-rack and ceiling
  - (1) Eight sprinklers where only one level of in-rack sprinklers is installed
  - (2) Fourteen sprinklers (seven on each of the top two levels) when more than one level of in-rack sprinklers is installed

367

Page: 13-177

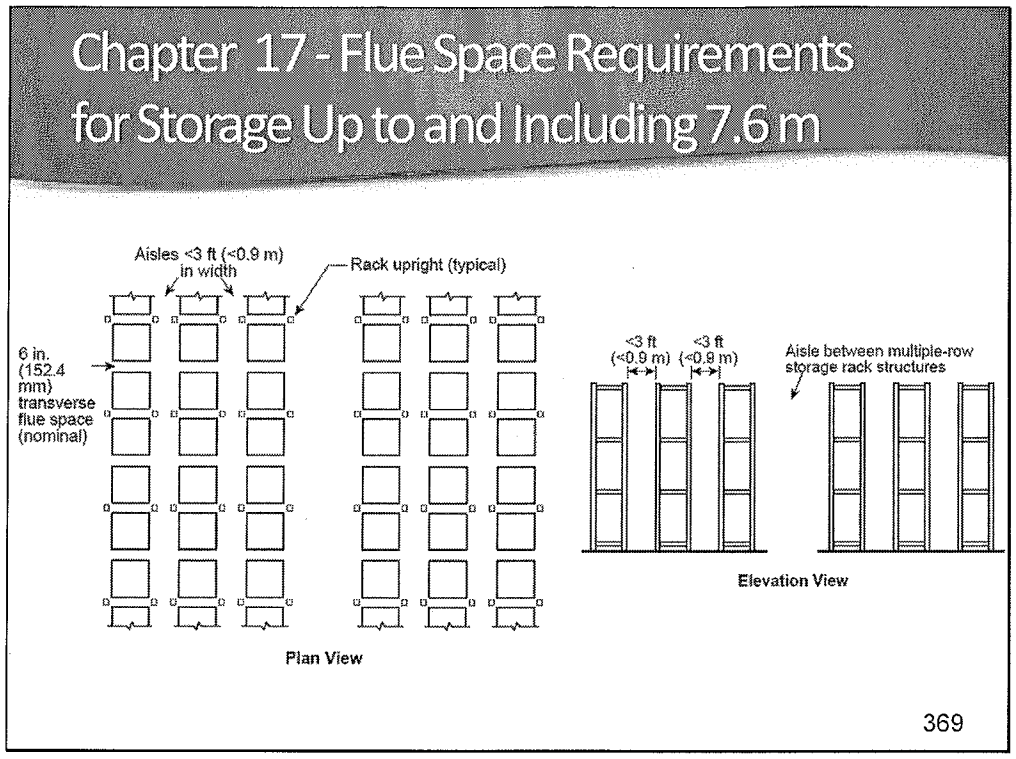
Chapter 17 - Horizontal Barriers

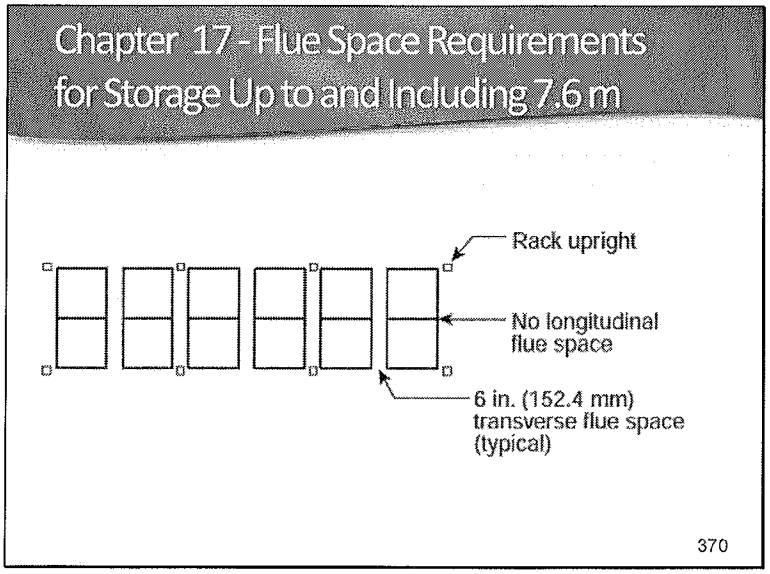
- Sheet metal or wood (or similar material)
- Extend the full length and depth of the rack
- Fitted within 51 mm horizontally around rack uprights

368

Module 6: Storage Applications

Presentation	Notes





Page: 13-177 (17.1.9.1 and 17.1.9.2)

Module 6: Storage Applications

Presentation **Notes**

Chapter 17 - Flue Space Requirements for Storage Over 7.6 m

- Nominal 152.4 mm transverse flue spaces between loads and at rack uprights shall be maintained in single-row, double-row, and multiple-row racks
- Nominal 152.4 mm longitudinal flue spaces shall be provided in double-row racks

371

Chapter 17 Structure

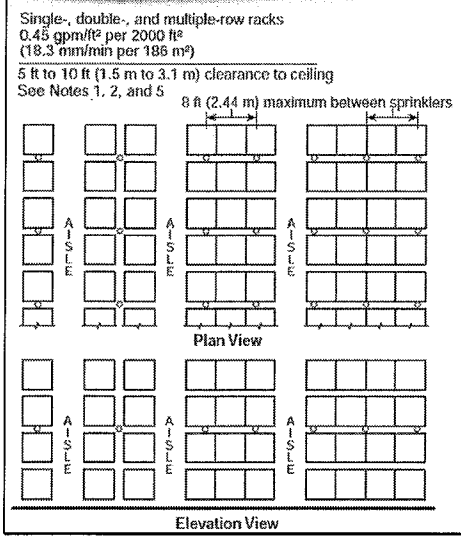
Sprinkler Technology	17.2 Protection Criteria for Rack Storage of Plastic and Rubber Commodities Stored Up to and Including 7.6 m in Height	17.3 Protection Criteria for Rack Storage of Plastic and Rubber Commodities Stored Over 7.6 m in Height
CMDA	17.2.1	17.3.1
CMSA	17.2.2	17.3.2
ESFR	17.2.3	17.3.3

372

Module 6: Storage Applications

Presentation	Notes

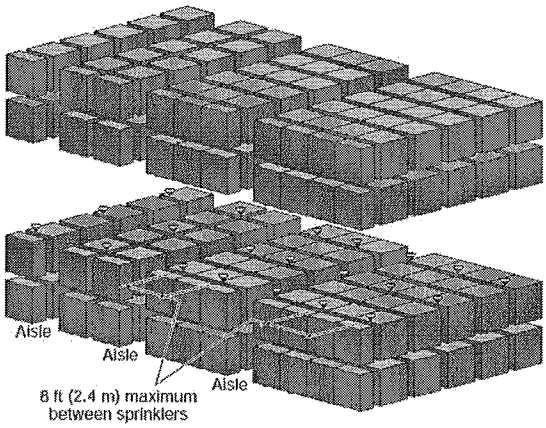
Chapter 17 – CMDA Approach for Storage ≤ 7.6 m



1. Single level of in-rack sprinklers [12.7mm or 13.5mm] operating at 1 bar installed as indicated in the transverse flue spaces.
2. Ceiling-only protection shall not be permitted for this storage configuration except where K-160 or larger orifice spray sprinklers listed for storage use are installed. In-rack sprinklers shall not be required, provided the ceiling sprinkler discharge criterion is increased to 24.5 mm/min over 186 m^2 and the ceiling height in the protected area does not exceed 8.2 m.
5. Each square represents a storage cube measuring 1.2 m to 1.5 m on a side. Actual load heights can vary from approximately 0.5 m up to 3.1 m.

Page: 13-178

Chapter 17 – CMDA Isometric View



Page: 13-178

Module 6: Storage Applications

Presentation	Notes

Chapter 17 – Interpolation Rules

- Linear interpolation of design densities and areas of application shall be permitted between storage heights with the same clearance to ceiling
- No interpolation between clearance to ceiling shall be permitted

375

Chapter 17 – CMDA Exposed Unexpanded Design Criteria for Storage ≤ 7.6 m

New to 2013

- 10 different design options
- May require in-rack
- Based on:
  - Ceiling height
  - Storage height

376

Module 6: Storage Applications

Presentation | **Notes**

Chapter 17 – CMDA In-Rack Requirements for Storage ≤ 7.6 m

- Included in figures
- 152.4 mm clear space required
- Intersection of transverse and longitudinal flues
- Additional sprinklers may be necessary for excessive transverse flue spacing
- Minimum 1 bar (unless noted in figures)
- 8 sprinkler calculation for 1 level of in-racks
- 14 sprinkler calculation for 2+ levels

377

Chapter 17 – CMSA Approach for Storage ≤ 7.6 m

TABLE 17.2.2.1 CMSA Sprinkler Design Criteria for Single-, Double-, and Multiple-Row Racks Without Solid Shelves of Plastics Commodities Stored Up and Including 25 ft (7.6 m) in Height

Storage Arrangement	Commodity Class	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	K-Factor/ Orientation	Type of System	Number of Design Sprinklers	Minimum Operating Pressure psi	Minimum Operating Pressure bar
Single-, double-, and multiple-row racks without solid shelves (no open-top containers)	Cartoned nonexpanded plastics	20	6.1	25	7.6	11.2 (160) Upright	Wet	15	50	3.5
						16.8 (240) Upright	Wet	15	22	1.5
						19.6 (280) Pendent	Wet	15	16	1.1
				30	9.1	11.2 (160) Upright	Wet	30	50	3.5
							Wet	20	75	5.2
						16.8 (240) Upright	Wet	15*	22	1.5
						19.6 (280) Pendent	Wet	15	16	1.1
		25	7.6	30	9.1	11.2 (160) Upright	Wet	15 + 1 level of in-rack	50	3.5
						16.8 (240) Upright	Wet	15*	22	1.5
Single-, double-,						19.6 (280) Pendent	Wet	15	16	1.1

Page: 13-187

Module 6: Storage Applications

Presentation **Notes**

Chapter 17 – CMSA In-Rack Requirements for Storage ≤ 7.6 m

- First tier at or above ½ rack height
- 152.4 mm clear space required
- Intersection of transverse and longitudinal flues
- Additional sprinklers may be necessary for excessive transverse flue spacing
- Minimum 1 bar
- 8 sprinkler calculation

379

Chapter 17 – ESFR Approach for Storage ≤ 7.6 m

TABLE 17.2.3.1 ESFR Protection of Rack Storage Without Solid Shelves of Plastics Commodities Stored Up to and Including 25 ft (7.6 m) in Height

Storage Arrangement	Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/ Roof Height ft	Maximum Ceiling/ Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar	In-Rack Sprinkler Requirement
Single-, double-, and multiple-row racks (no open-top containers)	Cartoned nonexpanded	20	6.1	25	7.6	14.0 (200)	Upright/pendent	50	3.4	No
						16.8 (240)	Upright/pendent	35	2.4	No
						22.4 (320)	Pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No
				30	9.1	14.0 (200)	Upright/pendent	50	3.4	No
						16.8 (240)	Upright/pendent	35	2.4	No
						22.4 (320)	Pendent	25	1.7	No
						25.2 (360)	Pendent	15	1.0	No
				35	10.7	14.0 (200)	Upright/pendent	75	5.2	No
						16.8 (240)	Upright/pendent	52	3.6	No
						22.4 (320)	Pendent	35	2.4	No
						25.2 (360)	Pendent	20	1.4	No

Page: 13-188

Module 6: Storage Applications

Presentation	Notes

Chapter 17 – ESFR Approach for Storage ≤ 7.6 m

- No solid shelving (without in-racks)
- No open top containers
- 12 sprinkler calculation
  - Four sprinklers on 3 branch lines

381

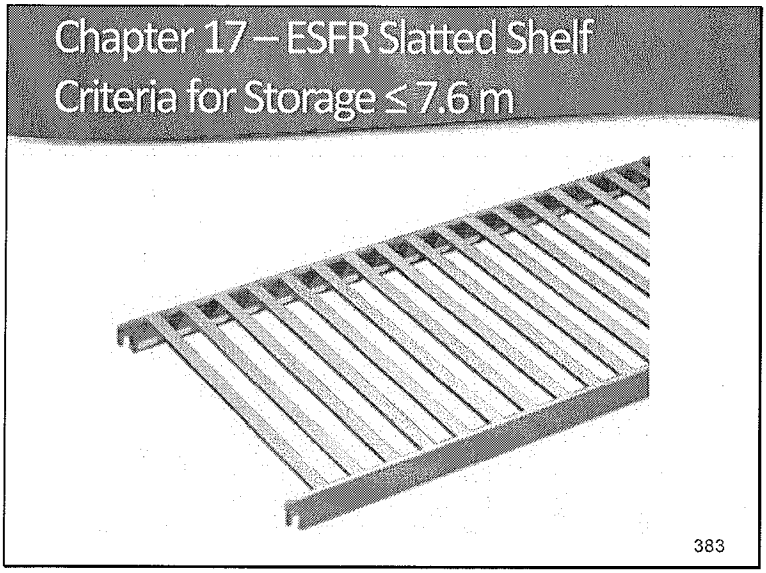
Chapter 17 – ESFR In-Rack Requirements for Storage ≤ 7.6 m

- K-115 or K-160 QR sprinklers
- First tier at or above ½ rack height
- 152.4 mm clear space required
- Intersection of transverse and longitudinal flues
- Additional sprinklers may be necessary for excessive transverse flue spacing
- Simultaneous operation with ceiling
  - 8 sprinklers @ 227 L/min

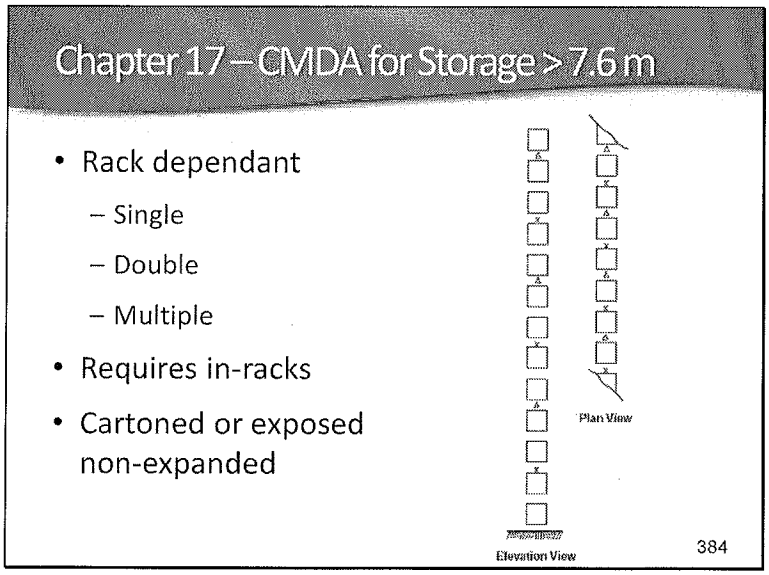
382

Module 6: Storage Applications

Presentation	Notes



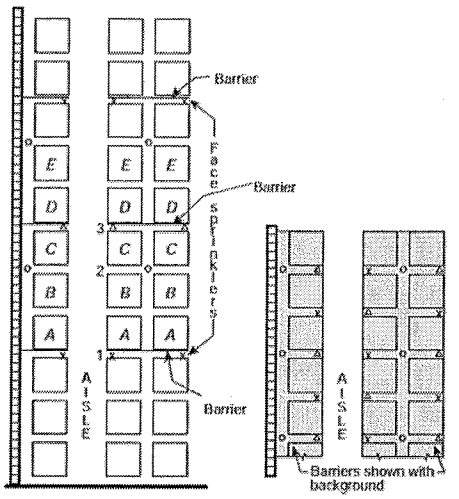
Page: 13-191



Module 6: Storage Applications

Presentation | **Notes**

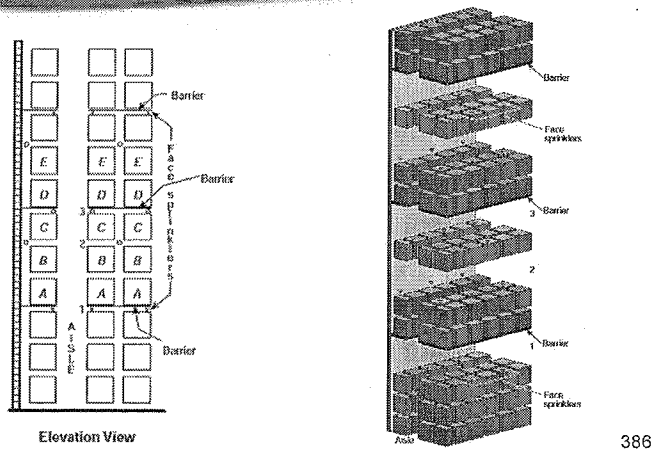
Chapter 17 – CMDA for Storage > 7.6 m



1. Sprinklers and barriers labeled 1 shall be required where loads labeled *A or B represent top of storage.*
2. Sprinklers labeled 1 and 2 and barriers labeled 1 shall be required where loads labeled *C represent top of storage.*
3. Sprinklers and barriers labeled 1 and 3 shall be required where loads labeled *D or E represent top of storage.*
4. For storage higher than represented by loads labeled *E, the cycle* defined by Notes 2 and 3 is repeated.
5. Symbol D or x indicates face sprinklers on vertical or horizontal stagger.
6. Symbol o indicates longitudinal flue space sprinklers.

385

Chapter 17 – Isometric View



386

Module 6: Storage Applications

Presentation **Notes**

Chapter 17 – CMDA In-Rack Requirements for Storage > 7.6 m

- Included in figures
- 152.4 mm clear space required
- Intersection of transverse and longitudinal flues
- Additional sprinklers may be necessary for excessive transverse flue spacing
- Minimum 113.6 L/min
- 8 sprinkler calculation for 1 level of in-racks
- 14 sprinkler calculation for 2+ levels

387

Chapter 17 – CMDA Water Supply Requirements for Storage > 7.6 m

TABLE 17.3.1.15 Hose Stream Allowance and Water Supply Duration Requirements for Rack Storage of Plastics Commodities Stored Over 25 ft (7.6 m) in Height

Commodity Classification	Storage Height		Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	ft	m	gpm	L/min	gpm	L/min	
Plastic	>25	>7.6	0, 50, or 100	0, 190, or 380	500	1900	120

388

Page: 13-198

Module 6: Storage Applications

Presentation **Notes**

CH 17 – CMSA Approach for Storage > 7.6 m

TABLE 17.3.2.1 CMSA Sprinkler Design Criteria for Single-, Double-, and Multiple-Row Racks Without Solid Shelves of Plastics Commodities Stored Over 25 ft (7.6 m) in Height

Storage Arrangement	*Commodity Class*	*Maximum Storage Height*		*Maximum Ceiling/Roof Height*		*K-Factor/ Orientation*	*Type of System*	*Number of Design Sprinklers*	*Minimum Operating Pressure*	
		ft	*m*	*ft*	*m*				*psi*	*bar*
Single-, double-, and multiple-row racks without solid shelves (no open-top containers)	Cartoned, nonexpanded plastics	30	9.1	35	10.6	19.6 (280) Pendent	Wet	15	25	1.7
		35	10.6	40	12.1	19.6 (280) Pendent	Wet	15	30	2.1

389

Page: 13-198

Chapter 17 – CMSA In-Rack Requirements for Storage > 7.6 m

None!!!!!

390

Module 6: Storage Applications

Presentation **Notes**

Chapter 17 – ESFR Approach for Storage > 7.6 m

TABLE 17.3.3.1 ESFR Protection of Rack Storage Without Solid Shelves of Plastics Commodities Stored Over 25 ft (7.6 m) in Height

Storage Arrangement	Commodity	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	Nominal K-Factor	Orientation	Minimum Operating Pressure psi	Minimum Operating Pressure bar	In-Rack Sprinkler Requirements
Single-, double-, and multiple-row racks (no open-top containers)	Cartoned nonexpanded	30	9.1	35	10.7	14.0 (200)	Upright/ pendent	75	5.2	No
						16.8 (240)	Upright/ pendent	52	3.6	No
						22.4 (320)	Pendent	35	2.4	No
						25.2 (360)	Pendent	20	1.4	No
				40	12.2	16.8 (240)	Pendent	52	3.6	No
						22.4 (320)	Pendent	40	2.8	No
						25.2 (360)	Pendent	25	1.7	No
				45	13.7	14.0 (200)	Pendent	90	6.2	Yes
						16.8 (240)	Pendent	63	4.3	Yes
						22.4 (320)	Pendent	40	2.8	No
						25.2 (360)	Pendent	40	2.8	No

Page: 13-199

Chapter 17 – ESFR In-Rack Requirements for Storage ≤ 7.6 m

- K-115 or K-160 QR sprinklers
- First tier at or above ½ rack height
- 152.4 mm clear space required
- Maximum 1.5 m spacing
- Intersection of transverse and longitudinal flues
- Additional sprinklers may be necessary for excessive transverse flue spacing
- Simultaneous operation with ceiling
  - 8 sprinklers @ 227 L/min

392

Module 6: Storage Applications

Activity 6.2

Instructions: Use the information below to determine the sprinkler type, the density, and the area.

Commodity	Height	Type of Storage	Bldg Height	Sprinkler	Density	Area
Class III	7 m	SRR	8.8 m			
Class II	5.4 m	Solid Piled	7.6 m	K80 ~~2 mm/min~~ wood tray	9.2 mm/min (8 mm/min)	300 m² (186 m²)
Class IV	4.8 m	Palletized	6.7 m	K115	15.9 mm/min (11.9 mm/min)	300 m² (186 m²)
Group A Expanded Unstable	5.7 m	Solid Piled Exposed	9.7 m	K160 (Chapt 12)	34.6	
Group B (Class IV)	4.2 m	MRR	6 m			
Group A Unexpanded Stable	2.7 m	Palletized Cartoned	4.8 m	K160	20.4	232 m²
Class I	7.6 m	DRR	8.8 m			
Group C (Class III)	6.7 m	Solid Piled	8.5 m	K115	11.4 mm/min 115% = 13 mm/min	300 m²
Group A Unexpanded	3.9 m	BBS Cartoned	4.8 m		25.3 mm/min	232 m²

Table 15.2.2 (interpolated).

Column C Curve interpolate)

Single Row Rack
Multiple Row Rack
Double Row Rack
Back to Back Shelving

Module 6: Storage Applications

Presentation	Notes

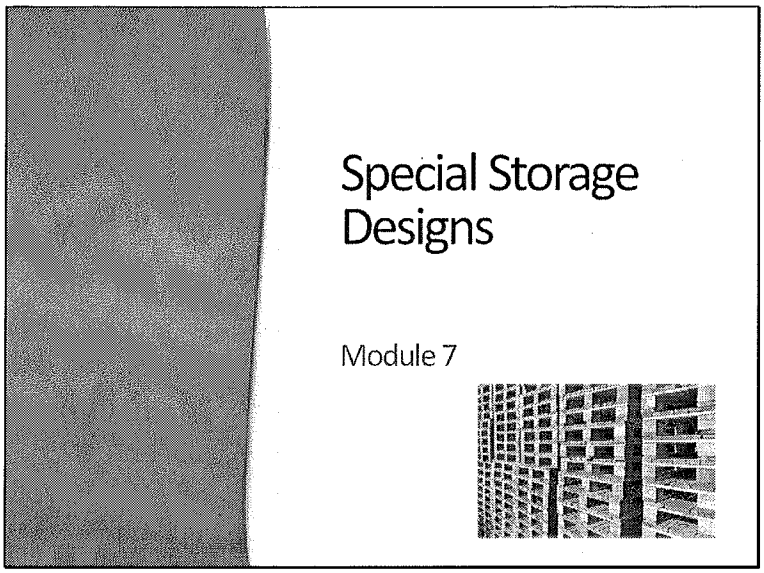
Module 6 Review

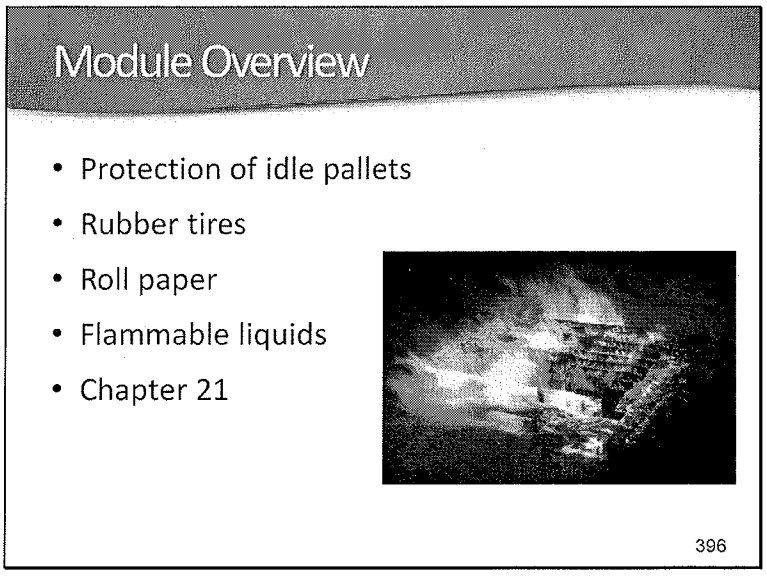
- Find the correct chapter
- Select sprinkler technology
- Understand in-rack rules
- Read the notes with the figures
- Look at modifiers/one-offs/limitations
- Understand hydraulic design requirements

394

Module 7: Special Storage Designs

Presentation	Notes





Module 7: Special Storage Designs

Presentation	Notes

Module 7 Objectives

Upon completion attendees should be able to:

- Identify the design rules for storage hazards not covered in chapters 13-17 of NFPA 13
- Discuss the definitions and storage arrangements associated with tire storage
- Identify design options for roll paper storage
- Locate protection criteria for storage schemes not covered within NFPA 13
- Explain criteria associated with the storage of idle pallets

397

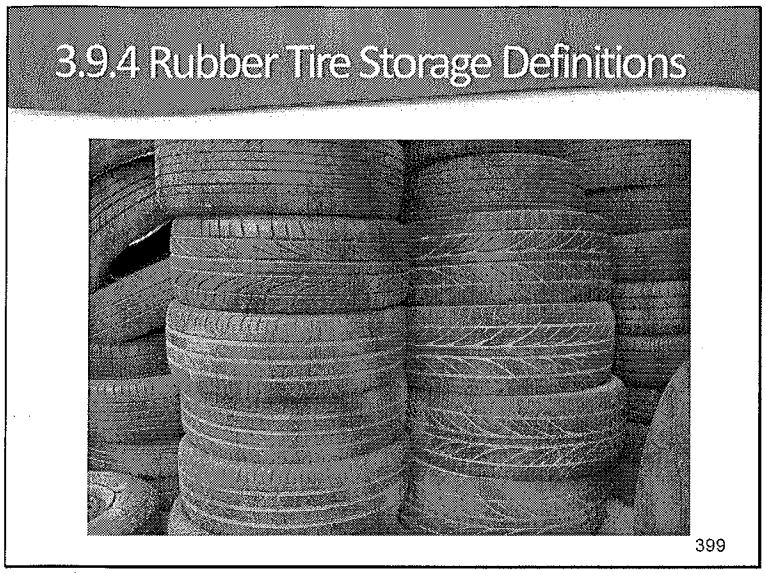
Rubber Tire Storage

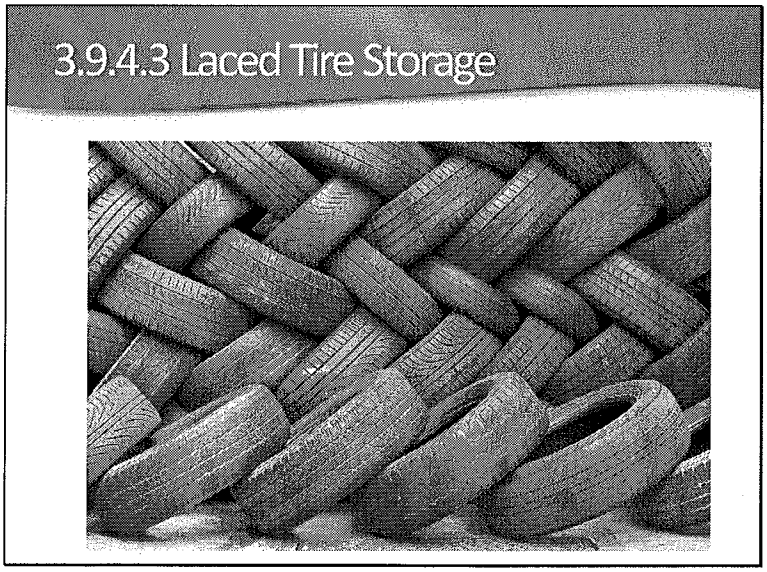
- Not covered by Chapters 15 and 17
- Miscellaneous storage approach
- Arrangement dependent
- Sprinkler technology options
- Column protection required



Module 7: Special Storage Designs

Presentation	Notes



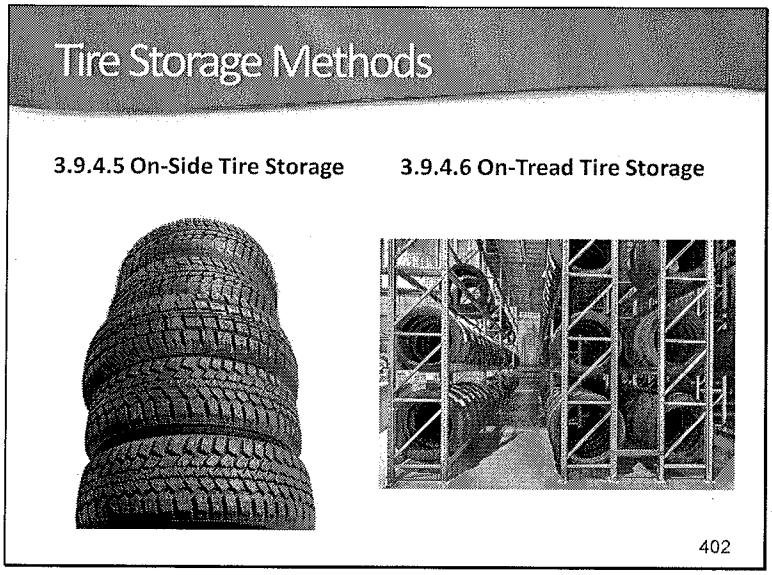


Module 7: Special Storage Designs

Presentation	Notes



Page: 13-23



Page: 13-23

Module 7: Special Storage Designs

Presentation	Notes

3.9.4.7 Palletized Tire Storage

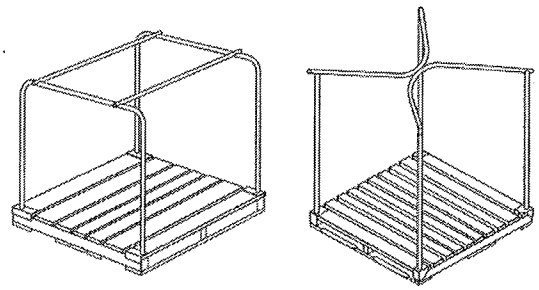


FIGURE A.3.9.4.9(b) Typical Palletized Portable Tire Rack Units.

403

Page: 13-23

3.9.4.8 Pyramid Tire Storage



Page: 13-23

Module 7: Special Storage Designs

Presentation | **Notes**

Portable Tire Racks

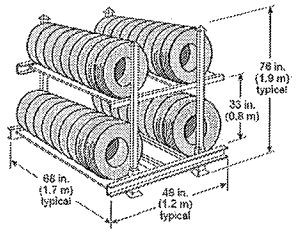


FIGURE A.3.9.4.9(c) Open Portable Tire Rack.

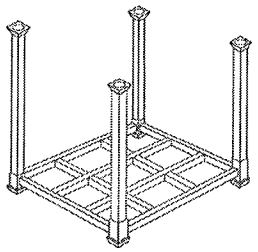


FIGURE A.3.9.4.9(a) Typical Open Portable Tire Rack Unit.

405

Determining Sprinkler Design

- Define arrangement
- Select sprinkler technology
- Use appropriate table
- Calculate hose allowance and water supply

406

Module 7: Special Storage Designs

Presentation **Notes**

Miscellaneous Rubber Tire Storage

TABLE 13.2.1 Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) in Height

Commodity	Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Tires		≤12	to ≤3.7					100	379			
	On floor, on tread, or on side	≤5	≤1.5	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
	Single-, double-, or multiple-row racks on tread or on side	≤5	≤1.5	----	----	OH2		0, 50, 100	0, 189, 379	250	946	90
	Single-row rack, portable, on tread or on side	>5 to ≤12	>1.5 to ≤3.7	32	9.8	EH1		0, 50, 100	0, 189, 379	500	1893	120
	Single-row rack, fixed, on tread or on side	>5 to ≤12	>1.5 to ≤3.7	32	9.8	EH1	0, 50, 100	0, 189,	379	500	1893	120
		>5 to ≤12	>1.5 to ≤3.7	32	9.8	OH2	+1 level of in-rack	0, 50, 100	0, 189, 379	250	946	90

407

Page: 13-133

Chapter 18 – Ceiling System Options

Sprinkler Technology	Chapter 18 Table
CMDA/Standard Spray	18.4(a) and (b)
CMSA	18.4(c)
ESFR	18.4(d)

408

Page: 13-201

Module 7: Special Storage Designs

Presentation	Notes

Chapter 18 – Ceiling System Options Example

- On-tread storage
- Fixed rack double-row rack
- No solid shelving
- No pallets
- 6.1 meters of storage
- 9.1 meter tall building

409

Chapter 18 Example – CMDA Options

Table 18.4(a) Protection Criteria for Rubber Tire Storage Using Control Mode Density/Area Sprinklers

Piling Method	Pile Height (m)	Sprinkler Discharge Density (mm/min over m2) (see Note 1)	Areas of Application (m2) (see Note 1)	
			Ordinary Temperature	High Temperature (see Note 1)
(8) Single-, double-, and multiple-row fixed rack storage without pallets or shelves, on-side or on-tread	Up to 1.5	7.7	186	186
	Over 1.5 to 3.7	24.4	465	279
		16.3 plus one level in-rack sprinklers	279	279
	Over 3.7 to 6.1	24.4 and	Not allowed	465
		36.7 (see Note 3) or	Not allowed	279
		16.3 plus one level in-rack sprinklers or	279	279
		12.2 plus high-expansion foam	279	279
	Over 6.1 to 9.1	12.2 plus high-expansion foam	Not allowed	279

410

Page: 13-20

Module 7: Special Storage Designs

Presentation | **Notes**

Chapter 18 Example – CMSA Options

TABLE 18.4(c) Control Mode Specific Application (CMSA) Protection for Rubber Tires

Piling Method	Maximum Storage Height ft	Maximum Storage Height m	Maximum Ceiling/Roof Height ft	Maximum Ceiling/Roof Height m	K-Factor	Type of System	Number of Sprinklers	Operating Pressure	Hose Stream Allowance	Water Supply Duration (hours)
Rubber tire storage, on-side or on-tread, in palletized portable racks, or open portable racks, or fixed racks without solid shelves	25	7.6	32	9.8	11.2 (160)	Wet	15	75 psi (5.2 bar)	500 gpm (1900 L/min)	3
	25	7.6	32	9.8	16.8 (240)	Wet	15	35 psi (2.4 bar)	500 gpm (1900 L/min)	3

411

Page: 13-203

Chapter 18 Example – ESFR Options

TABLE 18.4(d) Early Suppression Fast-Response (ESFR) Sprinklers for Protection of Rubber Tires (see Note 1)

Piling Method	Pile Height	Maximum Building Height ft	Maximum Building Height m	Nominal K-factor	Orientation	Number of Sprinklers	Minimum Operating Pressure (see Note 2) psi	Minimum Operating Pressure (see Note 2) bar	Duration (hours)	Hose Allowance gpm	Hose Allowance L/min
Rubber tire storage, on-side or on-tread, in palletized portable racks, open portable racks, or fixed racks without solid shelves	Up to 25 ft (7.6 m)	30	9.1	14.0 (200)	Upright/ pendent	12 (see Note 2)	50	3.5	1	250	946
				16.8 (240)	Upright/ pendent	12 (see Note 2)	35	2.4	1	250	946
				22.4 (320)	Pendent	12 (see Note 2)	25	1.7	1	250	946
				25.2 (360)	Pendent	12 (see Note 2)	15	1.0	1	250	946

412

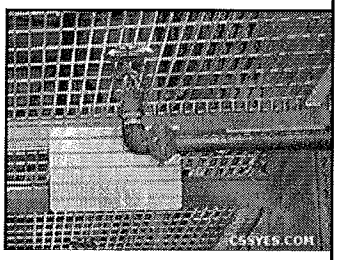
Page: 13-203

Module 7: Special Storage Designs

Presentation	Notes

Chapter 18 – In-Rack Sprinkler Design

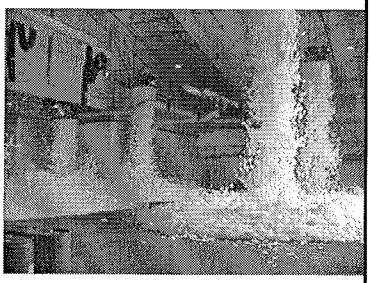
- Use Chapter 17 as a baseline
- Maximum spacing 2.4 m
- Demand considers simultaneous operation with ceiling sprinklers
- Minimum operating pressure of 2.1 bar



413

Chapter 18 – High-Expansion Foam Systems

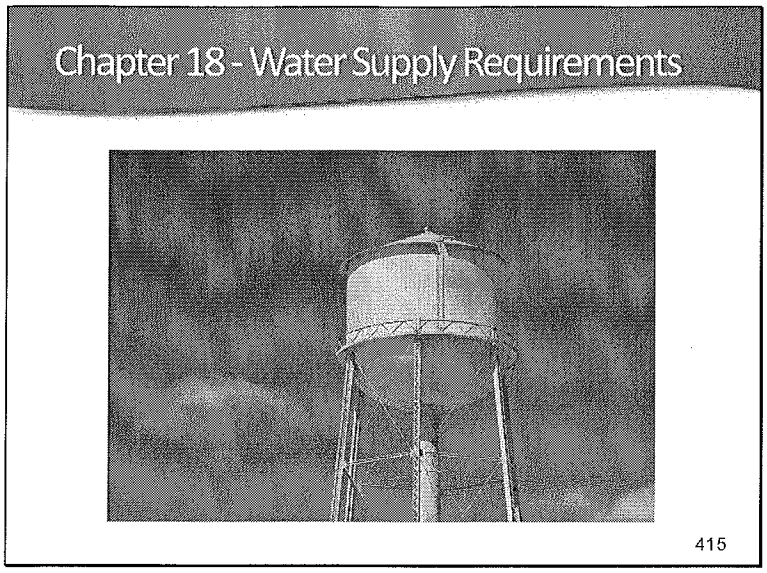
- Ceiling density reduction
- 50% reduction or 9.78 mm/min, whichever is higher
- Doesn't apply where foam is required per Table 18.4(a)



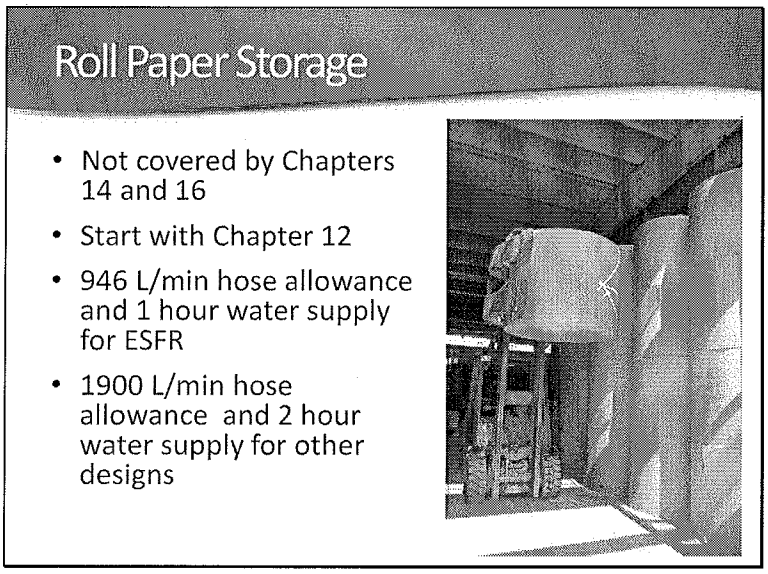
414

Module 7: Special Storage Designs

Presentation	Notes



Page: 13-201 (18.3)

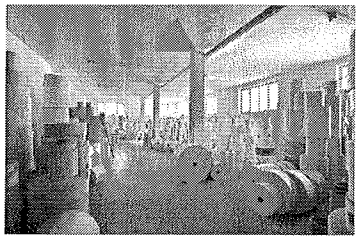


Module 7: Special Storage Designs

Presentation **Notes**

CMDA Design Options

- Heavy- and medium-weight up to 3.1 m use OH-2
- Lightweight up to 3.1 m use EH-1



417

CMDA Design Options

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Table 19.1.2.1.3(b) Control Mode Density/Area Sprinkler Protection Criteria for the Protection of Roll Paper Storage for Buildings or Structures with Roof or Ceilings Up to 9.1 m (Discharge Densities are mm/min over m^2)

Storage Height (m)	Ceiling (m)	Heavyweight					Mediumweight				Tissue All Storage Arrays
		Closed Array Banded or Unbanded	Standard Array		Open Array		Closed Array Banded or Unbanded	Standard Array		Open Array Banded or Unbanded	
			Banded	Unbanded	Banded	Unbanded		Banded	Unbanded		
3.1	≤1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	18.8/185.8
3.1	>1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	12.2/185.8	18.8/252.5
4.6	≤1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/252.5	12.2/278.7	12.2/185.8	12.2/185.8	18.8/252.5	18.8/252.5	24.5/185.8
4.6	>1.5	12.2/185.8	12.2/185.8	12.2/185.8	12.2/278.7	12.2/522.2	12.2/185.8	12.2/252.5	18.8/278.7	18.8/278.7	24.5/278.7
6.1	≤1.5	12.2/185.8	12.2/185.8	12.2/252.5	18.8/278.7	18.8/325.2	12.2/185.8	18.8/252.5	24.5/252.5	24.5/252.5	30.6/252.5
6.1	>1.5	12.2/185.8	12.2/252.5	12.2/278.7	18.8/325.2	18.8/371.6	12.2/252.5	18.8/278.7	24.5/278.7	24.5/278.7	30.6/278.7
7.6	≤1.5	18.8/252.5	18.8/278.7	18.8/325.2	24.5/252.5	24.5/278.7	18.8/278.7	24.5/278.7	30.6/252.5	30.6/252.5	*see Note 1*

Notes:
(1) Sprinkler protection requirements for tissue stored above 6.1 m have not been determined.
(2) Densities or areas, or both, shall be permitted to be interpolated between any 1.5 m storage height increment.

418

Page: 13-204

Module 7: Special Storage Designs

Presentation | **Notes**

CMDA Design Options

High-temperature heads where storage exceeds 4.6 m



419

CMSA Design Options

TABLE 19.1.2.2 CMSA Sprinklers for Protection of Roll Paper Storage [Number of Sprinklers at Operating Pressure, psi (bar)]

Storage Height		Maximum Building Height		Nominal K-Factor	Type of System	Heavyweight					Mediumweight					Tissue All Storage Arrays
						Closed Array	Standard Array		Open Array		Closed Array	Standard Array		Open Array		
ft	m	ft	m			Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	Banded or Unbanded	Banded	Unbanded	Banded	Unbanded	
20	6.1	30	9.1	11.2 (160)	Wet	15 at 50(3.4)	15 at 50(3.4)	15 at 50(3.4)	15 at 50(3.4)	NA	15 at 50(3.4)	15 at 50(3.4)	15 at 50(3.4)	NA	NA	See Note
20	6.1	30	9.1	11.2 (160)	Dry	25 at 50(3.4)	25 at 50(3.4)	25 at 50(3.4)	NA	NA	25 at 50(3.4)	25 at 50(3.4)	25 at 50(3.4)	NA	NA	NA
26	7.9	60	18.3	11.2 (160)	Wet	15 at 50(3.4)	15 at 50(3.4)	15 at 50(3.4)	15 at 50(3.4)	NA	NA	NA	NA	NA	NA	NA
20	6.1	30	9.1	16.8 (240)	Wet	15 at 22(1.5)	15 at 22(1.5)	15 at 22(1.5)	15 at 22(1.5)	NA	15 at 22(1.5)	15 at 22(1.5)	15 at 22(1.5)	NA	NA	See Note
20	6.1	30	9.1	16.8 (240)	Dry	25 at 22(1.5)	25 at 22(1.5)	25 at 22(1.5)	NA	NA	25 at 22(1.5)	25 at 22(1.5)	25 at 22(1.5)	NA	NA	NA
26	7.9	60	18.3	16.8 (240)	Wet	15 at 22(1.5)	15 at 22(1.5)	15 at 22(1.5)	15 at 22(1.5)	NA	NA	NA	NA	NA	NA	NA

420

Page: 13-205

Module 7: Special Storage Designs

Presentation **Notes**

ESFR Design Options

TABLE 19.1.2.3 ESFR Sprinklers for Protection of Roll Paper Storage (Maximum Height of Storage Permitted)

ESFR K-Factor	Orientation	System Type	Pressure		Building Height		Heavyweight						Mediumweight						Tissue All Arrays
							Closed		Standard		Open		Closed		Standard		Open		
			psi	bar	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	
14.0 (201)	Upright/ pendent	Wet	50	3.4	30	9.1	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	25	7.6	NA
16.8 (242)	Upright/ pendent	Wet	35	2.4															
22.4 (322)	Pendent	Wet	25	1.7															
25.2 (363)	Pendent	Wet	15	1.0															
14.0 (201)	Upright/ pendent	Wet	75	5.2	35	10.7	30	9.1	30	9.1	30	9.1	NA		NA		NA		NA
16.8 (242)	Upright/ pendent	Wet	52	3.6															
14.0 (201)	Pendent	Wet	75	5.2	40	12.2	30	9.1	30	9.1	30	9.1	NA		NA		NA		NA
16.8 (242)	Pendent	Wet	52	3.6															
22.4 (322)	Pendent	Wet	40	2.8															
25.2 (363)	Pendent	Wet	25	1.7															
22.4 (322)	Pendent	Wet	50	3.4	45	13.7	30	9.1	30	9.1	30	9.1	NA		NA		NA		NA
25.2 (363)	Pendent	Wet	50	3.4															

Page: 13-206

Flammable Liquids Storage

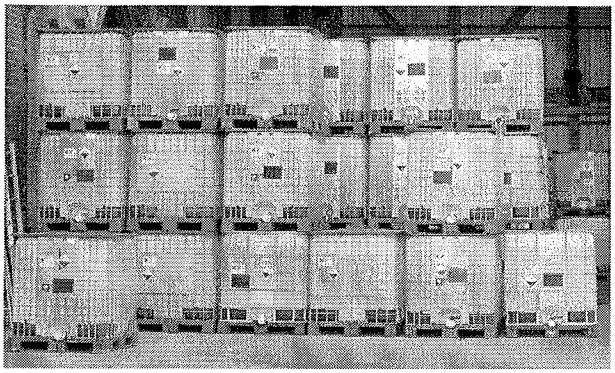


422

Module 7: Special Storage Designs

Presentation | **Notes**

Flammable Liquids – IBCs



423

NFPA 30 – IBCs Sprinkler Requirements

Container Style and Capacity (L)	Maximum Storage Height (m)	Maximum Ceiling Height (m)	Ceiling Sprinkler Protection: Sprinkler Type	Ceiling Sprinkler Protection: Sprinkler Response	Ceiling Sprinkler Protection: Design Density (mm/min)	Ceiling Sprinkler Protection: Design Area (M2)	In-Rack Sprinkler Protection: Sprinkler Type	In-Rack Sprinkler Protection: Sprinkler Response	In-Rack Sprinkler Protection: Discharge Flow (L/min)	In-Rack Sprinkler Protection: Layout	Notes	Fire Test Ref. (See Table D.2(a))
Relieving-Style Containers - Liquid Classes IB, IC, II, IIIA												
≤19	4.3	5.5	K≥160 pendent only	QR (HT)	26.5	186	No in-rack sprinklers required				4	7
	7.6	9.1	K≥115	SR or QR (HT)	12.2	279	K=80 or 115	QR (OT)	113.5	D	1,5	8
>19 and ≤227	7.6	9.1	K≥160	SR (HT)	24.4	279	K=80 or 115	QR (OT)	113.5	F	1	10
Portable tanks and IBCs	7.6	9.1	K≥160	SR (HT)	24.4	279	K=80 or 115	QR or SR (OT)	113.5	E	1	12

This table was converted to metric from table 16.5.2.1 in NFPA 30. It does not exist in metric form outside of this seminar

424

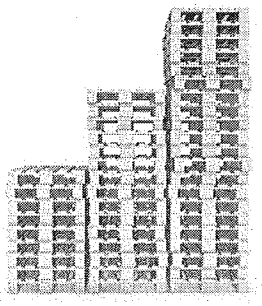
Table 16.5.2.1 from NFPA 30

Module 7: Special Storage Designs

Presentation **Notes**

Idle Pallets

- Idle Wood Pallet Storage
  - Table 12.12.1.2(a) CMDA limited to 6.1 m storage height and a maximum 9.1 m ceiling height
  - Table 12.12.1.2(b) CMSA limited to 6.1 m storage height and a maximum 12.1 m ceiling height
  - Table 12.12.1.2(c) ESFR limited to 6.1 m storage height and a maximum 12.1 m ceiling height
- Idle Plastic Pallet Storage
  - CMDA and CMSA limited to 1.2 m storage height when K-factor < 240
  - CMDA limited to 3 m storage height and a maximum 9.1 m ceiling height
  - Table 12.12.2.1 ESFR limited to 10.7 m storage height and a maximum 12.1 m ceiling height



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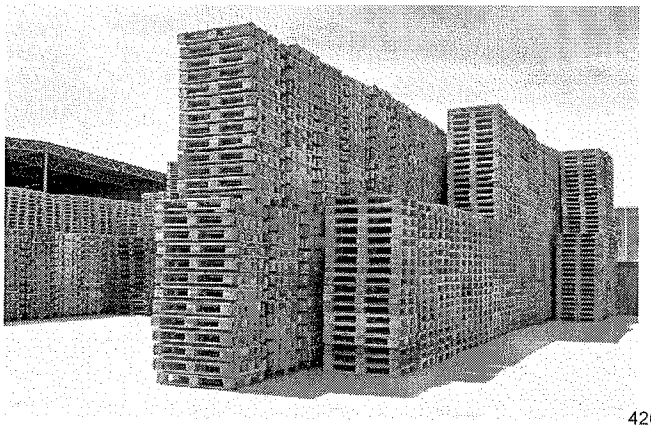
Other Options



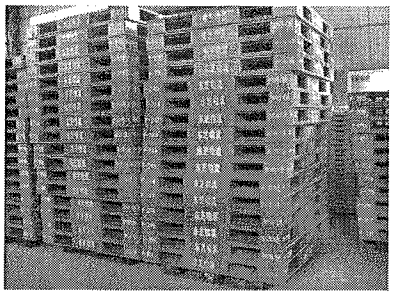
426

outdoor!

Module 7: Special Storage Designs

Presentation	Notes

Idle Plastic Pallets



- Outdoors
- Cut-off rooms
- Limitations on height

427

Page: 13-132 (12.12.2.2.4.2 and 12.12.2.2.4.3)

Idle Plastic Pallets – ESFR Scheme

TABLE 12.12.2.2.3 ESFR Sprinkler Protection for Indoor Storage of Idle Plastic Pallets

Type of Sprinkler (Orientation)	*Location of Storage*	*Nominal K-Factor*	*Maximum Storage Height*		*Maximum Ceiling/Roof Height*		*Minimum Operating Pressure*	
			ft	*m*	*ft*	*m*	*psi*	*bar*
ESFR (pendent)	On floor or rack without solid shelves	14.0 (200)	25	7.6	30	9.1	50	3.4
			25	7.6	32	9.8	60	4.1
		16.8 (240)	25	7.6	30	9.1	35	2.4
			25	7.6	32	9.8	42	2.9
			35	10.7	40	12.2	52	3.6

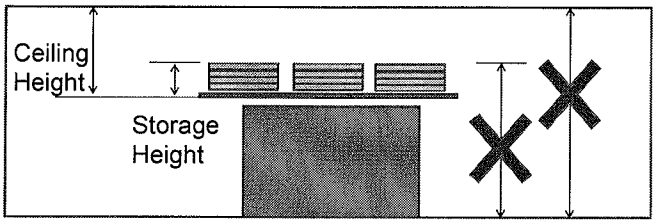
428

Page: 13-132

Module 7: Special Storage Designs

Presentation **Notes**

Pallet Storage Above Doors



429

Chapter 21—Alternative Sprinkler System Designs for Chapters 12 Through 20

TABLE A.21.2 Typical Example of 25 ft (7.6 m) Palletized Storage Under 30 ft (9.1 m) Ceiling Full-Scale Fire Test Series on Simulated Wet-Type Sprinkler System (considers ADD results)

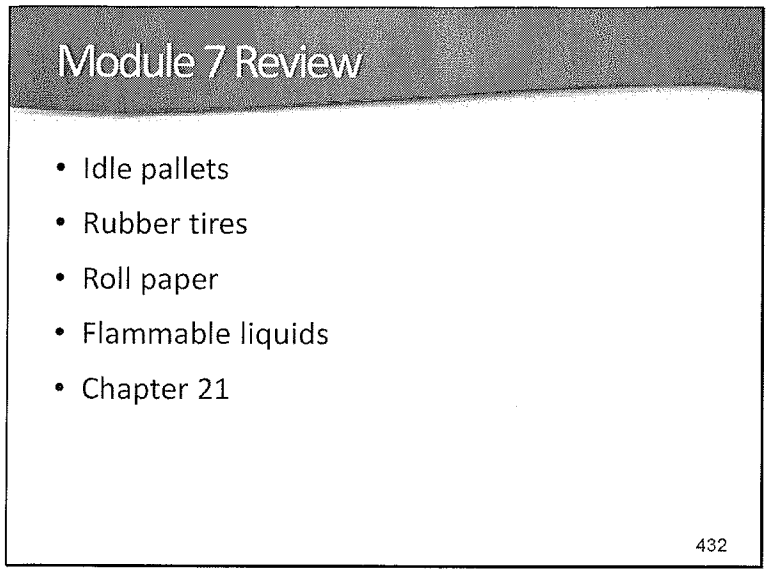
Parameter	*Test 1*	*Test 2*	*Test 3*	*Test 4*
Storage type	Palletized	Palletized	Palletized	Palletized
Nominal storage height, ft (m)	20 (6.1)	25 (7.6)	20 (6.1)	20 (6.1)
Nominal ceiling height, ft (m)	30 (9.1)	Adjusted to achieve minimum sprinkler deflector to commodity clearance	30 (9.1)	30 (9.1)
Sprinkler temperature rating	Minimum temperature rating	Maximum temperature rating	Minimum temperature rating	Minimum temperature rating
Nominal deflector to ceiling distance, in (cm)	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer	Maximum specified by manufacturer
Sprinkler spacing, 20 ft (6.1 m)	Maximum permitted by NFPA 13	Maximum permitted by NFPA 13	Minimum permitted by NFPA 13	Maximum permitted by NFPA 13
Nominal discharge pressure, psig (kPa)	Minimum operating	Minimum operating	Minimum operating	Minimum operating
Ignition location	Under one	Between two on same branch line or between four	Under one	Between two on same branch line or Between four
Test duration, minutes	30	30	30	30

430

Page: 13-367

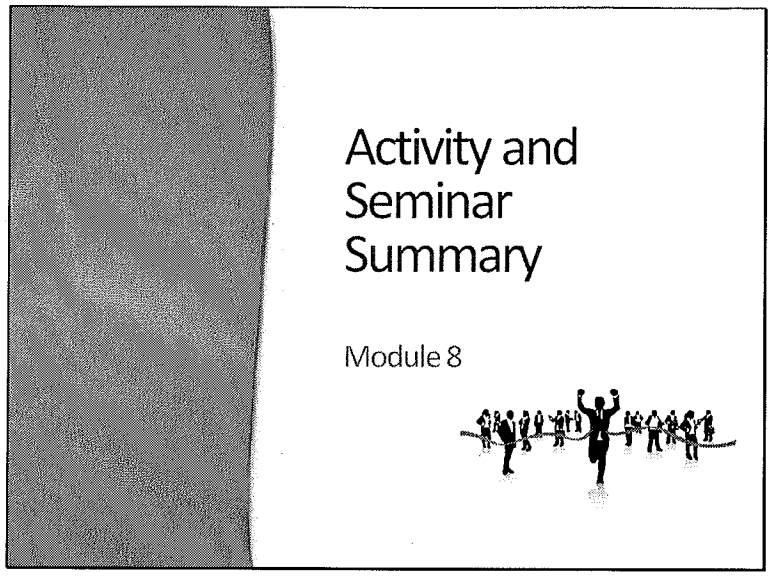
Module 7: Special Storage Designs

Presentation	Notes



Module 8: Activity and Seminar Summary

Presentation	Notes



Module 8: Activity

Activity 8.1

Instructions: Working in groups, use the given criteria to find the required information, then answer additional questions.

Group A

Criteria:

- 7.6 m building height
- Plastic buckets (face down)
- Wood pallets
- Encapsulated
- High-temperature sprinklers
- 6.1 m of storage
- Stored in racks
  - Double row
  - 2.4 m aisle

Find the following:

1. CMDA ceiling density
2. In-rack design criteria
3. Hose demand
4. Water supply duration

Module 8: Activity

Additional questions:

1. What if the rack has all solid shelves, how does the in-rack design change?

Required at every level

2. What would be an allowable ESFR design approach?

ESFR w/o in-rack

3. What if I had solid shelves with ESFRs?

In-rack required

Not allowed

4. What if it was ESFR with 1.2 m aisles and no solid shelves?

ESFR not typically w/ aisle width

5. What is the most effective design approach if the buckets are facing up and are banded (not encapsulated)?

Could use ESFR

Module 8: Activity

Group B

Criteria:

- 6.1 m building height
- Cartoned books
- Wood pallets
- 4.6 m of storage
- Solid piled

Find the following:

1. CMDA ceiling density

2. Hose demand

3. Water supply duration

Module 8: Activity

Additional questions:

1. What if the storage height was 3.6 m?

2. What if the pallets were made of reinforced plastic?

3. What if the cartons were encapsulated?

4. What if the books were replaced by synthetic stuffed toys?

Module 8: Activity

Group C

Criteria:

- 12.2 m building height
- Cartoned butane lighters
- Wood pallets
- 9.1 m of storage
- In-racks

Find the following:

1. CMDA design approach

2. Hose demand

3. Water supply duration

Module 8: Activity

Additional questions:

1. What would be an allowable ESFR design approach?

2. Which approach, ESFR or CMDA, is more efficient if a storage tank is used?

3. Can CMSA sprinklers be used?

4. What if the commodity was changed to Styrofoam meat trays?

5. What if the butane lighters are in large containers or PODs?

Module 8: Activity and Seminar Summary

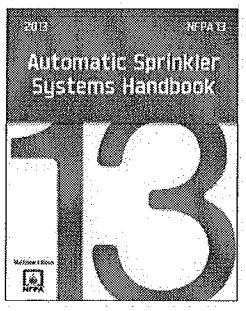
Presentation	Notes

Module Overview

- Questions?
- Process and workflow summary

435

Resources



- Document Information Pages
  - nfpa.org/aboutthecodes
- Handbook
- Technical Questions (member benefit)
  - 800-344-3555
  - nfpa.org/aboutthecodes

436

Module 2: Commodity and Packaging Classification

Activity 2.1 – Solution

Instructions: Working in groups, determine the commodity classification, storage arrangement, and the referenced chapter in NFPA 13 for the given examples.

Example 1: Wooden desks with an appreciable amount of plastic parts stacked a maximum of 5 desks high.

1. What is the commodity classification?

   Class IV (appreciable amount of plastic)

2. What is the storage arrangement?

   Solid Pile

3. In what chapter of NFPA 13 would the rules be found?

   Chapter 14

Example 2: A three story office building with a 111.5 m^2 storage area located on the first floor. The storage area will have supplies of paper products and cleaning supplies on 2.4 m high shelves.

1. What is the commodity classification?

   Group A plastics (cleaning supplies)

2. What is the storage arrangement?

   Miscellaneous Storage

3. In what chapter of NFPA 13 would the rules be found?

   Chapter 13

Module 2: Commodity and Packaging Classification

Example 3: Cartoned empty glass wine bottles stored on racks 4.3 meters high.

1. What is the commodity classification?

   Class I

2. What is the storage arrangement?

   Rack Storage

3. In what chapter of NFPA 13 would the rules be found?

   Chapter 16

Example 4: Small plastic bottles of nail polish in cartons stored on 5.5 meter high racks.

1. What is the commodity classification?

   Group A plastic

2. What is the storage arrangement?

   Rack Storage

3. In what chapter of NFPA 13 would the rules be found?

   Chapter 17

Example 5: Pallets of cartoned carpet tiles stacked a maximum of 3 pallets high.

1. What is the commodity classification?

   Group A plastics

2. What is the storage arrangement?

   Palletized Storage (4.6 meters high)

3. In what chapter of NFPA 13 would the rules be found?

   Chapter 15

Module 4: Storage Sprinkler Technology

Activity 4.1 – Solution

Instructions: Answer the following questions on ESFR sprinkler design.

1. Using the shift rule from 8.12.2.2.3 in NFPA 13, illustrate the modified spacing for a (3 m x 3 m) ESFR sprinkler where bar joists are installed at intervals of 1.8 m (o.c.).

2. How far must an ESFR sprinkler be located from a 610 mm x 610 mm column?

3. How high above a .9 m wide fluorescent light must an ESFR sprinkler be if the horizontal distance between the light and the sprinkler is 482.6 mm?

Module 5: System Design

Activity 5.1 – Solution

Instructions: Using the given scenario, determine the minimum density/area required for a rack storage area and a piled storage area.

Scenario: You've been contacted by a distributer of Sporting Goods equipment who is building a new warehouse facility 6,039 m^2 in area, plus a 372 m^2 office area. The warehouse is 9.1 m high with a 2 in 12 roof slope.

They plan to store a variety of goods in boxes, on wood pallets, non-encapsulated. 3,252 m^2 of the north side of the building will include single- and double-row pallet racks with 2.4 m aisles. The maximum storage height will be 6.7 m. The south side of the warehouse will include storage on the floor, palletized 5.5 m high maximum. The products are a combination of commodity classifications with the highest determined to be Class IV. High temperature K 160 sprinklers are used throughout.

Using CMDA sprinklers at the roof and no in-rack sprinklers, determine the minimum density/area required for each area.

Rack Storage Area

20.1 L/min/186 m^2 (starting) minimum density/area

Information used to get to this answer:

Table 16.2.1.3.2 (page 150) sends us to 16.2.1.3.2(d) Curve E for 20 ft high storage

Figure 16.2.1.3.4.1 applies: 130% of the density - 20.1 X 26.1 L/min/186 m^2 (adjusted)

Hose Allowance (Table 12.8.6.1): 1900 gallons

Duration: 90 minutes

Total Water Demand: 26.1 x 186 = 4854.6 L + 1900 L = 6754.6 L/min x 90 min = 607,914 Liters

Module 5: System Design

Piled Storage Area:

12 L/min/ 186 m^2 (starting) minimum density/area (Figure 14.2.4.2)

Information used to get to this answer:

Figure 14.2.4.3: allows 90% of the density (12 x .9 = 10.8 L/min/186 m^2 adjusted density/area)

Hose Allowance: 1900 L/min

Duration: 90 minutes

Total Water Demand: 10.8 L/min x 186 = 2008.8 L + 1900 L = 3,908.8 L x 90 min = 351792 Liters

Additional Questions

1. What options do we have to separate the two areas?

2. Where would a draft curtain be placed relative to the two storage areas if this was the option used to separate the two areas?

Module 6: Storage Applications

Activity 6.1 Solution

Instructions: Answer the questions for each scenario given.

Scenario 1: A distributor of flooring products is storing 305 mm x 305 mm vinyl floor tiles stacked in cardboard boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 7.9 meters above the floor. The building deck is 9.7 meters above the floor. The contractor installing the sprinkler system is going to use high-temperature, standard spray upright sprinklers at the ceiling

a. What is the commodity?
Class IV A.5.6.3 pg 13-271

b. How is it stored?
Palletized

c. How high?
7.9M

d. What is the correct figure and density/area to use?
Figure 14.2.4.2 pg13-136 12mm/min @ 186M^2

e. Do any adjustments need to be made?
Yes. Figure 14.2.4.3 pg13-136 149.5%

f. What is the final density/area?
17.9mm/min @ 186M^2

g. What is the acceptable K-factor?
160 or larger

Module 6: Storage Applications

Scenario 2: A bakery is storing hamburger and hot dog buns in plastic bags in paperboard cartons on cardboard trays. The packages are stored in the back of the store on 660.4 mm deep metal shelves. The top of the storage is 4.2 meters above the floor. The ceiling is 5.1 meters above the floor. The designer of the sprinkler system needs to know the correct density and area to use if they chose K-160 sprinklers.

a. What is the commodity?
Class III **A.5.6.3** **pg13-268**

b. How is it stored?
Shelf **3.9.2.6** **pg13-22**

c. How high?
4.2M

d. What is the correct figure and density/area to use?
11.6mm/min @ 186M^2

e. Do any adjustments need to be made?
Yes **14.2.4.3** **pg13-136**

68% of density used

f. What is the final density/area?
7.9mm/min @186M^2

Module 6: Storage Applications

Scenario 3: Metal junction boxes for electrical installations are being stored in cardboard boxes. The boxes are placed directly on top of one another until they reach a height of 4.8 meters above the floor. The roof deck is 6.1 meters above the floor.

a. What is the commodity?
Class I **5.6.3.1** **pg13-26**

b. How is it stored?
Solid Pile **3.9.2.7** **pg13-22**

c. How high?
4.8M

d. What is the correct figure and density/area to use?
6.2mm/min @ 186M^2 **14.2.4.2** **pg13-136**

e. Do any adjustments need to be made?
Yes. **14.2.4.3** **pg13-136**
75% of density used

f. What is the final density/area?
4.7mm/min @ 186M^2 as adjusted but cannot be below 6.1mm/min see 14.2.4.5

g. What is the acceptable K-factor?
80 or larger

Module 6: Storage Applications

Scenario 4: A manufacturer stores empty plastic bottles in boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 5.7 meters above the floor. The roof deck is 7 meters above the floor. The sprinkler system designer would like to use K-160 sprinklers.

a. What is the commodity?
Group A plastic A.5.6.4.1 pg13-274

b. How is it stored?
Palletized

c. How high?
5.7M

d. What is the correct figure and density/area to use?
15.2.6(b) Column C from Figure 15.2.2 pg13-141
24.4mm/min @ 232M^2

e. Do any adjustments need to be made?
No. Interpolation is allowed but densities are the same for lower and higher height

f. What is the final density/area?
24.4mm/min @232M^2

Module 6: Storage Applications

Scenario 5: A manufacturer stores empty plastic bottles in boxes. The boxes are stacked on pallets. The full pallet loads are stored on top of each other to a height of 5.7 meters above the floor. The roof deck is 7 meters above the floor. The sprinkler system designer would like to use K-320 ESFR pendent sprinklers.

a. What is the commodity?
Group A plastic. A.5.6.4.1 pg13-274

b. How is it stored?
Palletized

c. How high?
5.7M

d. What is the roof height?
7M

e. What is the correct table to use?
Table 15.4.1 pg13-145

f. What is the final pressure and number of sprinklers?
1.7bar
12 sprinklers 15.4.3 pg13-143

Module 6: Storage Applications

Scenario 6: A company that makes and ships materials for hobby enthusiasts stores small blocks of Styrofoam to be placed in their packaging. The blocks are placed directly on top of each other to a height of 2.1 meters above the floor. The sprinkler system designer would like to use K-160 sprinklers.

a. What is the commodity?
Group A plastic **5.6.4.1(15)** **pg13-26**

b. How is it stored?
Solid pile

c. How high?
2.1M

d. What is the roof height?
Not given. I used 4.6M for the remainder of the problem.

e. What is the correct column to use?
15.2.6(b) Column C

f. Are any adjustments needed?
Area can be adjusted if closed array but not specified in question

g. What is the final density/area?
12.2mm/min @186M^2 or 232M^2

Module 6: Storage Applications

Activity 6.2 Solution

Instructions: Use the information below to determine the sprinkler type, the density, and the area.

Commodity	Height	Type of Storage	Bldg Height	Sprinkler	Density	Area
Class III	7 m	SRR	8.8 m	≥160	25.4mm/min	186M^2
Class II	5.4 m	Solid Piled	7.6 m	≥80	8mm/min	186M^2
Class IV	4.8 m	Palletized	6.7 m	≥115	11.9mm/min	186M^2
Group A Expanded Unstable	5.7 m	Solid Piled Exposed	9.7 m	≥160	33mm/min	232M^2
Group B	4.2 m	MRR	6 m	≥160	17.9mm/Min	186M^2
Group A Unexpanded Stable	2.7 m	Palletized Cartoned	4.8 m	≥160	20.4mm/min	232M^2
Class I	7.6 m	DRR	8.8 m	≥115	23.5mm/min	186M^2
Group C	6.7 m	Solid Piled	8.5 m	≥115	13mm/min	186M^2
Group A Unexpanded	3.9 m	BBS Cartoned	4.8 m	≥160	20.4mm/min	232M^2

Module 8: Activity and Seminar Summary

Activity 8.1 – Solution

Instructions: Working in groups, use the given criteria to find the required information, then answer additional questions.

Group A

Criteria:

- 7.6 m building height
- Plastic buckets (face down)
- Wood pallets
- Encapsulated
- High-temperature sprinklers
- 6.1 m of storage
- Stored in racks
    - Double row
    - 2.4 m aisle

Find the following:

1. CMDA ceiling density

18.3 mm/min @ 186M^2

Figure 17.2.1.2.1(d)

2. In-rack design criteria

K=80, 1.03bar, 8 sprinklers in design area

Figure 17.2.1.2.1(d) Note 1 and 17.2.1.5.6

3. Hose demand

1900 L/min

Table 12.8.6.1

4. Water supply duration

120 min

Table 12.8.6.1

Module 8: Activity

Additional questions:

1. What if the rack has all solid shelves, how does the in-rack design change?

In racks required in every row 17.1.5

2. What would be an allowable ESFR design approach?

K=200 @ 3.4bar or K=240 @ 2.4 bar

Table 17.2.3.1

3. What if I had solid shelves with ESFRs?

Not allowed 17.2.3.1.1 (1)

4. What if it was ESFR with 1.2 m aisles and no solid shelves?

No change. Table 17.2.3.1 doesn't change with aisle width

5. What is the most effective design approach if the buckets are facing up and are banded (not encapsulated)?

Store on lowest rack, fixed in place lids over buckets A.3.9.1.19

Module 8: Activity

Group B

Criteria:

- 6.1 m building height
- Cartoned books
- Wood pallets
- 4.6 m of storage
- Solid piled

Find the following:

1. CMDA ceiling density

11.6mm/min @186M^2 Figure 14.2.4.1 then apply Figure 14.2.4.3 pg 13-136

70% of density

8.1mm/min @186M^2

2. Hose demand

1900 L/min

Table 12.8.6.1 pg13-129

3. Water supply duration

120 min Table 12.8.6.1 pg 13-129

Module 8: Activity

Additional questions:

1. What if the storage height was 3.6 m?

Use Chapter 13, Miscellaneous Storage

OH2 Curve, Figure 13.2.1

946L/min hose demand and 90 min duration

2. What if the pallets were made of reinforced plastic?

A 2 class upgrade to make the commodity Group A plastic

5.6.2.3 pg13-26

3. What if the cartons were encapsulated?

No change unless over 4.6M, 14.2.5 pg13-137

4. What if the books were replaced by synthetic stuffed toys?

Group A plastic protect under Chapter 15

15.2.6(b) Column E pg13-143

18mm/min @232M^2

Module 8: Activity

Group C

Criteria:

- 12.2 m building height
- Cartoned butane lighters
- Wood pallets
- 9.1 m of storage
- In-racks

Find the following:

1. CMDA design approach

18.3 mm/min @186M^2

Table 17.3.1.3

2. Hose demand

1900 L/min

12.8.6.1

3. Water supply duration

120 min

12.8.6.1

Module 8: Activity

Additional questions:

1. What would be an allowable ESFR design approach?

K240 @ 3.6bar

There are 2 other choices in ESFR but this is lowest L/min

2. Which approach, ESFR or CMDA, is more efficient if a storage tank is used?

ESFR K240

327,888 L system demand w/out hose vs

CMDA

272,304 L ceiling sprinklers + 190,848 L in-racks = 463,152 L w/out hose

3. Can CMSA sprinklers be used?

No, ceiling height limited to 12.1M

17.3.2.1

4. What if the commodity was changed to Styrofoam meat trays?

No change 17.3.1.5

5. What if the butane lighters are in large containers or PODs?

Assuming they are loose in the container, it is outside the scope of 13.

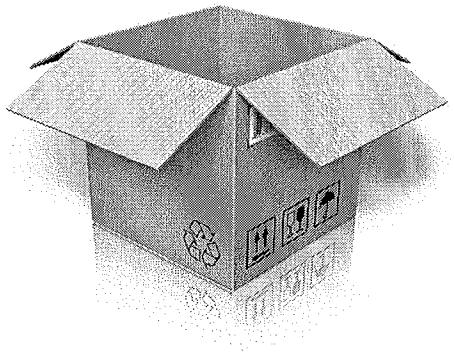
Considered Level 3 aerosol

A.5.6

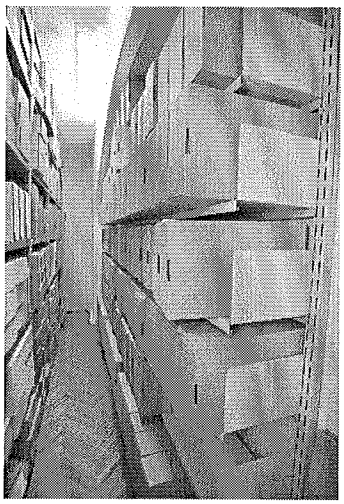
NFPA 13-2013
Storage Definitions

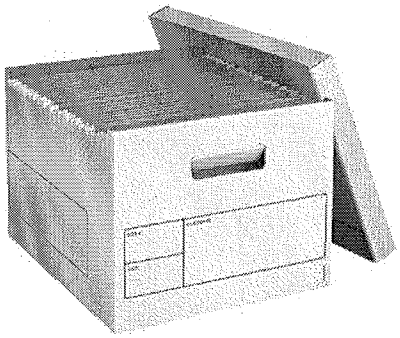
NFPA 13-2013 Storage Definitions

3.9.1.2 ***Cartoned.*** A method of storage consisting of corrugated cardboard or paperboard containers fully enclosing the commodity. (pg. 13-21)



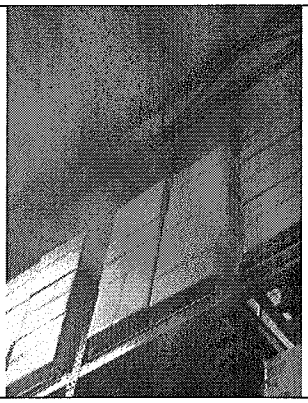
3.9.1.3 ***Carton Records Storage.*** A Class III commodity consisting predominantly of paper records in cardboard cartons. (pg. 13-21)



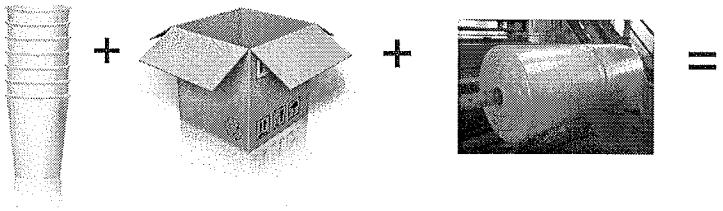


NFPA 13-2013 Storage Definitions

3.9.1.5 ***Clearance to Ceiling.*** The distance from the top of storage to the ceiling above. (pg. 13-31)
12.1.3.4 Clearance to Ceiling.
12.1.3.4.1* the clearance to ceiling shall be measured in accordance with 12.1.3.4.1.1 and 12.1.3.4.1.2



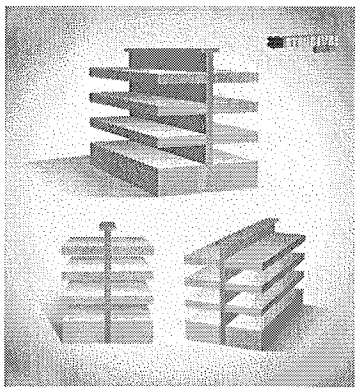
3.9.1.6 ***Commodity.*** The combination of products, packing material, and container that determines commodity classification. (pg. 13-21)



COMMODITY

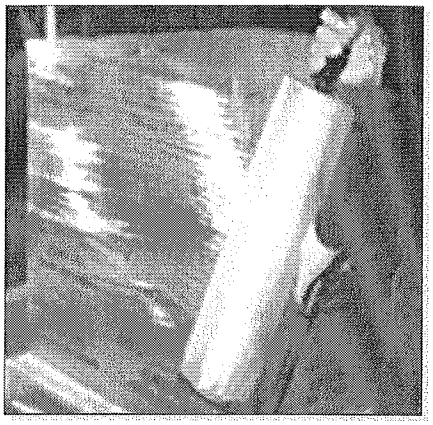
3.9.1.7 ***Compact Storage.*** Storage on solid shelves not exceeding 0.9 m in total depth, arranged as part of a compact storage module, with no more than 0.76 m between shelves vertically and with no internal flue spaces other than those between individual shelving sections. (pg. 13-21)

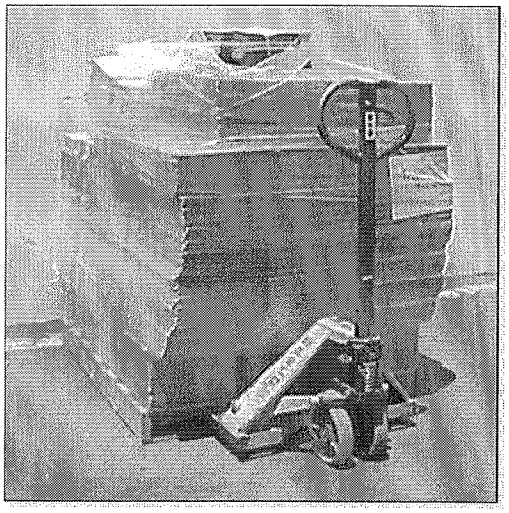




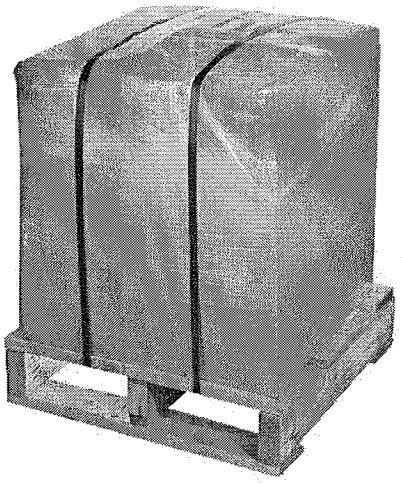
NFPA 13-2013 Storage Definitions

3.9.1.12 ***Encapsulation.*** A method of packaging that either consists of a plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity, a combustible package, or a group of combustible commodities or combustible packages, or consists of combustible commodities individually wrapped in plastic sheeting and stored exposed in a pallet load. (pg. 13-21)

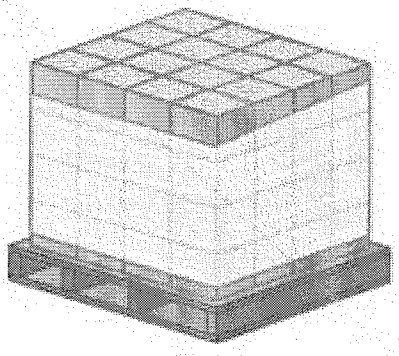




Encapsulated vs. Banded. Banded pallet loads consider plastic sheeting only around the four sides of the load, and not the entirety of the load. These two images show the difference between banded and encapsulated storage. (See A.3.9.1.12, pg. 13-259)



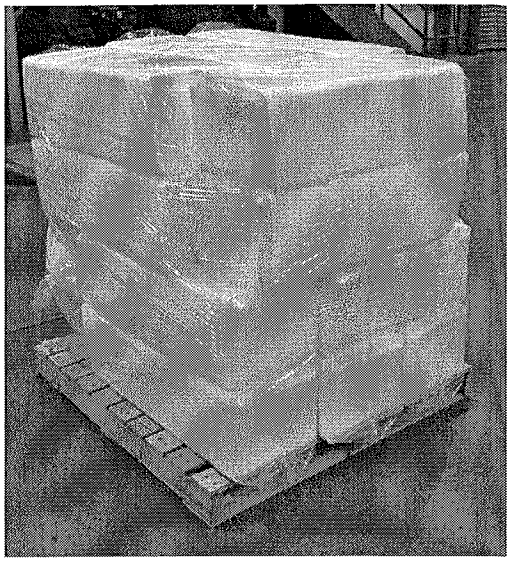
Encapsulated



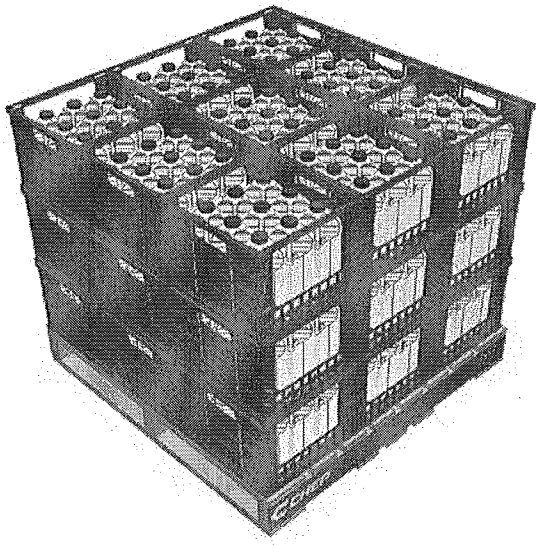
Banded

NFPA 13-2013 Storage Definitions

3.9.1.13 ***Expanded (Foamed or Cellular) Plastics.*** Those plastics, the density of which is reduced by the presence of numerous small cavities (cells), interconnecting or not, dispersed throughout their mass. (pg. 13-22)

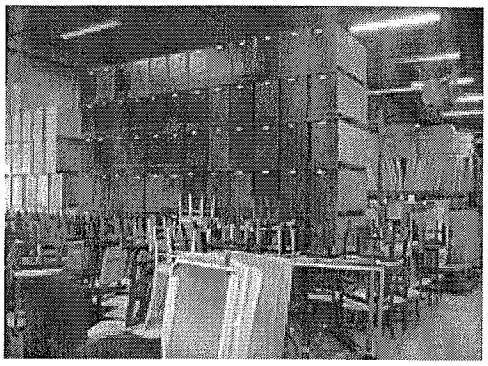


3.9.1.14 ***Exposed Group A Plastic Commodities.*** Those plastics not in packaging or coverings that absorb water or otherwise appreciably retard the burning hazard of the commodity. (Paper wrapped or encapsulated, or both, should be considered exposed.) (pg. 13-22)



NFPA 13-2013 Storage Definitions

3.9.1.17 ***High-Piled Storage.*** Solid-piled, palletized, rack storage, bin box, and shelf storage in excess of 3.7 m in height. (pg. 13-22)

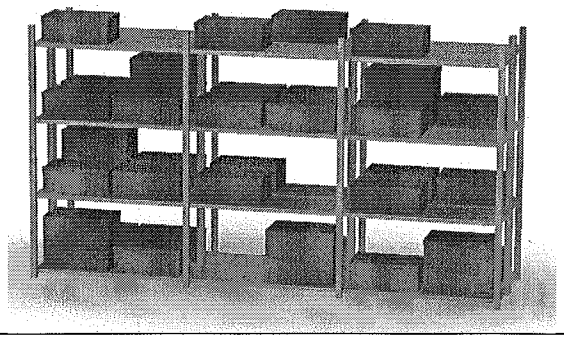




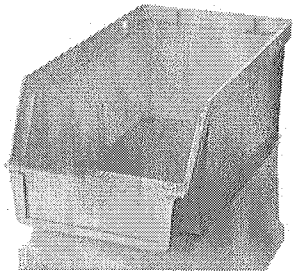
NFPA 13-2013 Storage Definitions

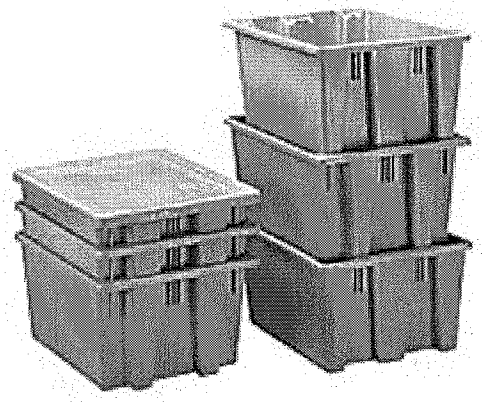
3.9.1.18 ***Miscellaneous Storage.***
Storage that does not exceed 3.66 m in height, is incidental to another occupancy use group, does not constitute more than 10 percent of the building area or 372 m^2 of the sprinklered area, whichever is greater, does not exceed 93 m^2 in one pile or area, and is separated from other storage areas by at least 7.62 m. (pg. 13-22)

Miscellaneous storage is restricted by the height and area of the goods stored. Although not permitted by the NFPA Manual of Style, this definition contains requirements and limitations. When applying the miscellaneous storage design approaches, it is important each time that the user come back to this definition to make sure that they are within the framework of what the NFPA discharge committee considers miscellaneous storage. Often people will go straight to Chapter 13 and look at the limitations in that chapter thinking those are the only restrictions on applying the miscellaneous storage design concepts.

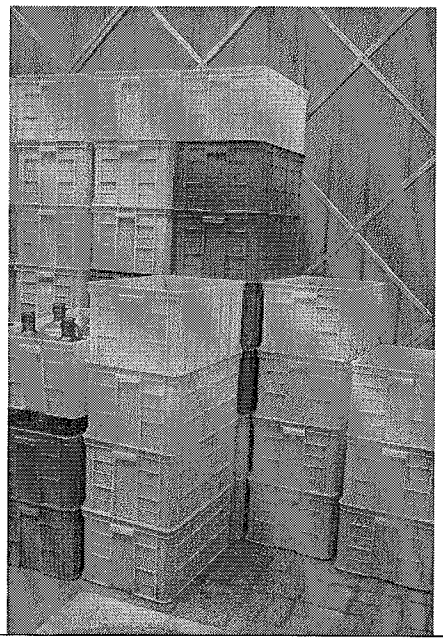


NFPA 13-2013 Storage Definitions



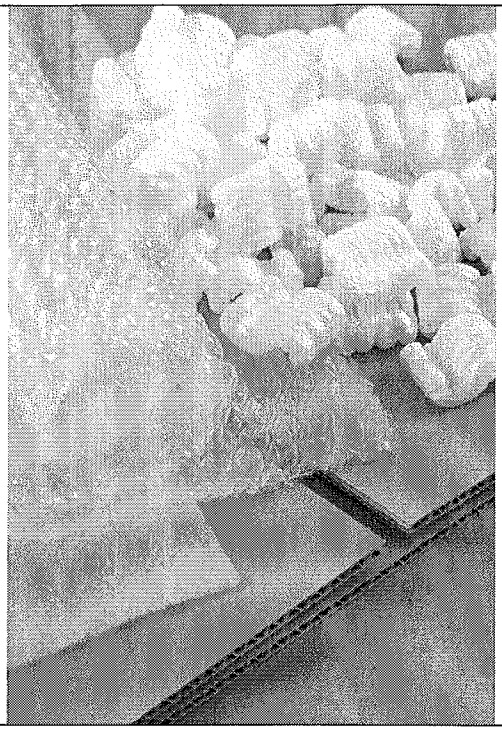


3.9.1.19 ***Open-Top Container.*** A container of any shape that is entirely or partially open on top and arranged so as to allow for the collection of discharging sprinkler water cascading through the storage array. (pg. 13-22)

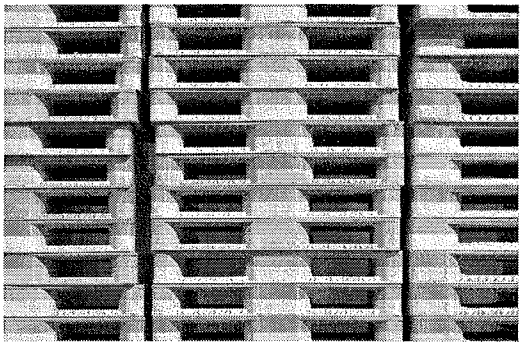


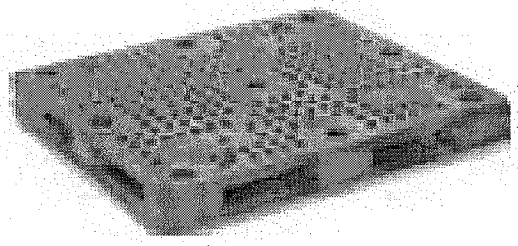
NFPA 13-2013 Storage Definitions

3.9.1.20 ***Packaging.*** A commodity wrapping, cushioning, or container. (pg. 13-22)

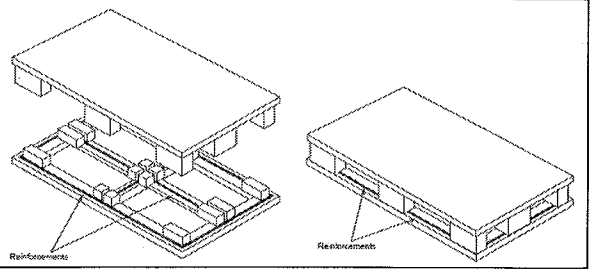


3.9.1.21 ***Plastic Pallet.*** A pallet having any portion of its construction consisting of a plastic material. (pg. 13-22)



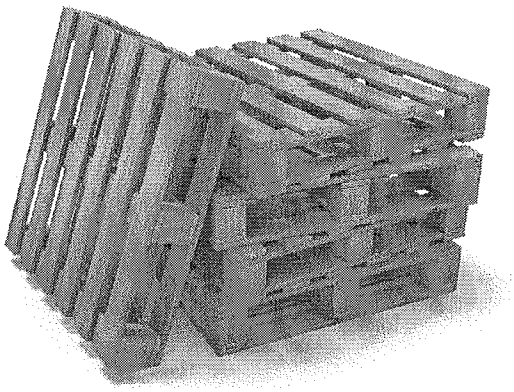


3.9.1.22 ***Reinforced Plastic Pallet.*** A plastic pallet incorporating a secondary reinforcing material (such as steel or fiberglass) within the pallet. (pg. 13-22)



NFPA 13-2013 Storage Definitions

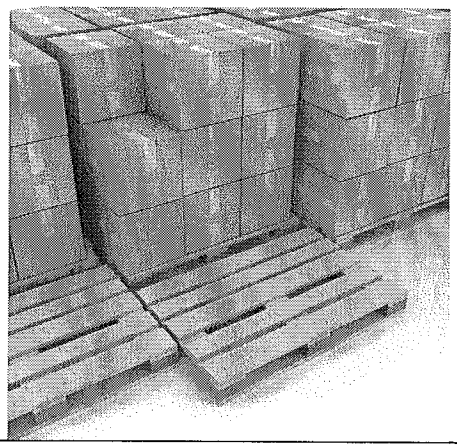
3.9.1.27 ***Wood Pallet.*** A pallet constructed entirely of wood with metal fasteners. (pg. 13-22)



3.9.1.26 ***Unit Load.*** A pallet load or module held together in some manner and normally transported by material-handling equipment. (pg. 13-22)

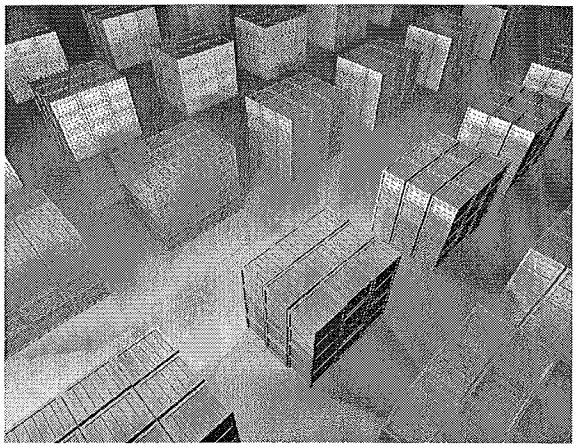


3.9.2.1.1 ***Closed Array.*** A storage arrangement where air movement through the pile is restricted because of 152 mm or less vertical flues. (pg. 13-22)

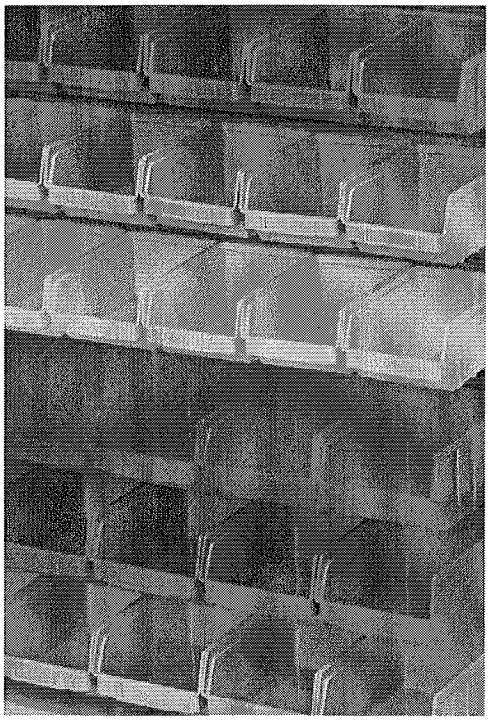


NFPA 13-2013 Storage Definitions

3.9.2.1.2* ***Open Array.*** A storage arrangement where air movement through the pile is enhanced because of vertical flues larger than 152 mm. (pg. 13-22)

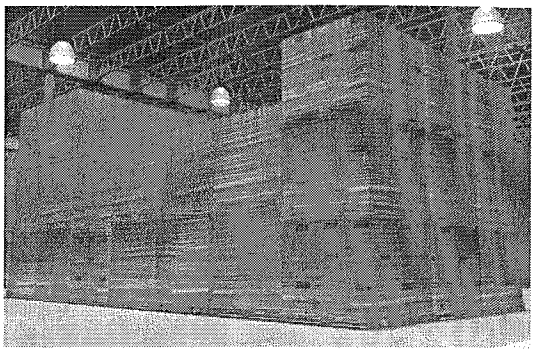


3.9.2.2 ***Bin Box Storage.*** Storage in five-sided wood, metal, or cardboard boxes with open face on the aisles in which boxes are self-supporting or supported by a structure so designed that little or no horizontal or vertical space exists around boxes. (pg. 13-22)

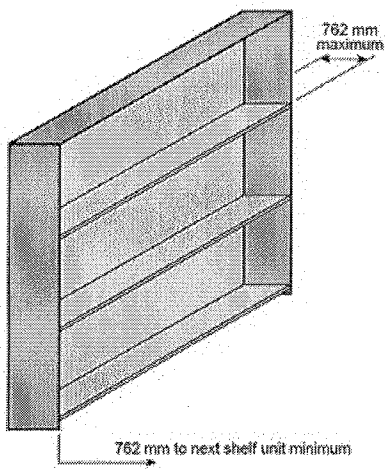


NFPA 13-2013 Storage Definitions

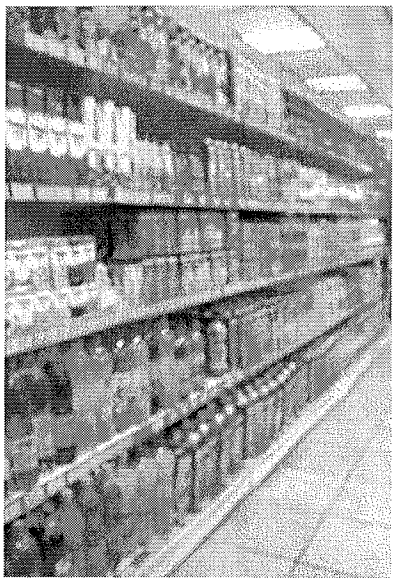
3.9.2.3 ***Palletized Storage.*** Storage of commodities on pallets or other storage aids that form horizontal spaces between tiers of storage. (pg. 13-22)



3.9.2.6* ***Shelf Storage.*** Storage on structures up to and including 0.76 m deep and separated by aisles at least 0.76 m wide. (pg. 13-22)

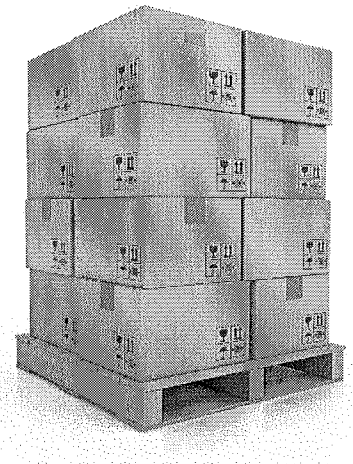


NFPA 13-2013 Storage Definitions



3.9.2.6.1* ***Back-to-Back Shelf Storage.*** Two solid or perforated shelves up to 0.76 m in depth each, not exceeding a total depth of 1.52 m, separated by a longitudinal vertical barrier such as plywood, particleboard, sheet metal, or equivalent with a maximum 6.4 mm diameter penetrations and no longitudinal flue space and a maximum storage height of 4.57 m. (pg. 13-22)

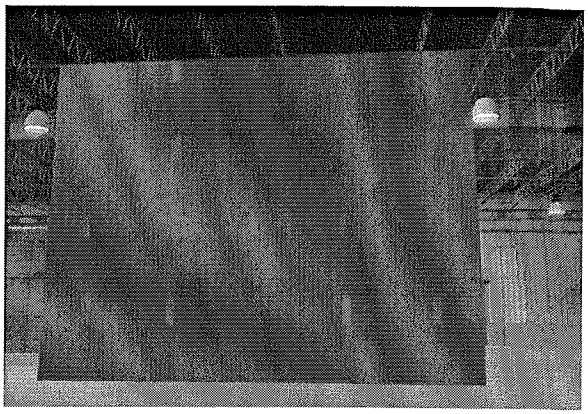




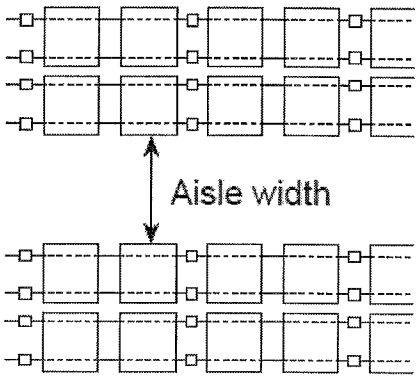
3.9.2.7 ***Solid-Piled Storage.*** Storage of commodities stacked on each other. (pg. 13-22)

NFPA 13-2013 Storage Definitions

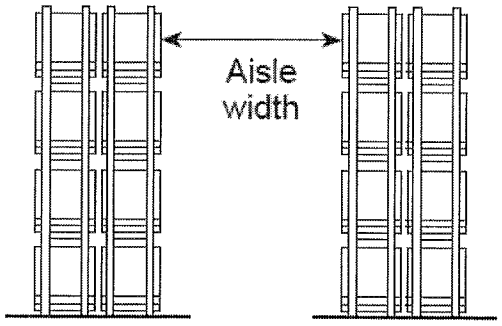
3.9.2.8 ***Solid Unit Load of Nonexpanded Plastic (Either Cartoned or Exposed).*** A load that does not have voids (air) within the load and that burns only on the exterior of the load; water from sprinklers might reach most surfaces available to burn. (pg. 13-22)



3.9.3.1* ***Aisle Width.*** The horizontal dimension between the face of the loads in racks under consideration. (pg. 13-22)



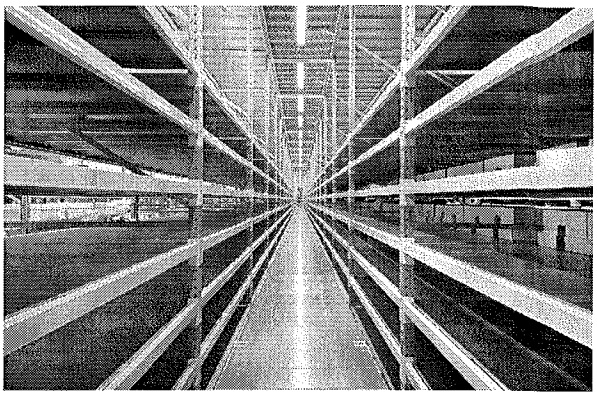
Plan View

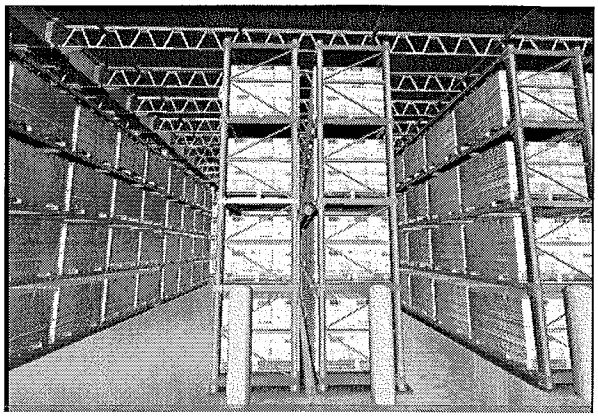


End View

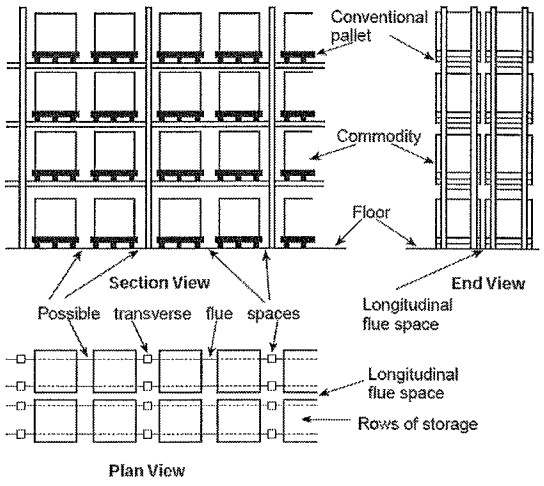
NFPA 13-2013 Storage Definitions

3.9.3.5 ***Horizontal Barrier.*** A solid barrier in the horizontal position covering the entire rack, including all flue spaces at certain height increments, to prevent vertical fire spread. (pg. 13-22)



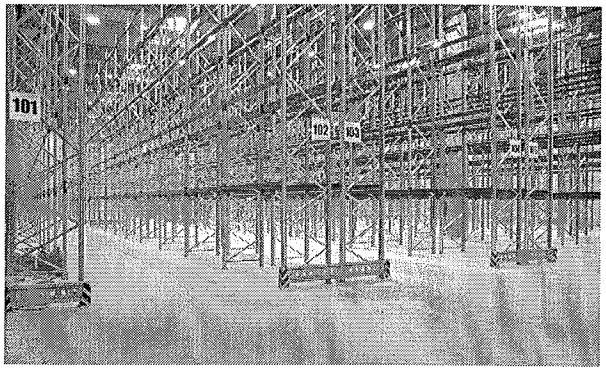


3.9.3.6* ***Longitudinal Flue Space.*** The space between rows of storage perpendicular to the direction of loading with a width not exceeding 610 mm between storage. (pg. 13-22)

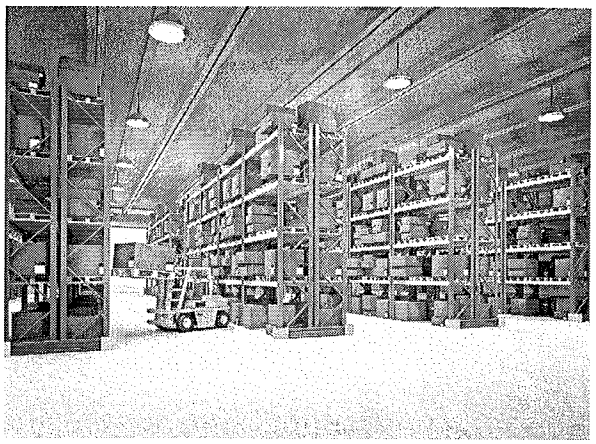


NFPA 13-2013 Storage Definitions

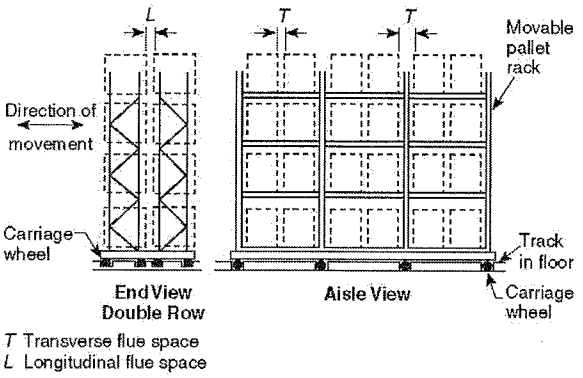
3.9.3.7* Rack. Any combination of vertical, horizontal, and diagonal members that supports stored materials. (pg. 13-23)



3.9.3.7.1 *Double-Row Racks.* Racks less than or equal to 3.7 m in depth or single-row racks placed back to back having an aggregate depth up to 3.7 m, with aisles having an aisle width of at least 1.1 m between loads on racks. (pg. 13-23)

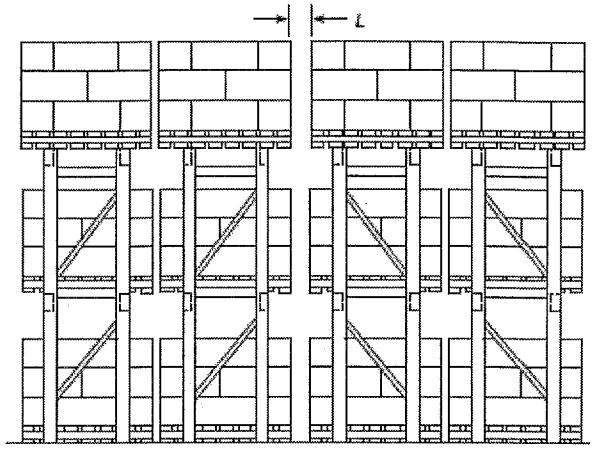


3.9.3.7.2 *Movable Racks.* Racks on fixed rails or guides that can be moved back and forth only in a horizontal, two-dimensional plane. A moving aisle is created as abutting racks are either loaded or unloaded, then moved across the aisle to abut other racks. (pg. 13-23)



NFPA 13-2013 Storage Definitions

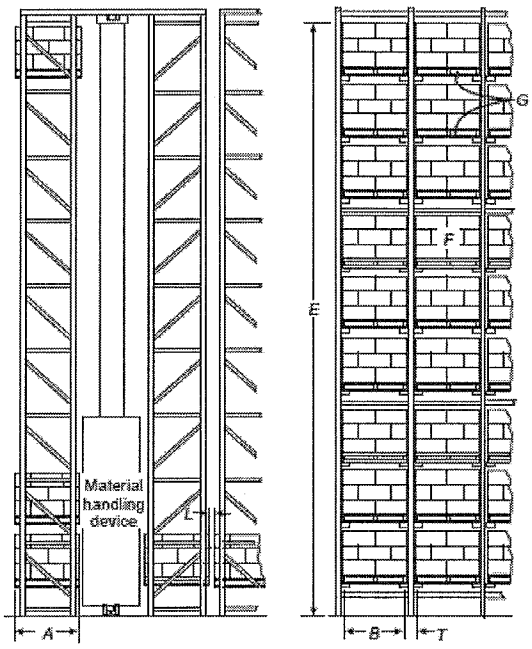
3.9.3.7.3 ***Multiple-Row Racks.*** Racks greater than 3.7 m in depth or single- or double-row racks separated by aisles less than 1.1 m wide having an overall width greater than 3.7 m. (pg. 13-23)



End View

L Longitudinal flue space

Automatic Storage-Type Rack: The pallet is supported by two rails running perpendicular to the aisle.

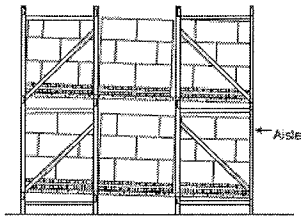


End View Aisle View

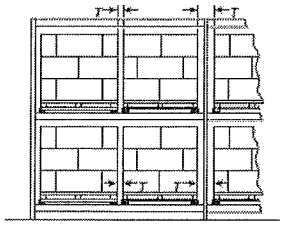
A Load depth
B Load width
E Storage height
F Commodity
G Pallet
L Longitudinal flue space
T Transverse flue space

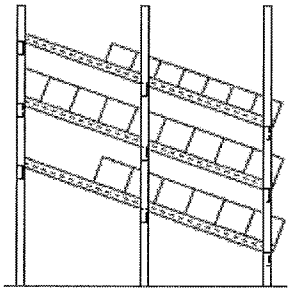
NFPA 13-2013 Storage Definitions

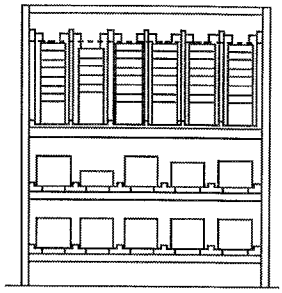
Flow-Through Racks: These racks include drive-in racks, drive-through racks, flow-through racks, portable racks arranged in the same manner, and conventional or automatic racks with aisles less than 1.07 m wide.



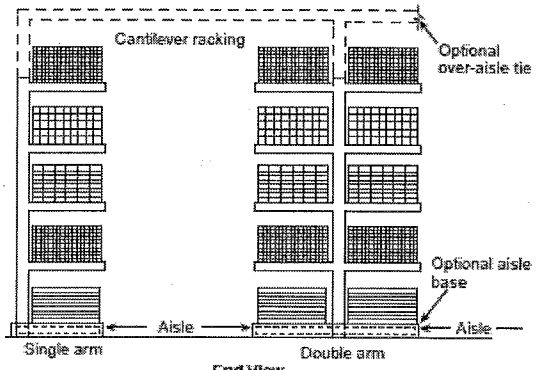
End View


Aisle View

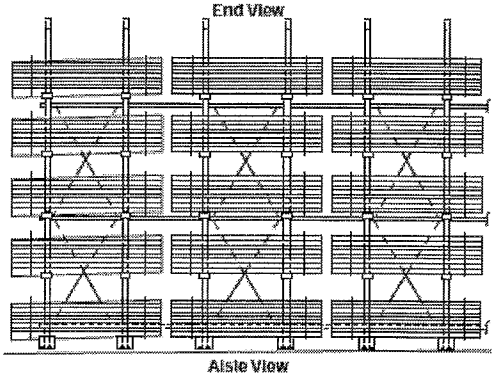

End View


Aisle View

Cantilever Rack: The load is supported on arms that extend horizontally from columns. The load can rest on the arms or on shelves supported by the arms.

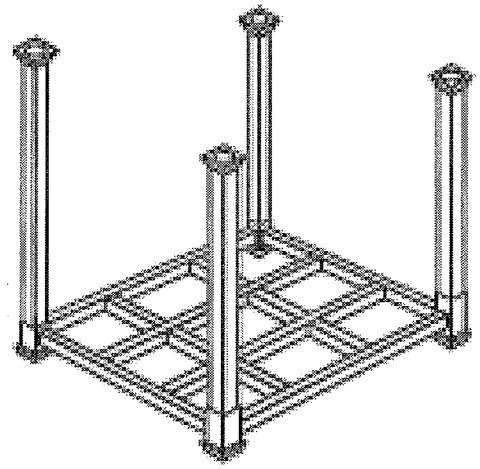


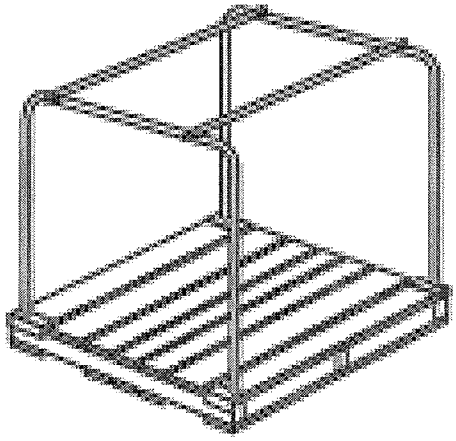
End View


Aisle View

NFPA 13-2013 Storage Definitions

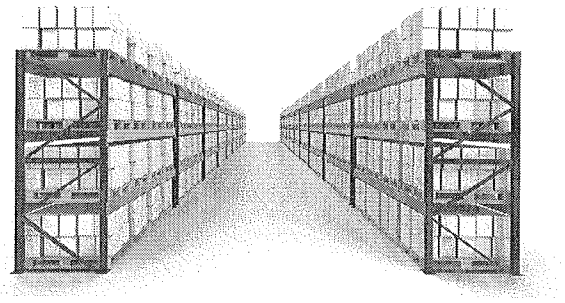
3.9.3.7.4 ***Portable Racks.*** Racks that are not fixed in place and can be arranged in any number of configurations. (pg. 13-23)

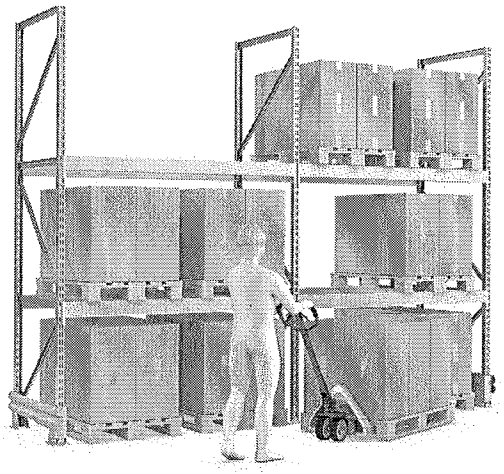




NFPA 13-2013 Storage Definitions

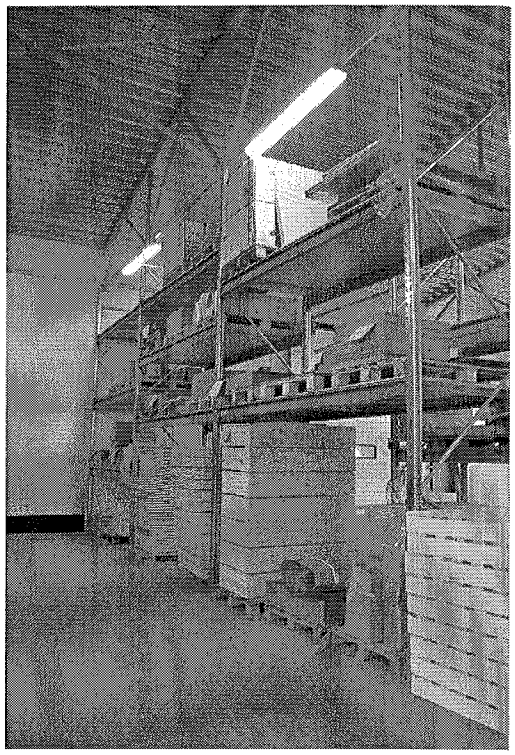
3.9.3.7.5 ***Single-Row Racks.*** Racks that have no longitudinal flue space and that have a depth up to 1.8 m with aisles having a width of at least 1.1 m between loads on racks. (pg. 13-23)



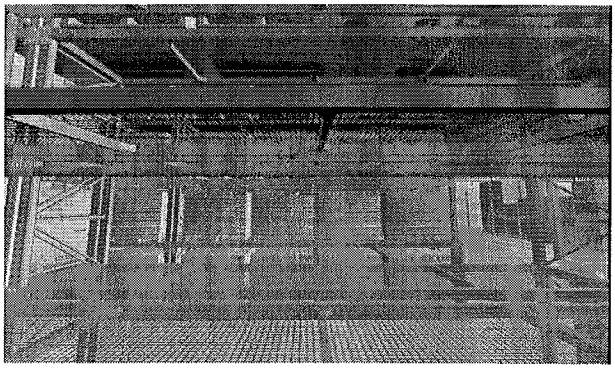


NFPA 13-2013 Storage Definitions

3.9.3.7.6 ***Rack Shelf Area.*** The area of the horizontal surface of a shelf in a rack defined by perimeter aisle(s) or nominal 152 mm flue spaces on all four sides, or by the placement of loads that block openings that would otherwise serve as the required flue spaces. (pg. 13-23)



3.9.3.7.7 ***Open Rack.*** Racks without shelving or with shelving in racks that are fixed in place with shelves having a solid surface and a shelf area equal to or less than 1.9 m^2 or with shelves having a wire mesh, slatted surface, or other material with openings representing at least 50 percent of the shelf area including the horizontal area of rack members and where the flue spaces are maintained. (pg. 13-23)



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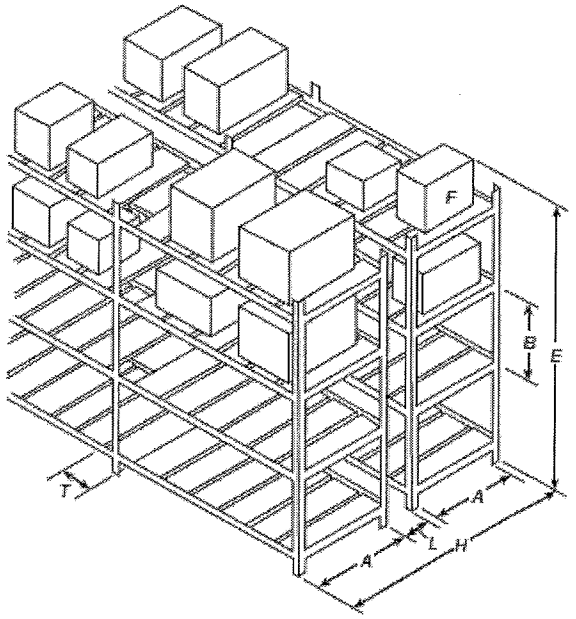
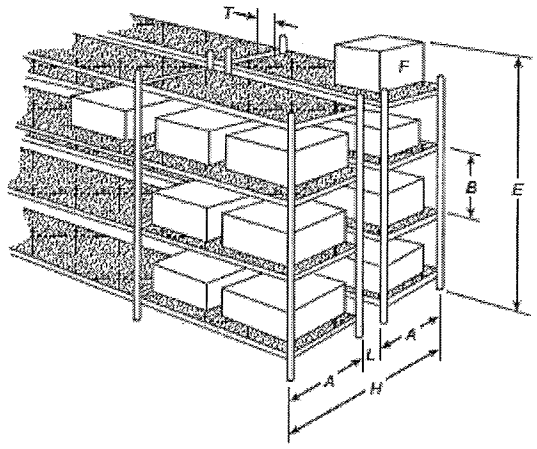
3.9.3.7.8 ***Slatted Shelf Rack.*** A rack where shelves are fixed in place with a series of narrow individual solid supports used as the shelf material and spaced apart with regular openings. (pg. 13-23)



A Shelf depth
B Shelf height
E Storage height
F Commodity
H Rack depth
L Longitudinal flue space
T Transverse flue space

3.9.3.8 ***Solid Shelving.*** Shelving that is fixed in place, slatted, wire mesh, or other type of shelves located within racks. The area of solid shelf is defined by perimeter aisle or flue space on all four sides. Solid shelves having an area equal to or less than 1.9 m2 are defined as open racks. Shelves of wire mesh, slats, or other materials more than 50 percent open and where the flue spaces are maintained are defined as open racks. (pg. 13-23)



A Shelf depth
B Shelf height
E Storage height
F Commodity
H Rack depth
L Longitudinal flue space
T Transverse flue space

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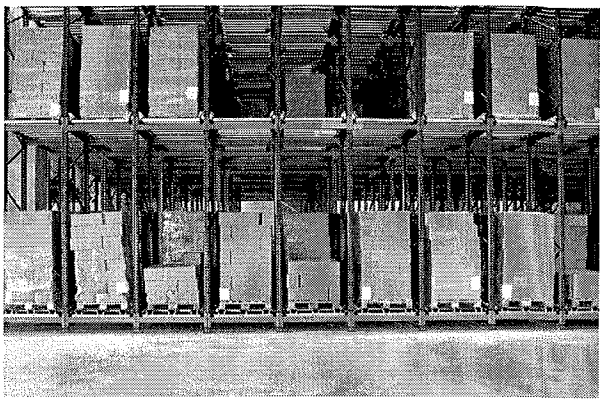
3.9.3.9 ***Transverse Flue Space.*** The space between rows of storage parallel to the direction of loading. (pg. 13-23)



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