Learning from History – Solid Shelf Protection Strategies

Fire Protection Research Foundation
Global Research Update: High Challenge Storage Protection

Grange Tower Bridge Hotel
London, England
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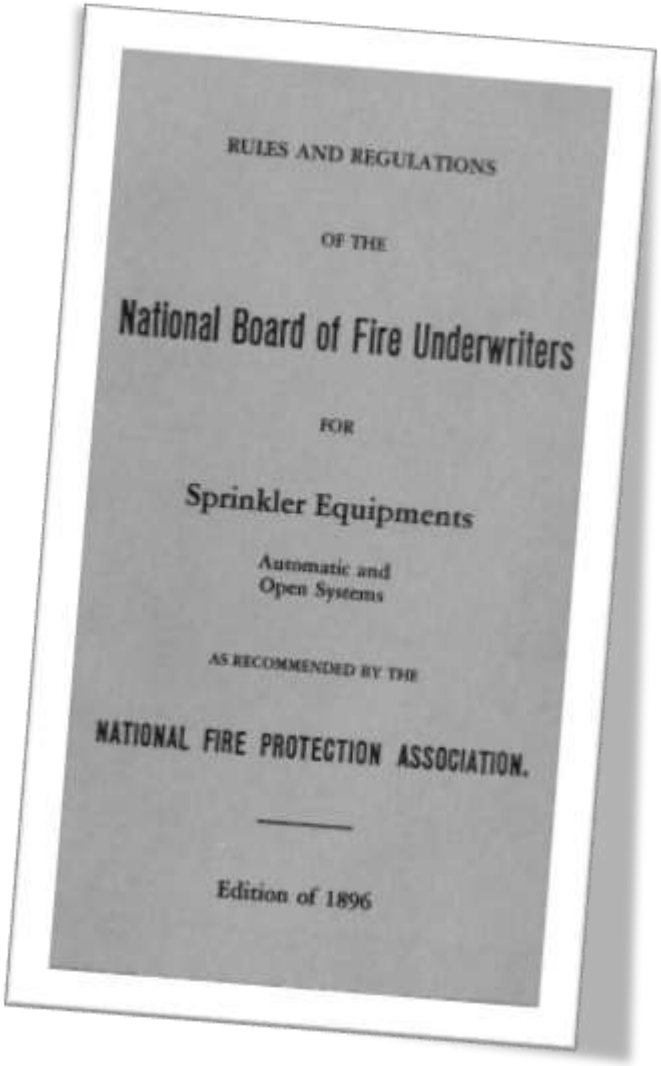
Convergence of Historic Research and Current Technology

Example

- Standard for the Installation of Sprinkler Systems, NFPA 13, published by the National Fire Protection Association
- Requirements from 1896 until recent times
- NFPA 13 committee to substantiate the requirements with scientific method
- Funding challenges
- Legacy testing used equipment that is obsolete today


RULES AND REGULATIONS

OF THE

National Board of Fire Underwriters

FOR

Sprinkler Equipments

Automatic and
Open Systems

AS RECOMMENDED BY THE

NATIONAL FIRE PROTECTION ASSOCIATION.

Edition of 1896

The Rise of Modern Warehousing

Golden Age of Capitalism (1945-1970)

- High worldwide economic growth
- Metamorphosis of warehousing
- More products, more storage facilities, and more efficient, effective means of storing and retrieving products.
- “Maximize the cube”
- Mega-warehouses – Larger fire risk than the previous facilities due large size and high bay storage.

Fire History Examples

Cheapside Street Whisky Bond Fire (Glasgow) – March 1960 is Britain's worst peacetime fire services disaster

- Over a million gallons of whisky and rum stored
- Neighboring buildings were engulfed
- Nineteen fire service members died

Photograph complements of the BBC

Fire History Examples (Continued)

- James Watt Street Whiskey Fire (Glasgow) – November 1968, when 22 people lost their lives
- 36 Roland Street Charlestown (Boston, MA USA) 1966 – Paper warehouse fire £894,615 loss

Photograph courtesy of the Glasgow Fire Journal

Result

Rack Storage Fire Protection Committee

- August 1967 the Rack Storage Fire Protection Committee (RSFP) was formed
- Largest, most ambitious fire test program ever – Over 190 full and small scale tests, 1968-1975
- Budget – £141,946 (£775,333 in 2014 GBP)
- Included representatives of the fire insurance interests, rack manufacturers, and fire protection equipment manufactures
- RSFP committee transmitted information to the NFPA committee for use in standard making

Purpose and Objective

Purpose

- To eliminate the widening gap between material handling and storage methods and existing fire protection technology.

Objective

- To obtain, by means of fire tests, data, which could form the basis for development of fire protection standards for rack storage.

Project Approach

Three Subdivisions of Variables

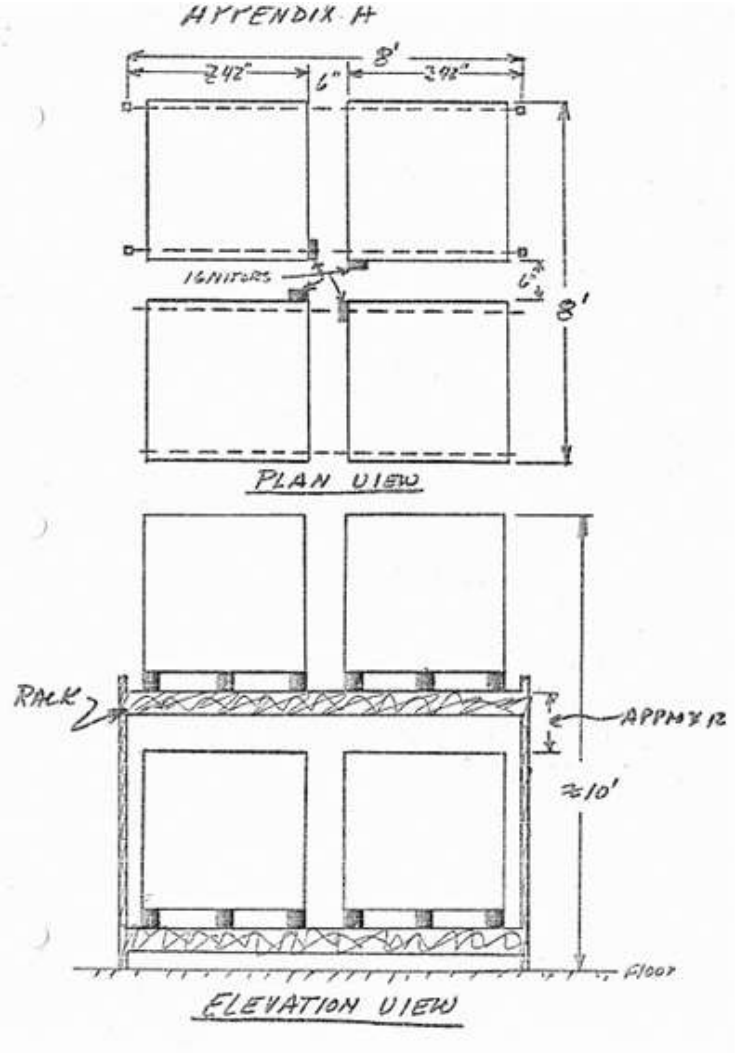
- Storage Arrangement – Type of racks, aisle spacing, flue spaces, etc.
- Unit Load – Commodity and packaging
- Level of Protection – Sprinkler type, design density, and placement

Storage Arrangement

- Storage height, aisle width, rack configuration was selected based upon current practice
- Over 60 free burning tests
- Type of pallet, flue spaces, and vertical tier height
- Test array
  - 2 pallets wide x 2 pallets long x 2 pallets high
- Pallet loads
  - 42 in x 42 in x 42 in
- Verification tests, 3 pallets high, were conducted with sprinklers designed to 0.30 gpm/sq. ft.

Test Results

- Test results indicated that 6-inch flues between racks and 12-inch vertical separation between loads were most severe.



Unit Load – Commodity and Packaging

- 70 small-scale commodity tests
- Identify a commodity which was representative of the broad range of combustibles found in a warehouse
- Readily available
- Inexpensive

Unit Load – Commodity and Packaging (Continued)

- Double tri-wall carton, six layers of corrugated cardboard.
- Hallmark products (greeting cards, paper party favors, cups, plastic table flatware, etc.) – Tested in full scale and observed to be similar to real life burning characteristics of standard products found in a warehouse.
- Adding metal liner to the double tri-wall carton resulting in a commodity that closely resembled Hallmark products. This became the standard commodity.
- High-hazard materials – Tires, plastics, flammable liquids, etc., were outside the scope of the series.

Level of Protection

Full-scale Testing

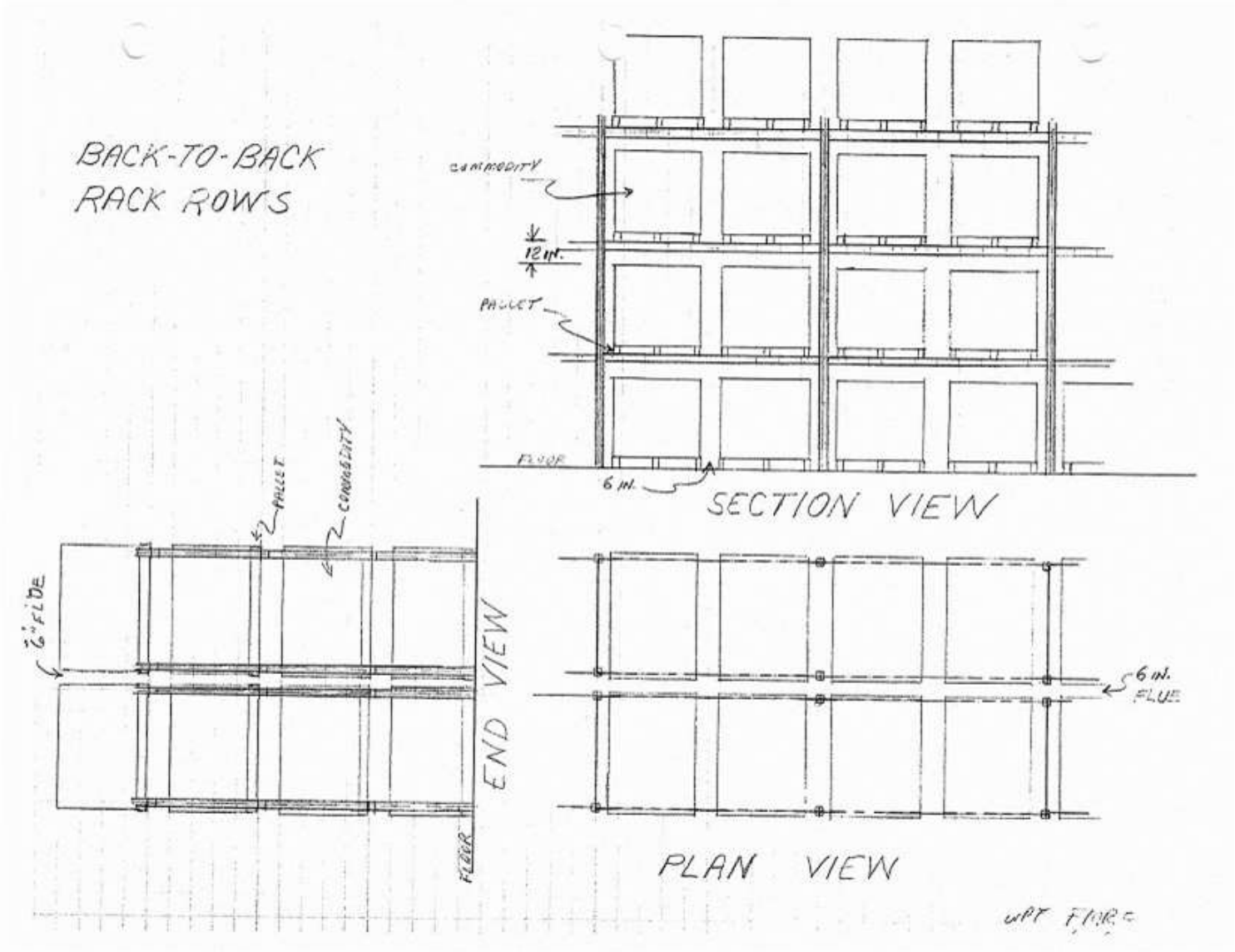
- Test Facility – FM Global Research Center in West Gloucester, Rhode Island (old test center)
  - 200 ft. x 250 ft. (50,000 square feet)
- 60 full-scale tests – Majority of the testing:
  - ½-inch orifice, 165 degree sprinklers
  - Design Density 0.30-0.45 gpm\sq. ft.
  - 20 ft. storage height = 10 ft. clearance
  - 4 or 8 ft. aisles
  - Standard commodity (Class II)
  - Approximately 4 tests (7%) with solid shelves

Level of Protection (Continued)

Acceptance Criteria

- Test was considered acceptable if the fire did not:
  - Burn to the end of the ignition rack
  - Burn beyond the first row of cartons in the target arrays
  - Open sprinklers to the outside wall of the test facility

Level of Protection (Continued)



Level of Protection (Continued)

Solid Shelf Testing

- Solid Shelf Testing Summary
  - Standard Commodity
  - 20 Ft Storage/30 Ft ceiling
  - 165 Degree F, ½-inch orifice sprinklers

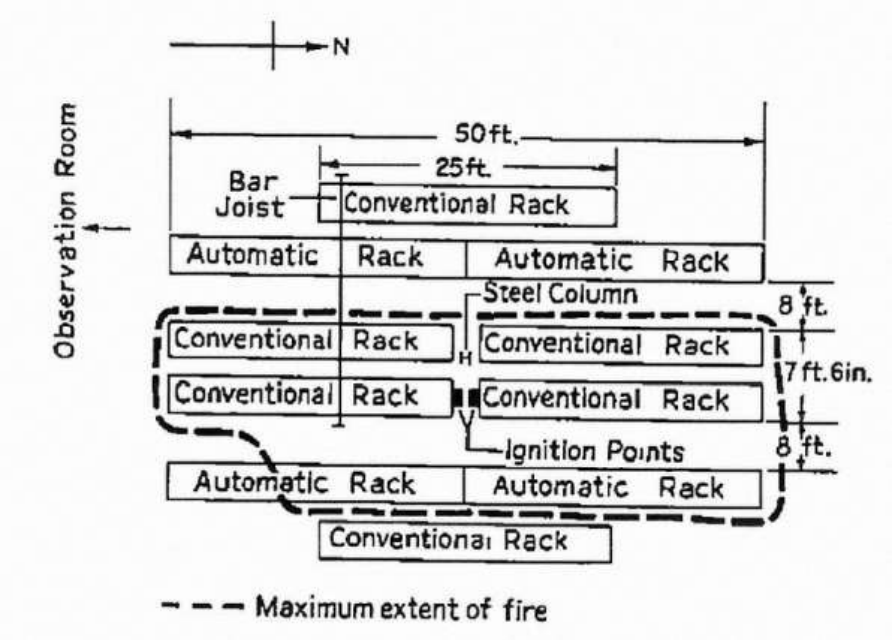
Level of Protection (Continued)

Test No.	Solid Shelf Size	Flue Space (In)	Aisle (Ft)	Sprinkler Density (gpm\sq. ft)	First Sprinkler Activation
98	7.5ft x 24ft 180 sq. ft.	0	8	Provided-0.30 Required-0.37	4:18
66	None	6LT	8	Provided-0.30 Required-0.37	3:11

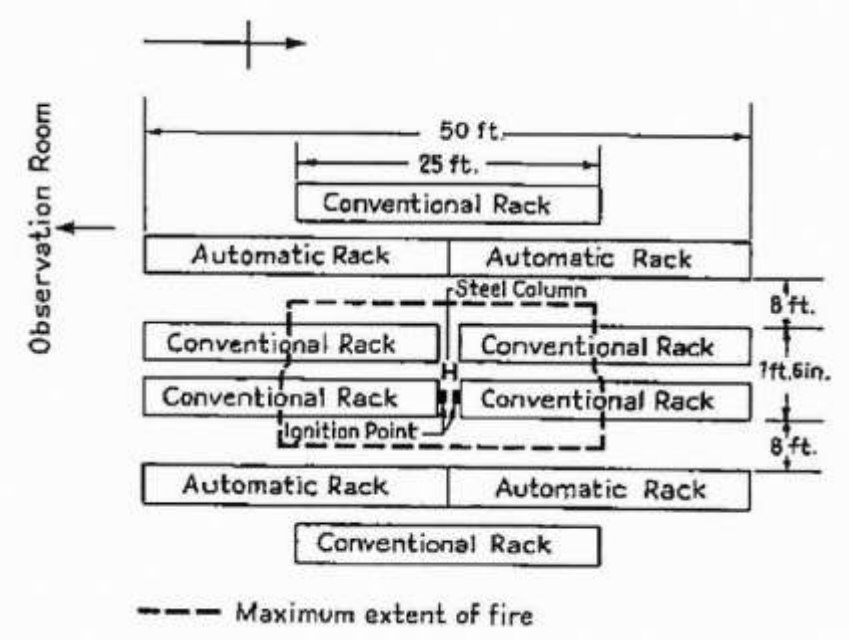
Test No.	No. Sprinklers Operated	Commodity Consumed Main Rack (%)	Commodity Consumed East Target (%)	Commodity Consumed West Target (%)	Max. Ceiling Air Temp (Degrees F)	Bar Joist Steel Temp (Degrees F)
98	58	100	0	18	1140-1:56	170
66	48	55	0	0	1630-19:50	180

Level of Protection (Continued)

Test 98



Test 66



Level of Protection (Continued)

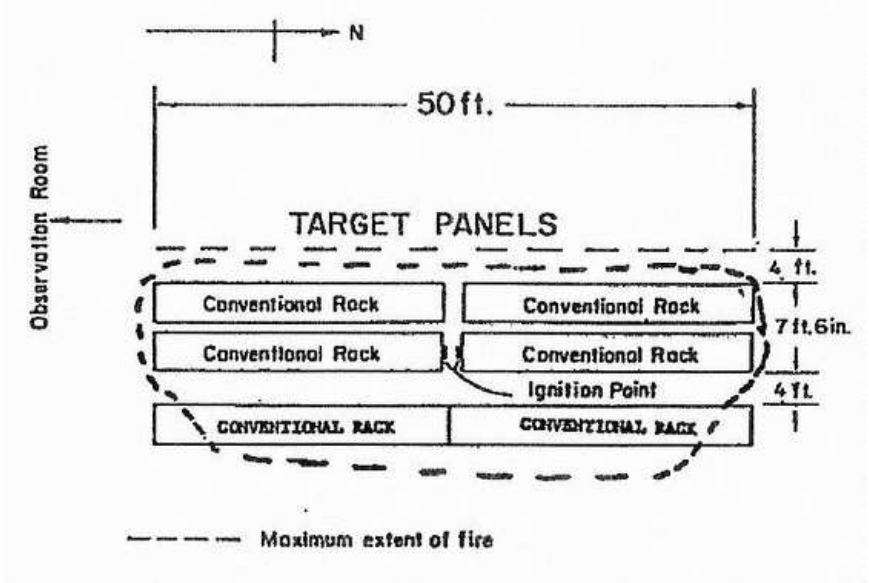
Solid Shelf Testing

Test No.	Solid Shelf Dimensions	Flue Space (In)	Aisle (Ft)	Sprinkler Density (gpm\sq. ft.)	First Sprinkler Activation	No. Sprinklers Operated
147	3.5ft x 7.75ft 27 sq. ft.	6 LT	4	Provided-0.45 Required-0.45	1:23	47
89	None (slave pallet)	6LT	4	Provided-0.45 Required-0.45	2:57	7

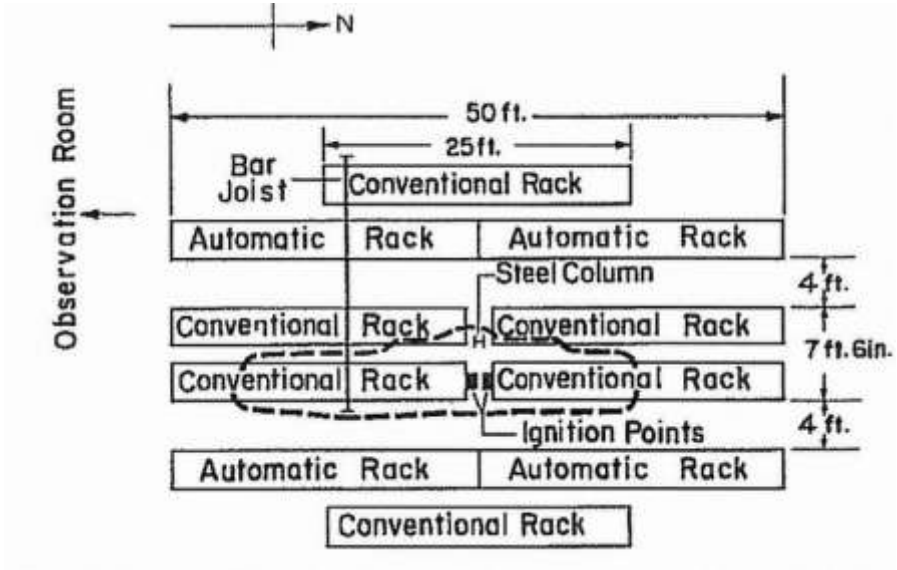
Test No.	Commodity Consumed Main Rack (%)	Commodity Consumed East Target (%)	Commodity Consumed West Target (%)	Max. Ceiling Air Temp (Degrees F)	Bar Joist Steel Temp (Degrees F)
147	91	74	0	1545-6:00	175
89	30	0	0	925	105

Level of Protection (Continued)

Test 147



Test 89



Concerns

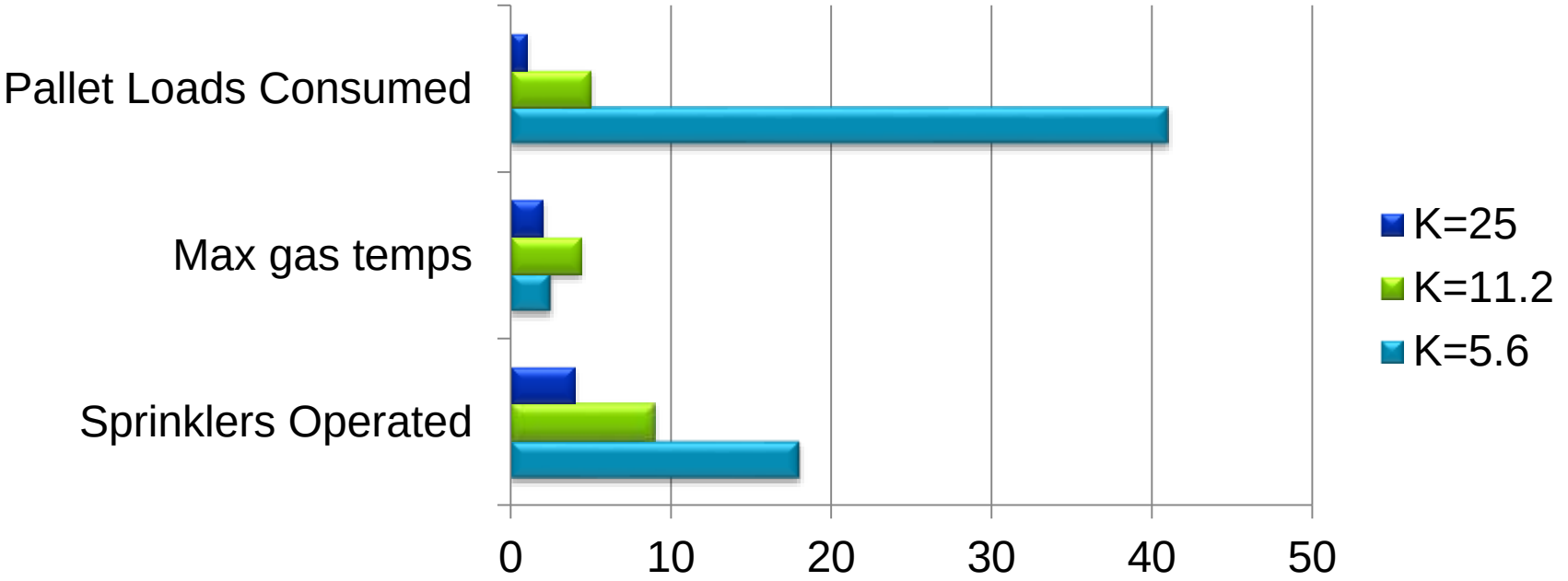
Use of Insufficient Sprinkler Design Density Test 98

Test No.	Solid Shelf Dimensions	Flue Space (In)	Aisle (Ft)	Sprinkler Density (gpm\sq. ft)
98	7.5ft x 24ft 180 sq. ft.	0	8	Provided-0.30 Required-0.37
66	None	6LT	8	Provided-0.30 Required-0.37

Concerns (Continued)

Use of ½-Inch Orifice Sprinklers

- Sprinkler Performance vs. Orifice Size
  - Rack Storage: 20 ft. High Class II\30 ft. Ceiling
  - Density: 0.37 gpm\sq. ft.



Troup and Vincent *Fire Test Performance of K-Factor 25 Control-Mode Extended-Coverage Sprinklers for Storage Occupancies* – NFPA World Safety Congress May 14, 2001

Concerns (Continued)

Current NFPA 13 Sprinkler Density\Orifice Size Requirements

Design Density (gpm\sq. ft.)	Minimum Sprinkler K Factor (gpm\min-psi ½)	Orifice Size (Inches)
≤ 0.20	5.6	0.5
> 0.20-0.34	≥ 8.0	≥ 0.53
> 0.34	≥ 11.2	≥ 0.64

Concerns (Continued)

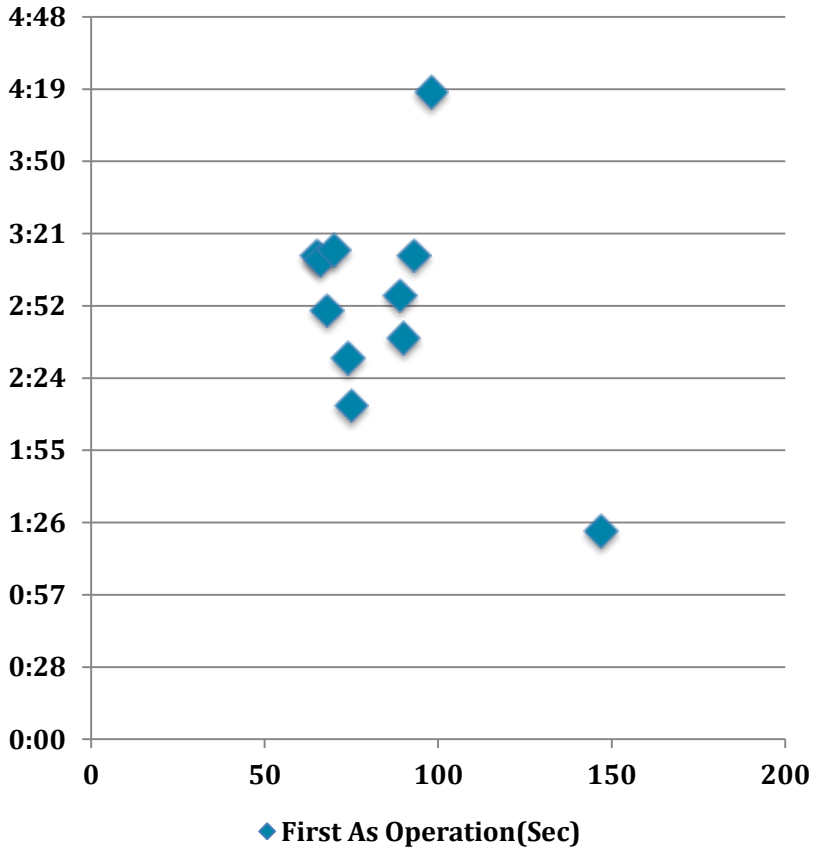
Use of Slave Pallets

Standard commodity on regular pallet on top of plywood slave pallet.

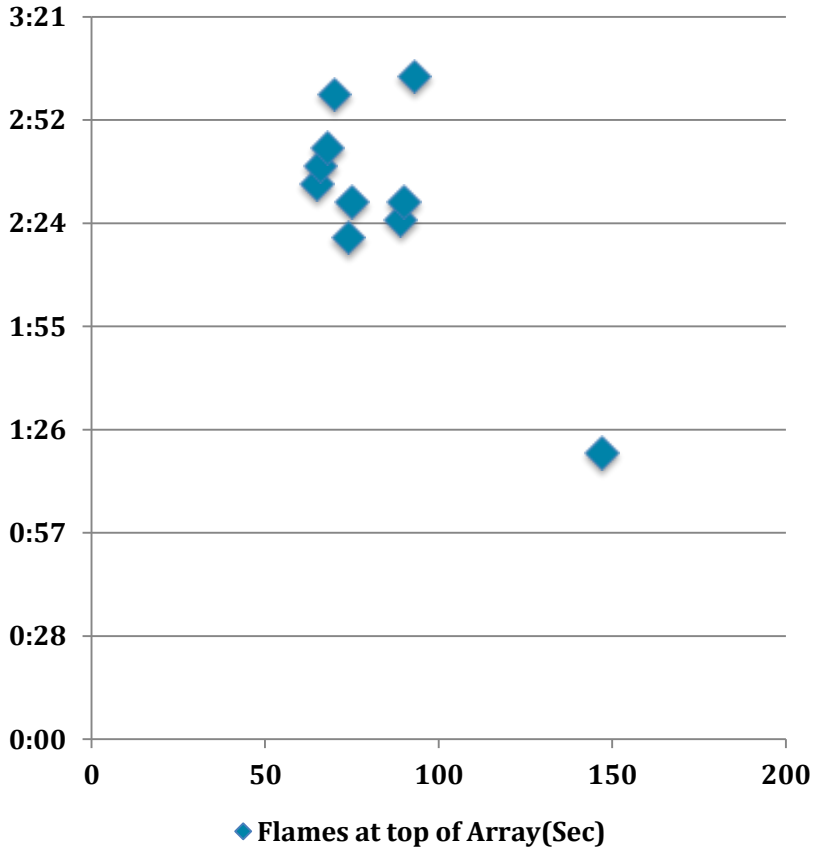
Concerns (Continued)

Review of Fire Behavior

Operation Time of First Sprinkler (Min.)

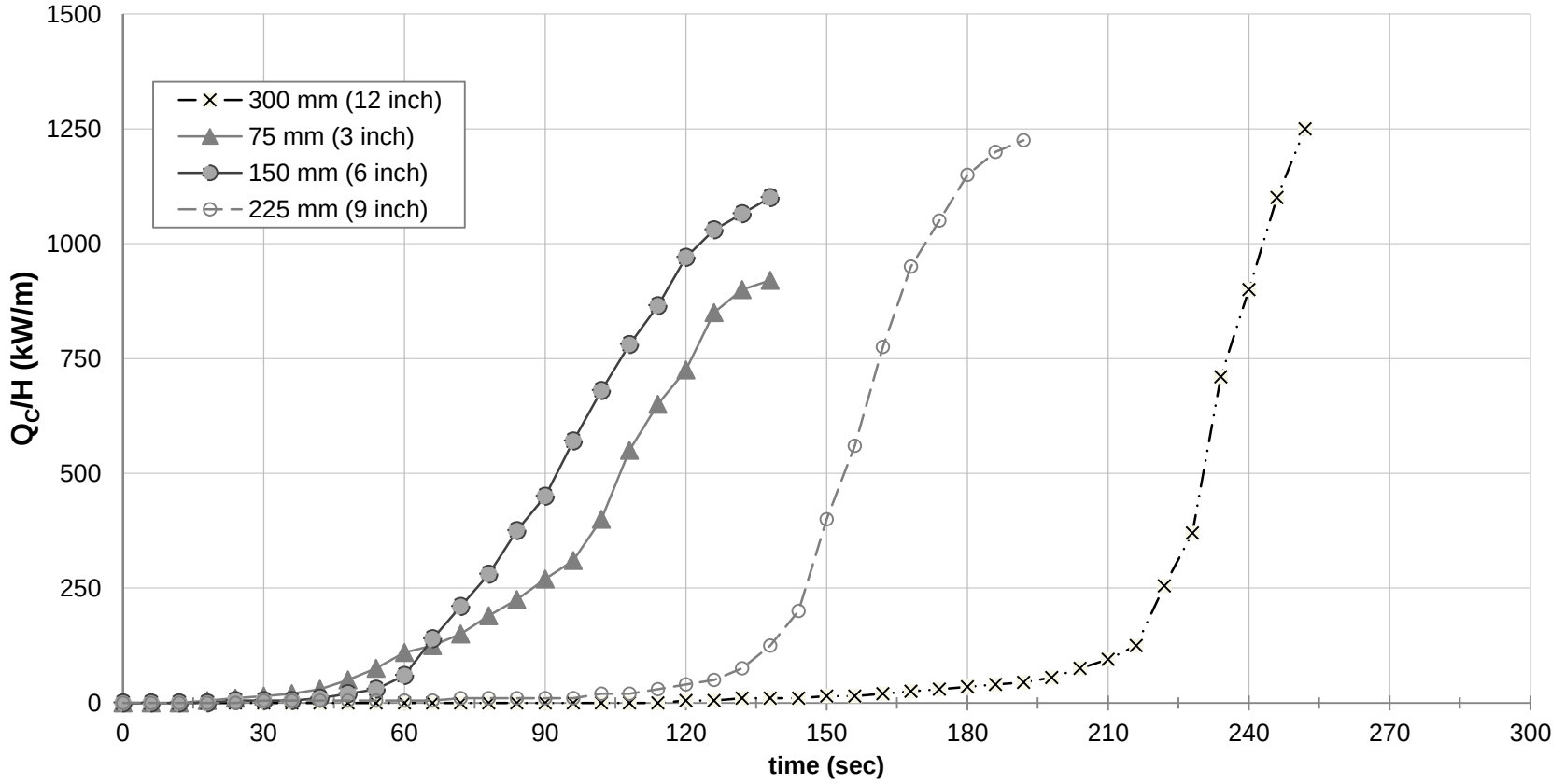


Flames at Top of Array (Min.)



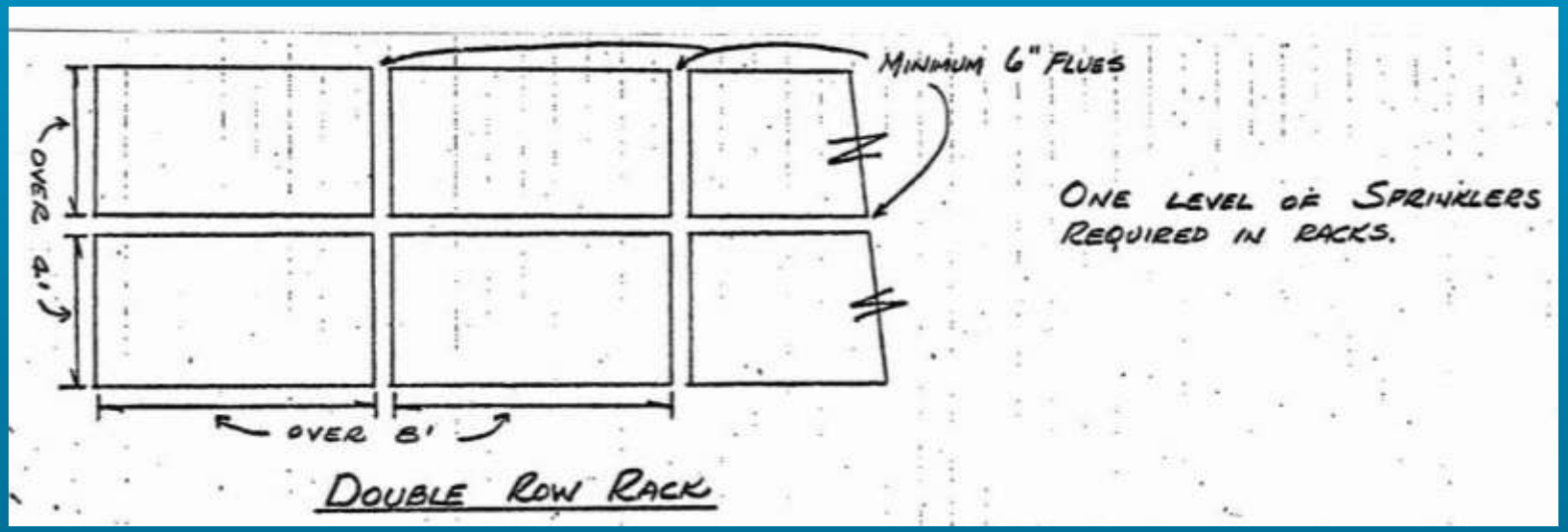
Rack Storage Fire Growth Rate

Convective Heat Release Rates per Height of Rack Storage Various Flue Space Width



Ingason H.- Effects of Flue Spaces and the Initial In-Rack Plume Flow-Fire Safety Science, Seventh International Symposium

Rack Storage Fire Protection Committee's Opinion



Observations – General

- Legacy fire testing provides a window into the technical level of science at that time
- Background and a starting point for future research
- Relevance of the work should always be considered

Observations – Specific

- The legacy fire research regarding solid shelf fire protection was appropriate for its time
- The sprinklers used in the testing are now out of date
- Modern sprinklers perform much better
- The limited number of tests makes the evaluation of the testing results challenging

Summary Statement

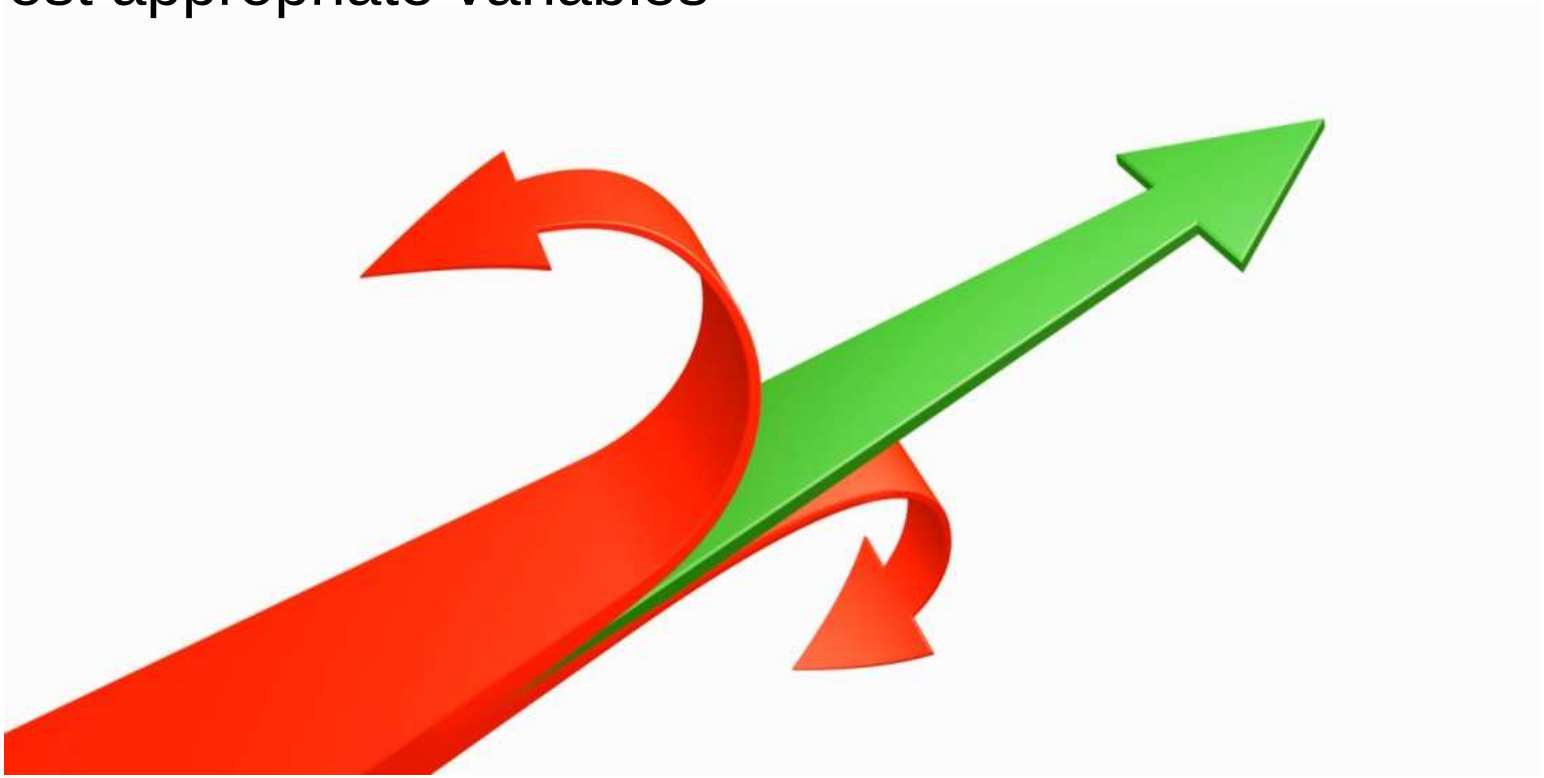
"These tests did not yield sufficient information to develop a comprehensive protection standard for solid shelf racks. Items such as increased ceiling density, use of bulkheads, other configuration in racks, and limitation of shelf length and depth should be considered."

Chester Schirmer, P.E.

The Rack Storage Fire Protection Committee

Direction Forward

- Conduct testing program using modern sprinkler technology
- Expand number tests
- Test appropriate variables



Questions