



The Impact of Scaled Testing vs Prescriptive Code & Standard Requirements

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Outline

- **Commodity Classification examples (small scale testing)**
 - Reusable plastic containers storing non-combustible meats and produce
 - Rack storage of mattresses and box springs complying with 16 CFR Part 1633
- **Full Scale Testing example**
 - Rack storage of mattresses and box springs – full scale fire test
- **Impact of full-scale Performance Based Design testing on prescriptive options.**
 - Existing systems designed for OH I & II, now confronted with protecting Group A plastics.

“All it takes is time and money!!”

Reusable Plastic Containers Storing Non-combustible Meats & Products



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Reusable Plastic Containers - Background

- Polypropylene reusable plastic containers are increasingly replacing corrugated cardboard containers for storing and shipping food products in stores and distribution centers
- Materials stored in Polypropylene (PP) containers would typically be classified as Class IV or Group A Plastics
 - Class IV if PP is 5% to 15% by mass or 5% to 25% by volume (NFPA 13:2007 5.6.3.4.1)
 - Group A plastics if plastic content is above Class IV limits
- Most foods stored in cardboard boxes are considered Class II commodities
- Many existing food warehouses and distribution centers include Automatic Fire Sprinkler Systems designed to provide protection for Class II commodities.

Reusable Plastic Containers - Problem Statement

- Reusable plastic totes are desirable for efficient warehouse and distribution center operations, but costs associated with a significant upgrade to building fire sprinkler system would likely negate any operational savings.

What is the appropriate commodity classification for Reusable Plastic Totes containing typical food products?



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- Commodity Classification is a recognized technique for comparing a “real world” commodity against the fire behavior of benchmark commodities used during full scale fire testing
- Factory Mutual has published an Approval Standard for Commodity Classification of Idle Plastic Pallets
 - FM Class 4995
 - “The standard specifically addresses plastic pallets. It can also be used for the testing of plastic totes or for the testing of pallets and totes made from other materials...”



Approval Standard

for

**Commodity Classification
of Idle Plastic Pallets**

Class Number 4995

May 1992

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Commodity Classes – Class II



Metal-lined double tri-wall corrugated carton on a wood pallet

Commodity Classes – Class III



Paper cups in compartmented cardboard cartons on wood pallets

- A limited amount (5% by weight or volume or less) of Group A or Group B plastics permitted.

Commodity Classes – Class IV



A mixture of paper and plastic cups (15 % plastic by weight) on wood pallets.

- Constructed partially or totally of Group B plastics
- Consists of free-flowing Group A plastic materials*

* Contains within itself or its packaging an appreciable amount (5-15 % by weight or 5-25 % by volume) of Group A plastics

Commodities Tested – Group A



Plastic Cup in Standard Group A Commodity



Pallet Load of Standard Group A Plastic Commodity

- The standard Group A Plastic commodity consists of rigid crystalline polystyrene cups packaged in compartmented, single-wall, corrugated cardboard cartons.
- Cups are arranged in five layers, 25 per layer for a total of 125 per carton.

Reusable Plastic Containers - Commodity Classification Testing

- Three different commodities were evaluated by the FM Class 4995
 - Loose lemons
 - Plastic clamshell packed tomatoes
 - “Case-Ready” meat
- Sprinkler System Parameters
 - 286 °F, Standard Response (RTI 500 ft^{1/2}sec^{1/2})
 - 100 ft² coverage area, 7 inches below ceiling
 - Ignition Centered Between 4



Reusable Plastic Containers - Results

Test ID	Commodity	Reusable Container	Water Density (gpm/ft2)	1 minute average Peak HRR (MW)	Calculated Sprinkler Activation Time	Calculated Commodity Classification
1	Meat	Virgin HDPE and glass filled nylon: NPL-677	0.11	5.3	DNA	Class I
2	Meat	Virgin HDPE and glass filled nylon: NPL-677	0.21	3.0	23:37	
6	Meat	Virgin HDPE and glass filled nylon: NPL-677	0.31	4.3	17:26	
3	Lemons	Medium Impact Polypropylene Copolymer: GPL-6428	0.21	7.7	6:08	Class II
5	Lemons	Medium Impact Polypropylene Copolymer: GPL-6428	0.31	5.0	3:57	
7	Lemons	Medium Impact Polypropylene Copolymer: GPL-6425	0.11	0.3	DNA	
4	Tomatoes	Medium Impact Polypropylene Copolymer: GPL-6416	0.21	0.6	DNA	Less Than Class I
8	Tomatoes	Medium Impact Polypropylene Copolymer: GPL-6416	0.11	0.3	DNA	
9	None - Empty Bins	Medium Impact Polypropylene Copolymer: GPL-6428	0.39	13.4	2:25	Extra Hazard

Reusable Plastic Containers - Results

- Reusable Plastic Totes containing produce can likely be protected as a Class II Commodity
 - Lemons estimated as a Class II commodity
 - Case Ready Meats estimated as Class I commodity
 - No ready classification could be developed for Tomatoes as sprinklers did not activate
- In 50% of tests, fire size was insufficient to activate sprinklers
 - 286 °F, Standard Response Sprinklers
- Classification as Class IV or Group A plastic only appropriate in the case of empty plastic totes

Reusable Plastic Containers - Lessons Learned

- It may be appropriate to treat reusable plastic totes containing produce as a Class II Commodity, however empty plastic totes should be treated per current NFPA 13 guidelines
- Strict interpretation of the code MAY lead to an “overdesigned” suppression system or even limit the use of other beneficial technologies
- The descriptions contained in NFPA 13 used to estimate commodity classification are not precise. Fire behavior cannot be predicted on the simple basis of mass/volume of combustible materials.

The Code/Standard may be overly conservative which is not a bad thing

Rack Storage of Mattresses & Box Springs – Small Scale Test



Charleston, SC Furniture Fire – 9 Firefighters Killed

Rack Storage of Mattresses & Box Springs - 2007

Background & Problem Question

- New regulations governing the flammability of mattresses require exposure to small, open flame sources for at least 30 minutes
 - Regulation: 16 CFR Part 1633
 - Test Standard: UL 1633
- Furniture Warehouse fire in Charleston, NC raised awareness of the fire hazard associated with upholstered furniture & mattresses
 - AHJ's are taking a harder look at these facilities to determine if they are adequately protected

Problem question: *Does the new flammability requirement have an impact on the level of protection required for facilities storing mattresses and box springs?*



Rack Storage of Mattresses & Box Springs - Background & Problem Statement

- NFPA and FM treat mattresses and upholstered furniture as Unexpanded, Exposed Group A Plastic
- Protection schemes for 25 ft of storage – 35 ft ceiling requires either ESFR sprinklers or in-rack sprinklers
- NFPA & FM
 - K17 ESFR @ 52 psi
 - K14 ESFR @ 75 psi
- Minimum Theoretical Water Demand approximately 1500 gpm @ 52 psi (K17)

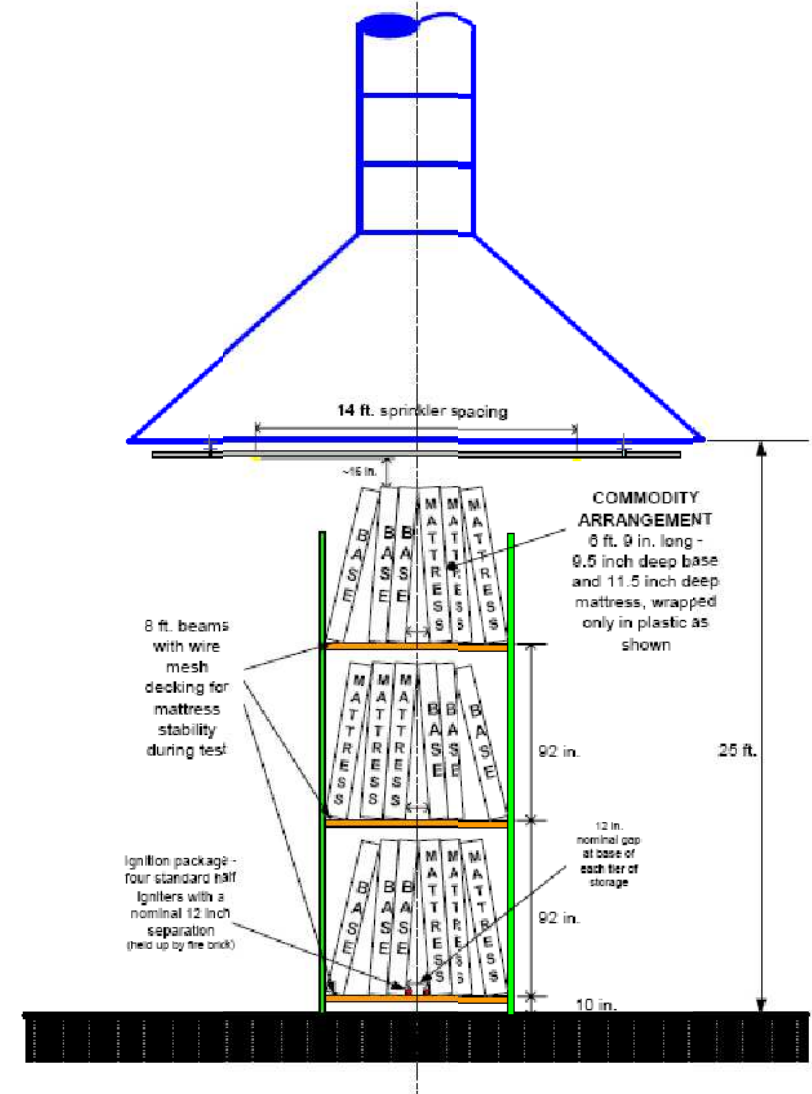
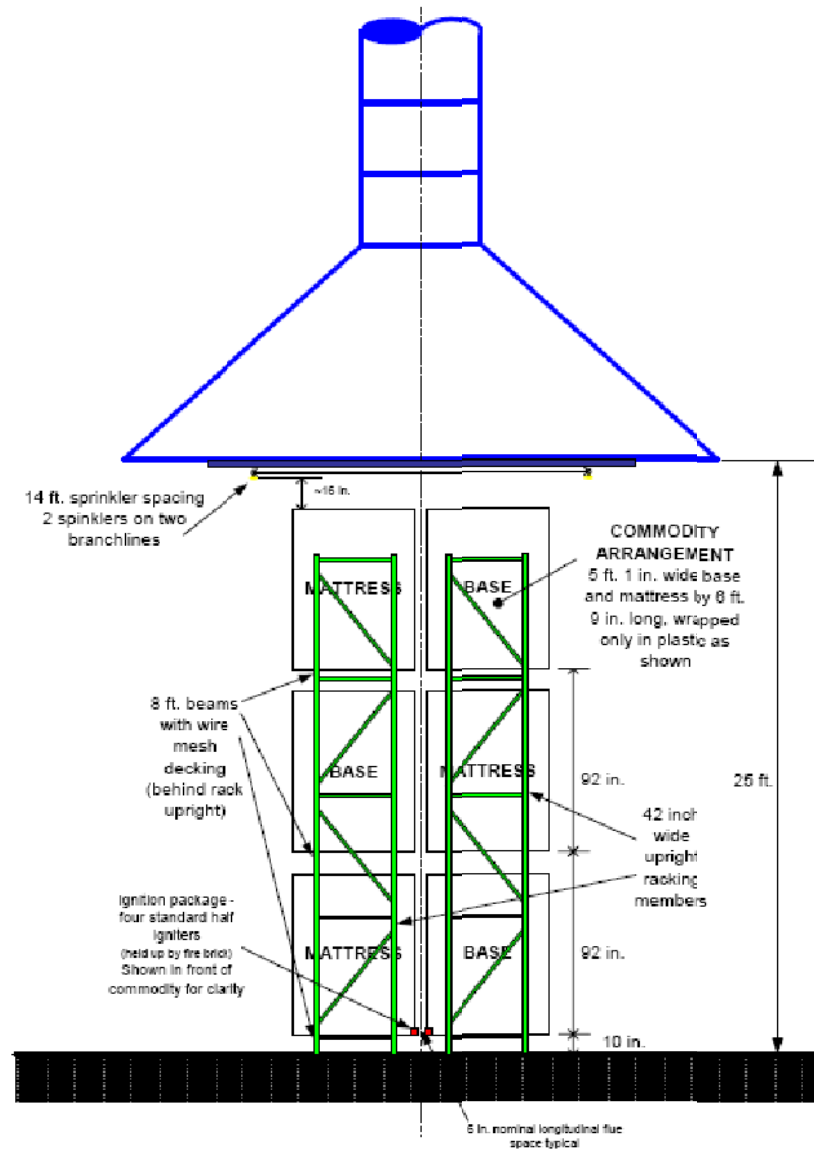


Rack Storage of Mattresses & Box Springs - Commodity Classification Testing

- Proposal to conduct commodity classification testing to evaluate the fire risk associated with mattresses compliant with 13 CFR Part 1633
 - Demonstrate that these mattresses were fire resistant and as a result did not require the same level of protection
- Design density of 0.45 gpm/ft² using K17 control mode sprinklers was selected somewhat arbitrarily
 - 286 °F Temperature Rating
 - Standard Response
 - Activation time predicted from calorimeter data
- Mattresses “on end” in racks
 - Wire mesh used on racks to support mattresses during fire test
 - Mattresses wrapped in plastic



Rack Storage of Mattresses & Box Springs-Test Set-Up



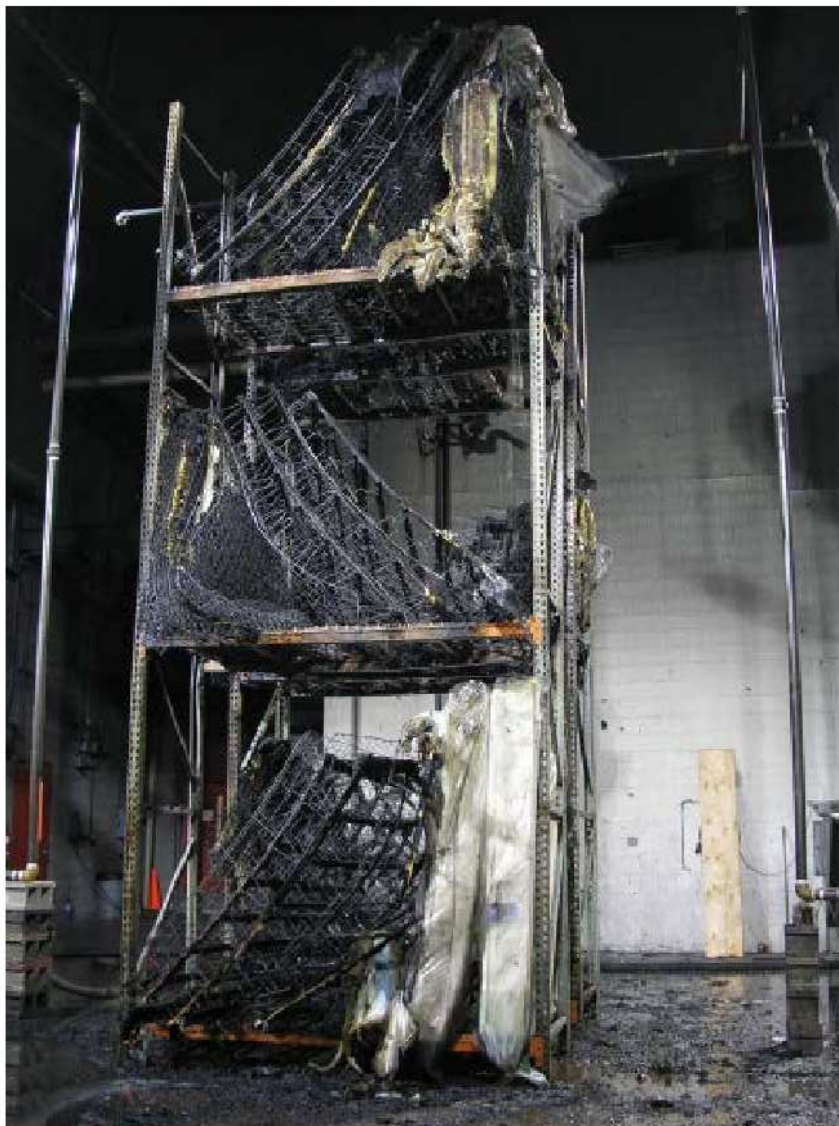
Rack Storage of Mattresses & Box Springs - Test Set-Up



Small Scale Mattress/Box Spring Test Video

Rack Storage of Mattresses & Box Springs - Test Results

Test termination at 3:20



Rack Storage of Mattresses & Box Springs - Results

- Mattresses stored in this configuration are:
 - More hazardous than unexpanded, exposed
 - Less hazardous than expanded, exposed
- Compliance with CFR 13 Part 1633 does not appear to result in any reduction in protection requirements for mattress storage
- 0.45 gpm/ft² density is insufficient to provide fire control when using 286°F, standard response sprinklers and no in-racks
- Alternate storage configuration, such as stored flat, may result in significantly different results
- Commodity classification testing permitted a comparatively low cost method of evaluating the behavior of this commodity as compared to full scale testing

Rack Storage of Mattresses & Box Springs - Lessons Learned

- *Compliance with NFPA 13:2007 or FM 8-9 is likely to provide an adequate level of protection for rack storage of mattresses up to 25 ft.*
- *The incorporation of a barrier intended to limit fire growth associated with small ignition sources (cigarettes, etc) and in one orientation does not appear to result in any decrease in the overall hazard of the commodity when stored in large quantities*

In this case the Code/Standard provide adequate protection!

Rack Storage of Mattresses & Box Springs – Full Scale Testing 2017

- Large national retailer and their consultant team identified a protection dilemma for mattress/box spring storage in existing retail stores.
- Fire protection surveys indicated existing fire protection systems were inadequate to protect these products, among others.
- NFPA 13 prescriptive solutions would be inordinately expensive when connecting to existing store fire sprinkler systems.
- Customized protection schemes were developed that would allow use of existing water supplies.
- Client provided product and funded testing



Rack Storage of Mattresses & Box Springs – Full Scale Testing



In-rack sprinklers selected - 25.2K EC uprights
Ceiling sprinklers – 25.2K EC uprights *and* ESFR-17 uprights



Product stored as intended



Plywood horizontal & horizontal barriers
(each bay & above lowest level respectively)



+



In-rack feed from existing ceiling sprinkler system

Rack Storage of Mattresses & Box Springs – Full Scale Testing

- Testing objectives:
 - Performance Based Design employing most economical solution
 - Provide most efficient in-rack fire control using existing facility water supplies.
 - Must be applicable to entire fleet of 700 stores
- Conducted 4 full scale fire tests at UL
 - Utilizing different water supply values and starting pressures.
 - Two levels of storage had to be tested separately – in-rack 25.2EC 165F and ceiling upright 16.8K ESFR 165F.
 - Bottom level wired shelving
 - Horizontal barrier of plywood every 3-mattress bay
 - Vertical barrier of plywood between mattresses and box springs on top.



Rack Storage of Mattresses & Box Springs – in rack test

Rack Storage of Mattresses & Box Springs – overhead test



Rack Storage of Mattresses & Box Springs – Results/Conclusions

- In-rack sprinklers achieved control *and* suppression
- Overhead ESFR's achieved satisfactory fire control, operating 3 sprinklers. Massive amount of smoke generation.
- Owner could utilize existing water supplies and existing ceiling sprinklers to protect the storage of mattresses and box springs bases in their intended storage configuration.
- Performance Based Design approach backed by successful full scale tests provided the owner with an economical alternative at no sacrifice – actually an enhancement - in the degree of fire protection.
- Storage of mattresses and box springs presents a unique hazard and fire challenge, and should be addressed very carefully.



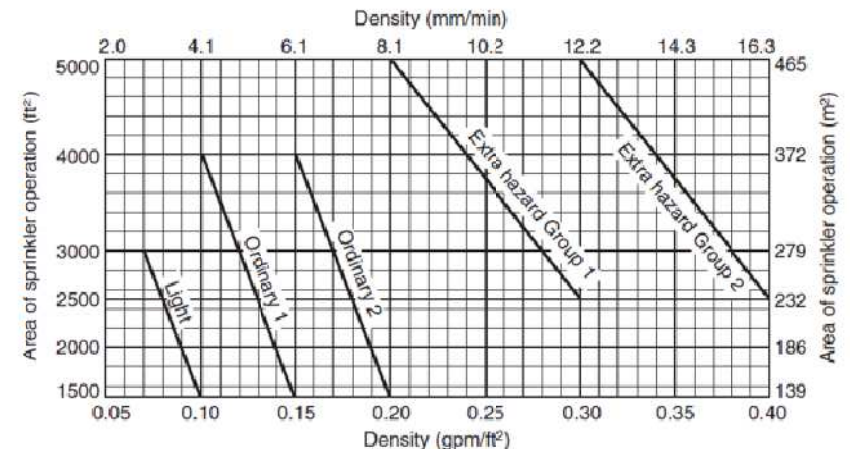
The Automatic Fire Sprinkler – Simple, Straightforward...and Prescriptive?



- Designed to meet the requirements of an *existing product standard* for use in accordance with an *existing installation standard*.
- Sprinklers are classified as:
 - Occupancy/Hazard Classification
 - LH/OH/EH
 - Storage
 - Residential
 - Coverage
 - Standard
 - Extended
 - Response
 - Standard
 - Quick (Fast)
- Sprinklers designed for multiple coverage areas, spacings, and clearances can result in inefficient spray patterns and water use for specific & narrow applications.

Inefficient Spray Patterns and Water Use

- High Factors of Safety
- Large Design Areas
- Increased Number of Design Sprinklers
- Increased Water Demand
- Requirement for Pumps
- High Hose Stream Allowances and Duration
- Larger Pipe Sizes



13-198

INSTALLATION OF SPRINKLER SYSTEMS

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		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 (no open-top containers)	Class I or II	30	9.1	35	10.7	11.2 (160) Upright	Wet	20 + 1 level of in-rack	25	1.7
							Dry	30 + 1 level of in-rack	25	1.7
		35	10.7	40	12.2	16.8 (240) Upright	Wet	20 + 1 level of in-rack	15	1.0
							Dry	30 + 1 level of in-rack	15	1.0
		35	10.7	40	12.2	19.6 (280) Pendant	Wet	15	25	1.7
						11.2 (160) Upright	Dry*	36	55	3.8
	Class III or IV	30	9.1	35	10.7	16.8 (240) Upright	Dry*	36	22	1.5
						19.6 (280) Pendant	Wet	15	30	2.1

*High temperature-rated sprinklers shall be used. Dry system water delivery shall be determined in accordance with 7.2.3.6 with a maximum time of water delivery of 30 seconds with four sprinklers initially open.

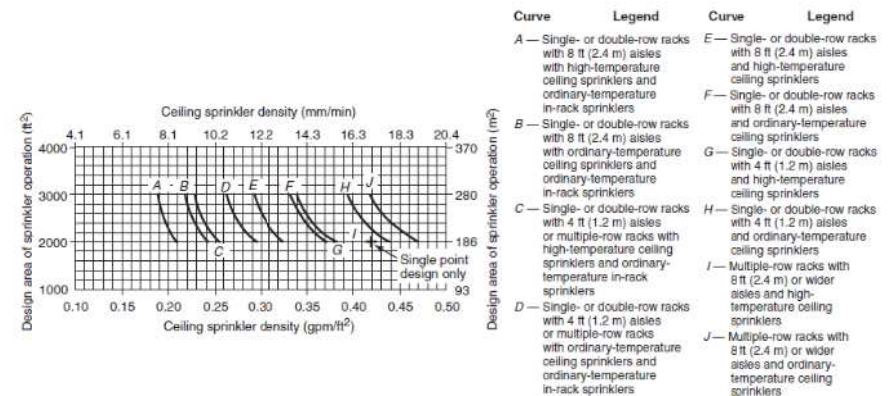


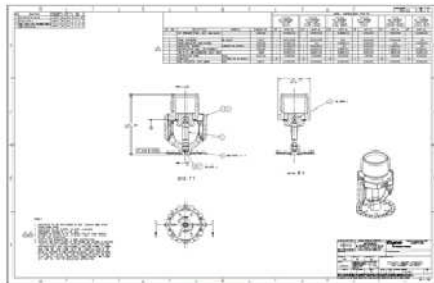
FIGURE 16.2.1.3.2(b) Sprinkler System Design Curves — 20 ft (6.1 m) High Rack Storage — Class II Nonencapsulated Commodities — Conventional Pallets.

Customized Fire Protection vs Prescriptive Requirements

- *The Client* – Large international business with multiple storage facilities
 - Multiple wet systems with differing design requirements throughout each facility.
- *The Challenge* – Client's existing fire sprinkler systems required updates to address higher hazard commodity classifications.
- *The Requirements* - a repeatable fire protection solution to upgrade existing facilities, providing operational flexibility for future facilities.
 - Client needed a cost-effective retrofit solution economically deployed across its facility footprint, and sufficient flexibility to address complex storage arrays.
 - Significant capital expense of installing fire sprinkler systems addressing higher fire challenges using *prescriptive* requirements also required an increase in water discharge, and in many cases the addition of fire pumps.
 - Design challenges required solutions that could be installed into existing fire sprinkler system infrastructure while utilizing existing water supplies *without fire pumps*.
 - Time/labor intensity of updating sprinkler systems often required facility closure, a consequence the client could not entertain.
 - Proactively addressing current and future fire protection challenges would help ensure the safety of employees, visitors, and inventory.
 - All this while minimizing impact to facility operations with very little downtime.

Customized Fire Protection vs Prescriptive Requirements

- *The Task* - develop a non-prescriptive, customized fire protection solution significantly reducing upgrade cost to an end user while...
 - Enhancing the ability of the existing fire sprinkler systems to protect a higher hazard
 - Providing a unique fire protection solution using existing sprinklers & water supply
 - Providing a unique fire protection solution using custom designed sprinklers.
 - Off-the-shelf sprinklers also used where feasible and applicable.
 - Backed by successful full scale fire testing for each design scenario.
 - Utilizing Performance Based Design employing NFPA 13's Equivalency Clause:



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.

ELO Sprinklers

Extra Large Orifice (ELO) sprinklers are designed to control high challenge fires with relatively low required pressures. These sprinklers have proven performance in storage applications backed by full-scale fire testing.

Options include: ELO-231, ELO-231B, and ELO-231FRB.



Customized Fire Protection vs Prescriptive Requirements

- Scope & Scale
 - JCI BD team approached by Client and their consultant team for potential solutions to upgrade fire protection for ~ 2800 facilities
- Fire protection surveys indicated facility fire protection systems were inadequate to protect Group A (.6 density/varying areas) commodities.
- NFPA 13 prescriptive solutions would cost over \$1B USD.
- Four unique areas of protection in each facility defined.
- Off-the-shelf sprinklers found to be suitable for some areas.
- Other areas for which developing *customized protection schemes* and possibly *customized sprinklers* was *proposed*, allowing the use of existing water supplies.
- Conducted ~ 50 full scale fire tests at UL.



Customized Fire Protection vs Prescriptive Requirements

sprm/ft ²										Area	Location	Totals
0.560	1.160	0.120	0.080	0.080	0.060	0.040	0.020	0.020	0.020	1	Between 2	1.720
0.020	0.040	0.040	0.080	0.120	0.120	0.080	0.080	0.060	0.040	2	Between 4	2.080
0.020	0.020	0.080	0.160	0.240	0.200	0.160	0.120	0.120	0.080	3	Between Areas 1 & 2	1.360
0.040	0.060	0.120	0.320	0.360	0.200	0.160	0.080	0.080	0.080	4	6 x 4	4.800
0.080	0.120	0.200	0.400	0.320	0.160	0.120	0.080	0.040	0.020	5	6 x 10	8.800
0.200	0.240	0.320	0.320	0.200	0.160	0.120	0.080	0.060	0.020	6	100 pan	13.000
0.240	0.240	0.240	0.160	0.160	0.120	0.120	0.080	0.080	0.060			
0.160	0.160	0.150	0.120	0.120	0.120	0.120	0.080	0.060	0.060			
0.120	0.120	0.120	0.120	0.080	0.080	0.080	0.080	0.040	0.020			
0.080	0.120	0.080	0.080	0.080	0.060	0.060	0.060	0.040	0.020			

- End user provides parameters
 - Ceiling height
 - Storage height
 - Commodity type
 - Storage arrangement
 - Spacing
 - Available water supply – GPM and PSI
- Manufacturer responsibilities
 - Review Fire Test Database for similar uses
 - Evaluate existing sprinklers for potential candidates
 - Conduct water spray evaluations
 - Develop alternative deflector designs to maximize spray efficiency
 - Provide prototype sprinklers for full scale fire testing
 - Participate in all full scale tests
 - Obtain UL listing or UL verification



The Result - Custom Engineered Automatic Sprinklers



Sprinkler

Effective Date
February 22, 2018 - February 21, 2019

Verify ID:	A826244
Brand:	Tyco Fire Products LP
Model:	TY7158 Upright K=16.8 Sprinkler, TY7258 Recessed Pendant K=16.8 Sprinkler
	View Less

Fire Test
Performance
Characteristics
Verified



- Sprinklers designed based on end user's specific use:
 - Ceiling height
 - Storage height
 - Commodity type
 - Storage arrangement
 - Spacing
 - Available water supply – GPM and PSI
- Sprinkler optimized to maximize use of water
 - Reduce total water demand
- Optimize response time
 - Reduce number of operating heads/design area
- Optimize K-factor
 - Reduce pressure and eliminate the use of pumps or pump upgrades
- Goal – allow for upgraded fire protection system by simply swapping out the fire sprinklers



Creating a Custom-Engineered Fire Sprinkler

Sprinkler

Effective Date
February 22, 2018 - February 21, 2019

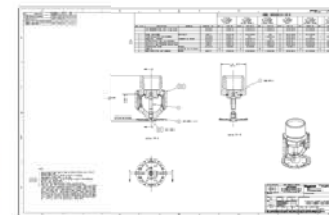
Verify ID:	A826244
Brand:	Tyco Fire Products LP
Model:	TY7158 Upright K=16.8 Sprinkler, TY7258 Recessed Pendent K=16.8 Sprinkler
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- Owner/Owner's Agent and manufacturer collaborate on developing worst case full scale fire test(s):
 - Mitigate number of tests required.
 - Follow similar process used for schemes shown in Chapter 20, NFPA 13.
 - Follow guidelines in Chapter 21, NFPA 13.
- UL:
 - Conduct full scale fire testing.
 - Prepare fire test report(s).
 - Conduct tests as necessary on the new sprinkler to obtain UL Verification.
 - Add sprinklers to UL Verify website
 - The UL Verification process meets the definition of "Listed" per NFPA 13
- New sprinkler model(s) created for the owner's specific use and project conditions.
- Owner/Owner's Agent uses fire test report(s) and UL Verification information to obtain AHJ approval in accordance with the Equivalency allowance within Section 1.5 of NFPA 13.
- <https://verify.ul.com/mark?id=A826244>

Conclusions

- Although providing significant benefits, direction, and detail, standards such as NFPA 13 are not fool proof or absolute.
 - Even fundamental premises may be invalidated over time due to changes or new data.
- The value of NFPA or other consensus standards would be substantially enhanced if the data used by the committee was readily accessible to users
 - Perhaps a proposal to incorporate “addendum” material in ALL standards providing technical basis for requirements
 - Facilitates possible PBD evaluations for alternative means and methods.
- Successful testing for any specific application is more likely to exhibit results that are *not* well-aligned with the prescriptive code, but *effective* with regard to intent, application, and performance.
- Scaled testing requires employment of significant time, money, and human resources.
- When used within a PBD framework Customized Fire Protection tests, sprinklers, design schemes can provide *significant* economic and operational benefits.

[illegible]



Thank You for Everything!



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