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Fire Protection Challenges Presented by Composite Intermediate Bulk Containers

Prepared by

The Fire Protection Research Foundation

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Presentation Purpose

- Introduce the Benefits, Limitations, and Fire Protection Challenges of Using Composite Intermediate Bulk Containers (CIBCs);
- Review Applicable Requirements for Storage of Liquid-filled Composite IBCs;
- Present Results of Fire Testing and Evaluation of CIBCs;
- Discuss the Difference between CIBCs that are Classified (“Listed and Labeled”) for Combustible Liquid Service and those that are not; and
- Discuss the Storage Limitations for non-Listed and non-Labeled Composite IBCs.

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Learning Objectives

- Understand common Composite IBC Nomenclature;
- Become aware of Fire Protection challenges presented by Composite IBCs;
- Understand the prohibition of using Composite IBC's for the storage of Class I flammable liquids contained in most model fire codes;
- Understand and apply the current storage and protection practices available in NFPA 30 for Composite IBCs used to store combustible (Class II and Class III) liquids;
- Become aware of the existing international body of publicly available Composite IBC fire testing data;
- Understand the issues surrounding Listed and Labeled Composite IBCs contained in NFPA 30, and the impact on protected and unprotected storage classification; and
- Be able to better understand the fire control challenge presented by composite IBCs used to store combustible liquids, and more effectively use the protection strategies available in NFPA 30.

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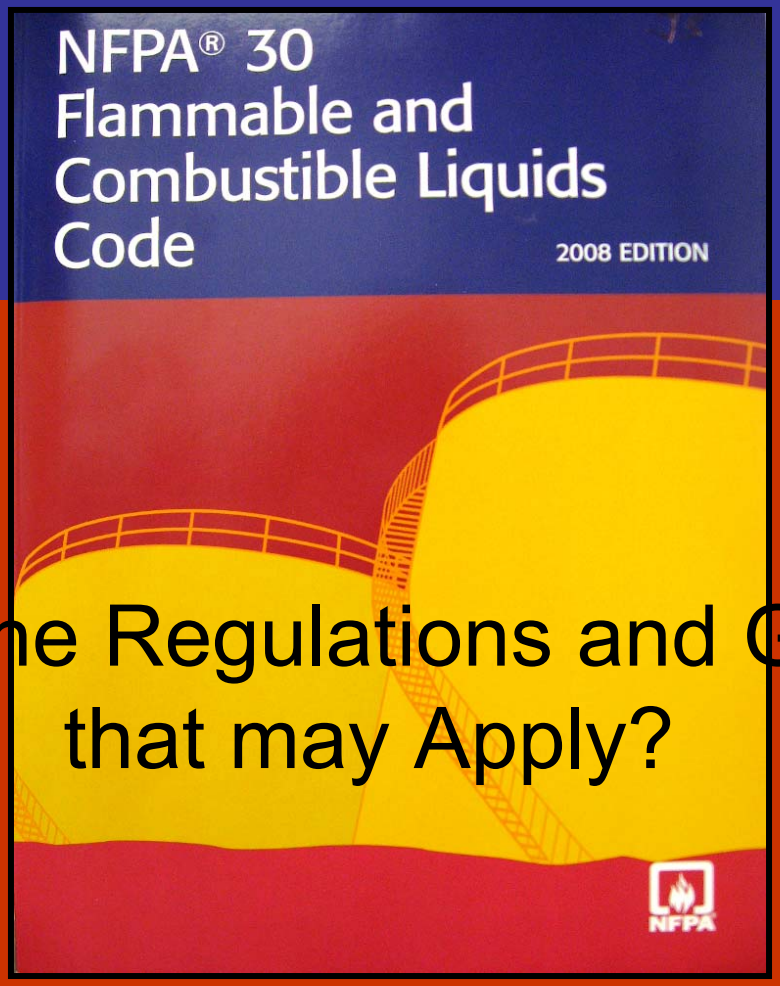
Contents of this Presentation

- Part 1 – What are the Regulations and Guidelines that may apply?
  - Current storage and protection practices form a regulatory and insurance standpoint
- Part 2 – What are the characteristics of Composite Intermediate Bulk Containers?
  - Nomenclature and construction characteristics
- Part 3 – Industry Fire Tests of IBCs sponsored by The Fire Protection Research Foundation
  - Testing used to identify characteristics of hardened, fire resistive IBCs and the development of an associated listing and approval process
- Part 4 – Testing of Composite IBCs Storing Combustible Liquids
  - Follow-on testing of common, nonapproved Composite IBCs storing higher flashpoint liquids, and comparison with Listed CIBCs
- References – 1996 to present

PART I



What are the Regulations and Guidelines that may Apply?

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Who May Regulate or Restrict the Use of Liquid Containers?

- In transit
  - US Department of Transportation
- In buildings and facilities
  - State and Local Building and Fire Codes
    - *International Building and Fire Code;* and
    - Many jurisdictions adopt or recognize NFPA 30, *Flammable and Combustible Liquids Code.*
  - US Dept of Occupational Safety and Health (OSHA)
    - NFPA 30, 1969; and
    - State adoption.
  - Insurers

Important Definitions

- Intermediate Bulk Container (DOT)
  - > 450 L (119 gal), up to 3,000 L (793 gal)
- DOT Packing Groups for CIBCs
  - "Medium Danger" – Packing Group II, FP < 23°C (73.4°F), BP > 35°C
  - "Low Danger" – Packing Group III, FP ≥ 23°C (73.4°F), ≤ 60.5°C (140.9°F), BP > 35°C
- Flammable Liquid (NFPA 30)
  - FP < 37.8°C (100°F)
    - Class IA – FP < 22.8°C (73°F), BP < 37.8°C (100°F)
    - Class IB – FP < 22.8°C (73°F), BP ≥ 37.8°C (100°F)
    - Class IC – FP ≥ 22.8°C (73°F), but < 37.8°C (100°F)
- Combustible Liquid (NFPA 30)
  - FP ≥ 37.8°C (100°F)
    - Class II – FP ≥ 37.8°C (100°F), but < 60°C (140°F)
    - Class IIIA – FP ≥ 60°C (140°F), but < 93°C (200°F)
    - Class IIIB – FP ≥ 93°C (200°F)

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DOT

- Many composite IBCs are approved by DOT as a Packing Group II Container (UN 31H1, UN 31H2, UN 31HZ1).
  - A variety of “medium hazard” products; and
  - Includes Class **IB**, **IC**, II, and III Flamm/Combustible Liquids.
- Containers must pass physical tests, e.g., pressure test, drop test.

Note: Explicit fire testing of container is not performed for DOT approval.

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NFPA 30

- Scope – Container and portable tank storage (particularly within buildings)
- Acceptable Containers
  - Governed by Chapter 9, Section 9.3 – UN/DOT container classifications are generally used for large containers;
  - Covers Classes I, II, and IIIA liquids; and
  - Includes
    - glass
    - metal
    - plastic
    - fiber

- Maximum Allowable Sizes – Table 9.3.3
  - Limits capacity of specific container types when storing particular Classes of liquid; and
  - Prohibits use of certain container types for particular Classes of liquid.

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NFPA 30 Full Scale Fire Tests

- Table 9.3.3 Containers not permitted for specific liquids
  - NP – not permitted for the container categories so classified, *unless* a fire protection system is provided that is developed in accordance with Chapter 16 and is approved for the specific container under consideration.

- Full-scale fire test;
- Verification that specified level of protection is capable of fire control;
- For specific container design; and
- For specific Classes of liquid.

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NFPA 30 Protected & Unprotected Storage

- Unprotected Storage
  - Regulatory limits on storage configuration & amounts;
    - More flexibility in Liquid Warehouses
  - Storage of combustible liquids in non-listed IBCs is automatically classed as “unprotected” storage; and
  - Insurance implications of Unprotected Storage.
- Protected Storage
  - Unlimited storage amounts;
  - Storage configuration limitations;
  - Sprinkler systems with large hydraulic demands are required;
    - Most fire codes also have fire water containment provisions
  - Storage of combustible liquids in listed Composite IBCs can be classed as “protected storage.”

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Storage Requirements for Composite IBCs
Protected Storage (Unlimited Quantity)

- First, containers must be Listed and/or Labeled;
- Secondly, storage configuration must be maintained; and
- Lastly, adequate fire protection must exist.
- Palletized Storage (NFPA 30 (2008) – Table 16.5.2.10)
  - One-high – 0.45 gpm/sq ft over 3000 sq ft; and
  - Two-high – 0.60 gpm/sq ft over 3000 sq ft.
    - For two-high storage, minimum sprinkler pressure is 30 psig.
- Rack Storage (NFPA 30 (2008) – Table 16.5.2.10)
  - Use Scheme B from NFPA 30 (2008) – 16.6.2;
  - Requires horizontal barriers at each rack level; and
  - Requires face and flue sprinklers at each level and a ceiling sprinkler density of 0.60 gpm/sq ft over 3000 sq ft.

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Storage Limitations for Composite IBCs Unprotected Storage

- Applies any time an Unlisted Composite IBC is used.
- May not be used for Storage of Class I Liquids.
- Storage arrangements and amount limited by NFPA 30 (2008) Table 12.6.2.
- Additional allowances for occupancies Classified as “Liquid Warehouses.”
- Unprotected means that it is reasonably expected that in a fire situation, large (or total) loss will occur, regardless of protection provided.

NFPA 30 (2008) Table 12.6.2.2			
Liquid Class	**Max Storage Height (Feet)**	**Max Storage per Pile (Gal)**	**Max Total Qty (Gal)**
II	7	4125	8250
IIIA	7	13750	27500
IIIB	7	13750	55000

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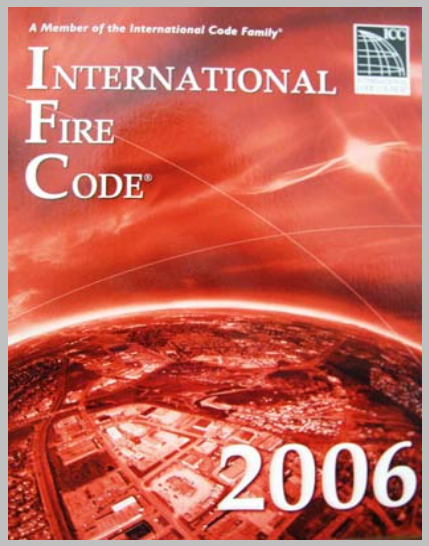
International Fire Code – 2006

- Portable Tanks
  - Shall not exceed 2495 L (660 gal).
  - Must comply with 9.4.1 of NFPA 30 2008 Edition (reference to 49 CFR).
  - Only “Approved” containers and portable tanks shall be used.
  - By reference to NFPA 30, the IFC effectively limits liquids stored in CIBCs to **combustible** liquids.



- Note – portable tanks are the predecessor to metal IBCs and are no longer manufactured.
  - Existing metal portable tanks may be used if they pass periodic DOT-required tests.

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OSHA

- Section 1910.106
- Based on NFPA 30 (1969)
- Plastic containers discussed in several interpretation letters
  - http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=1778

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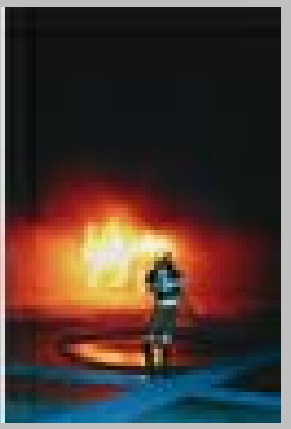
Insurers

- FM Global Property Loss Prevention Data Sheets Regarding Composite IBCs
  - Data Sheet 7-29, specifically regarding composite IBCs
    - "Additional Research is needed to finalize a test for evaluating the fire performance of IBCs."
    - No recognition of "approved" composite IBC.
  - For palletized liquids at or below 200°F FP
    - Inside Cutoff Room Storage – "Not Acceptable."
    - Outside Cutoff Room Storage.
      - K = 11.2 water sprinklers at 75 psi, plus drainage



- For palletized liquids above 200°F FP – see data sheet protection options.

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Summarizing Key Fire Protection Issues

- NFPA 30 serves as a mandatory Flammable & Combustible Liquid rule in many jurisdictions.
- Occupancies using Composite IBCs are subject to the limitations of Unprotected Storage, unless:
  - The containers are Listed and Labeled;
  - Approved storage configurations are used; and
  - Adequate fire sprinkler capacity is available.

  Note: Facilities classified as Liquid Warehouses have some additional flexibility.
- Current fire codes do not allow storage of Class I Flammable Liquids in Composite IBCs.

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Summarizing Key Fire Protection Issues (Cont'd)

- Continued fire testing and field experience may change the method for how containers are Classified (Listed) and what protection criteria is specified.
- The key is for fire professionals to stay informed on this important topic.

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Part I - Summary and Conclusions

- It is important to understand the differences between flammable and combustible liquids. Combustible liquids have higher FPs, and are more difficult to ignite than flammable liquids. Combustible liquids, once ignited, can release as much and sometimes more thermal energy per gallon (per pound) as do flammable liquids.
- Many people assume that “DOT” approval automatically translates into container approval for indoor storage. **This is not true.**

- NFPA 30 has adopted “protected” and “unprotected” storage concepts. The circumstances where a regulator or insurer will allow “unprotected” storage are limited.

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Unresolved Issues

- There appears to be a significant amount of warehouse flammable and combustible liquid storage in non-Listed IBCs.
- Class IB and IC liquid storage is not approved for Composite IBCs.
- DOT approval vs. NFPA Listing requirement.
- DOT “approved” containers not equal to fire resistive “Listed” containers.
- Importing of IBCs storing liquids into the U.S. creates issues since fire regulation of composite IBCs is not consistently enforced.
- Cost – Listed units cost between 2x and 4x that of non-Listed units.
- The current Listed units have not been commercially successful.
- Lack of HPR insurer recognition.
- Lack of consistent fire code enforcement of non-Listed composite IBCs (restrictions of unprotected storage).

PART II

What are the Characteristics of Composite Intermediate Bulk Containers?

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DOT Container Categories

- Non-bulk container
  - up to 450 L (119 gal)
- Intermediate bulk container
  - > 450 L (119 gal), up to 3,000 L (793 gal)
- Bulk container
  - > 3,000 L (793 gal)

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Non-metallic Intermediate Bulk Containers

- Rigid plastic IBC (UN 31H)
- Composite plastic IBCs
  - “metal cage” (UN 31HA)
  - “spam can” (UN 31HA)
  - “bag-in-the-box”

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What is a Typical Composite IBC (CIBC) Used for Storage of Liquids?

- A family of "mini-bulk" containers between 60 and 660 gallons.
  - The most common units are 275 gallons (1 m^3).
- "Composite" refers to multiple materials of construction, typically polyethylene (inner container) and steel (outer system).
  - Plastic vessel serves as primary liquid holding component; and
  - Also called "Rigid non-metallic IBCs" in several codes.

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What are the Advantages of Composite IBCs?

- Improved Space Utilization
- Optimized Transportation Footprint
- Handling & Filling Simplification
- Recycling & Environmental Advantages
- Many Units are Approved by DOT as a Packing Group II Container (UN 31H1, UN 31H2, UN 31HZ1)
  - A variety of "medium hazard" products; and
  - Includes Class IB, IC, II, and III Flamm/Combustible Liquids

Most Fire Codes Limit Use of Composite IBCs to Store Class II and III Liquids Only

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Concerns Regarding Composite IBCs (CIBCs)

- While not typically the "start" of a fire, large leaks of liquids may serve as significant fuel sources.
- Unprotected CIBCs might fail rapidly during fire exposure and rush 275 gallons (or more) of fuel into an existing fire.
  - This may overwhelm fire sprinkler designs, particularly where water is used instead of foam.

- The large capacity of the containers raises concerns about potential fuel contribution to a fire from multiple container failures.
- On the other hand, IBCs probably would not rocket like steel containers exposed to fire.
- Insurers are hesitant to recognize storage of these containers.

The Industry responded by conducting full scale tests starting in 1996.

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Part II - Summary and Conclusions

- Composite intermediate bulk containers used for liquids usually consist of plastic bottles surrounded by a metal outer structure.
- DOT recognizes variations of these units for transport of liquids.
- There are significant operational advantages for using these containers to store liquids.
- There are questions about the suitability of using these containers should a fire occur in a warehouse.


PART III
Industry Fire Tests of IBCs
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Guiding Principles

- NFPA 30 “Protected” and “Unprotected” Protection Criteria
  - Goal of “protected storage.”
- NFPA 30 Annex E *Suggested Test Protocol for Developing Fire Protection for Containers of Flammable and Combustible Liquids*
  - Used as a guide in developing test plan.
- FPRF Test Program
  - Scope failure mechanisms;
  - Test palletized arrays;
  - Identify protection criteria;
  - Develop test methods; and
  - Extend results to rack storage.

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Performance Parameters – Palletized Arrays

- No overpressure of the container
- No involvement of adjacent units
  - No liquid leakage; and
  - Holing in ullage might be permitted if liquid doesn't spill.
- Structural stability of units and array
  - No collapse.
- Maintain ceiling structural steel below critical temperatures

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Palletized Array Testing

- 10 gal. heptane spill + 2 gpm running fuel fire
- “Nested” location (interior of array) 30 ft ceiling
- 1- and 2-high arrays
- 2 x 2 array and 2 x 4 with target array
- 30 minute exposure

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Conclusions – Palletized Arrays

- IBCs are designed and perform differently.
- For the best performing IBCs, liquid leakage from the container could be prevented by overhead water sprinkler protection.
  - One-high storage – 0.45 gpm/sq.ft.
  - Two-high storage – 0.60 gpm/sq.ft.

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Rack Storage Tests

- 5-high storage, 8-ft. aisle
- 10-gal heptane spill + 2 gpm running fuel fire
- 30-ft. ceiling
- In rack sprinklers
  - Flue and/or face;
  - With and without barriers; and
  - Water or foam.

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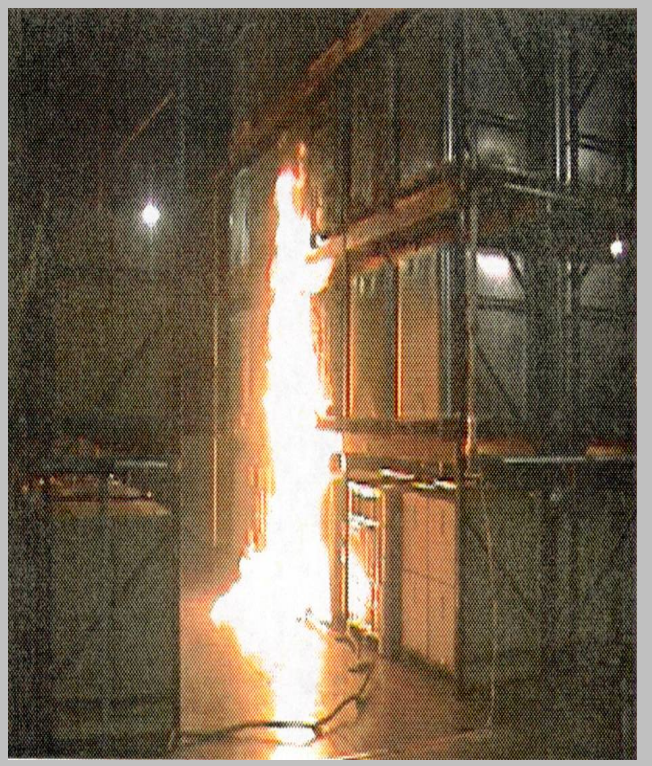
Conclusions – Rack Storage Tests

- Need horizontal barriers
- "Surround and drown" water suppression (NFPA 30, Section 16.6.2 Scheme B)
  - Face sprinklers at uprights;
  - Flue sprinklers 4 ft O.C.; and
  - 50 gpm/sprinkler.



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Development of Listing Program

- UL 2368 test standard (60-793 gal IBCs)
  - Based on the FPRF large scale and verification tests;
  - Alternative tests methods;
    - Reduced scale
    - Large scale
  - Performance criteria;
    - No loss of liquid
    - Structural stability
  - Currently there are two Classified containers.
    - http://www.ul.com/regulators/ibc.cfm.

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Changes Resulting from IBC Testing

- Changes to NFPA 30
  - Palletized and rack storage protection criteria;
    - Tables 16.5.2.9 and 16.5.2.10
  - Listed containers;
  - Class II and III liquids; and
  - Bag-in-box tested and recognized for Class IIIB liquids (Table 16.5.2.5).
- Other tests were and continue to be performed – proprietary (not in the public domain).

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Storage Requirements for Composite IBCs
Protected Storage (Unlimited Quantity)

- First, Containers Must be Listed and/or Labeled;
- Secondly, Storage Configuration must be Maintained; and
- Lastly, Adequate Fire Protection Must Exist.
- Palletized Storage (NFPA 30 (2008) – Table 16.5.2.10)
  - One-high – 0.45 gpm/sq ft over 3000 sq ft.; and
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  - Requires face and flue sprinklers at each level and a ceiling sprinkler density of 0.60 gpm/sq ft. over 3000 sq ft.

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PART III - Summary and Conclusions

- Industry performed an extensive series of fire tests.
- Protection criteria and an associated Listing process were developed based on this testing.
- Composite IBCs must be Listed/Labeled to take advantage of the benefits of “protected storage” in NFPA 30.

PART IV

Testing of *Composite* IBCs
Storing *Combustible* Liquids

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Perceptions

- There is not much difference between Listed and non-Listed containers.
- The protection of Class IIIB liquids at or above 200°F (93°C FP) might be protected in non-Listed containers.

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Additional Concerns

- Use of water ladening in original FPRF tests
  - Heptane was floated on the water ladening surface; and
  - A verification test was performed with hep ladening.
    - Would testing with 100% liquid ladening effect results?
- Review HSL (UK) Report and Video "Fire Risks of IBCs"
  - Conclusion that high FP liquid may lead to quicker container failure than lower FP liquids – attributed to potential hydrocarbon permeation through HDPE.
    - http://www.hse.gov.uk/research/rrhtm/rr564.htm

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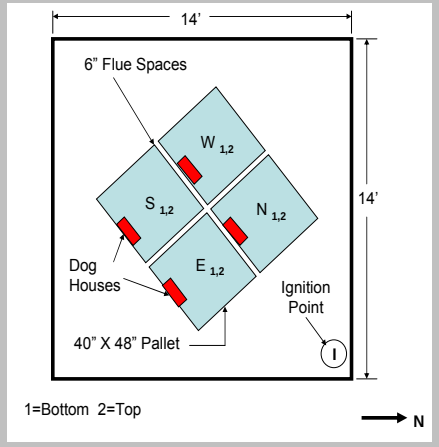
Phase I – Determine if Non-Listed IBCs Storing Combustible Liquids could be Protected

30-ft Warehouse Scenario

- Water or AFFF
  - 16 standard response heads on 10 x 10 ft spacing
  - 2 x 2 x 2-high array of full IBCs with 6-in. flue in a 14 ft x 14 ft pan
  - Mineral Seal Oil, FP = 270°F



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Performance Parameters – Palletized Arrays

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- Structural stability
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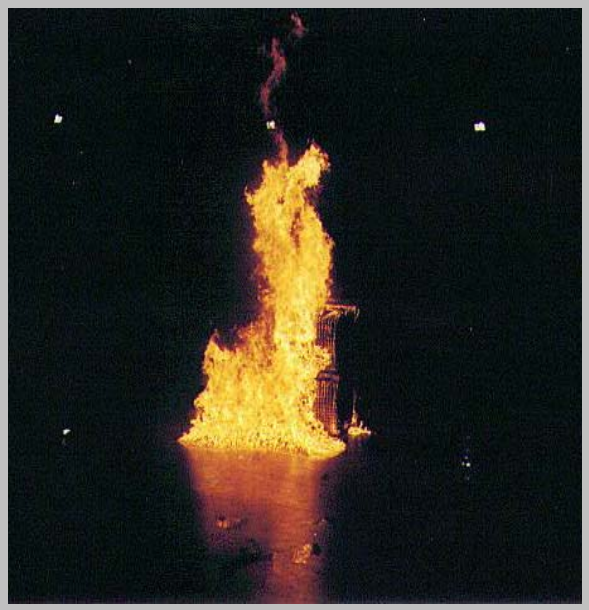
- Maintain ceiling structural steel below critical temperatures



Intermediate Bulk Container (IBC)

- Model SX-EX composite IBCs (non-Listed), provided by Schutz Container Systems
  - 275-gal capacity;
  - Inner HDPE bottle, wrapped in an outer layer of galvanized steel;
  - Integral steel pallet; and
  - Mineral seal oil – FP 264ºF.

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Test 1

- 286ºF, k = 11.2 sprinkler heads
- 0.60 gpm/ft^2 of water
- Sprinkler actuation time – 3:06
- # sprinklers operated – 4

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Test 1 Results

- Fire not extinguished – test terminated after 11 minutes
- Number of units breached – 4
- Maximum air temperature – 450ºF/3:08
- Maximum steel temperature – 175ºF/3:12

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Test 1 – Post-test damage

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Test 2

- 155ºF, k = 11.2 sprinklers
- 0.45 gpm/ft^2 AFFF
- Sprinkler actuation time – 1:43
- # sprinklers operated – 6

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Test 2 Results

- Time to extinguish (after sprinkler operation) – 1:49
- Number of units breached – 1 (container remained essentially full)
- Maximum air temperature – 257ºF/1:43
- Maximum steel temperature – 121ºF/2:39

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Tests 3–4

- 286ºF, k = 11.2 sprinklers
- 0.45 gpm/ft^2 of a foam/water solution
- Sprinkler actuation
  - 2 sprinklers at 3 min, outside ring;
  - 7 minutes – 3rd sprinkler operated; and
  - wind effects.
- Test terminated after 10 min
- 6 containers breached
- Results inconclusive

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General Conclusions from Phase I

- Non-Listed IBCs storing high FP liquids can probably be protected using AFFF with high application rates.
- High FP pool fire was controlled with water, but not well-established flue fire.
  - Would faster response sprinklers be more effective?
- Validation testing needed.

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Questions from Phase I to Answer in Phase II

- Is there a difference in Listed vs. non-Listed IBCs for the large pan fire scenario?
- If not, are the performance differences due to:
  - Test method (large pan in these tests vs. smaller pan or floor fire in Listing test method), or
  - Liquid ladening?

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Phase II – Test Constants

- 30 ft ceiling
- 286ºF, standard response, k=11.2 pendant sprinklers
- 0.60 gpm/sq.ft. water sprinkler protection
- Test array – 2 x 2 x 2
- All containers – UL Classified – Schutz SX-EX UL

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Phase II – Variables

- Test configuration
  - Test 1 – 14'X14'pan
  - Tests 2 & 3 – UL large-scale classification method (2 gpm heptane spill)
- Liquid ladening
  - Mineral oil – Tests 1 & 3
  - Water – Test 2
- Test 1 – Repeat of Phase I, Test 1, using Classified (Listed) IBC
- Test 2 – Repeat of Test 1 using 2 gpm spill with water ladening
- Test 3 – Repeat of Test 2 using mineral oil ladening

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Test 1 – Repeat of Test 1, Phase I, Using Listed CIBC

- 20 minute duration
- First sprinkler – 1:22
  - 4 sprinklers operated
- Steel temperature
  - Max. – 85ºF
  - At end of test – 68ºF
- Damage
  - 5 units – catastrophic failure
  - 1 unit leaking

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Test 2_– Repeat of Test I Using Floor Fire Scenario and Water as the Liquid Ladening

- 30 minute duration
- First sprinkler – 0:43
  - 2 sprinklers operated
- Steel temperature
  - Max – 89ºF
  - At end of test – 59ºF
- Damage
  - 1 unit w/slit leak
  - 1 unit w/ullage holing
  - 1 unit w/cap burned off

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Test 3 – Repeat of Test 2 using Mineral Oil Ladening

- 30 minute duration
- First sprinkler – 0:27
  - 3 sprinklers operated
- Steel temperature
  - Max – 87ºF
  - At end of test – 63ºF
- Damage
  - 1 w/valve outlet leak plus doghouse leak
  - 1 w/face leak

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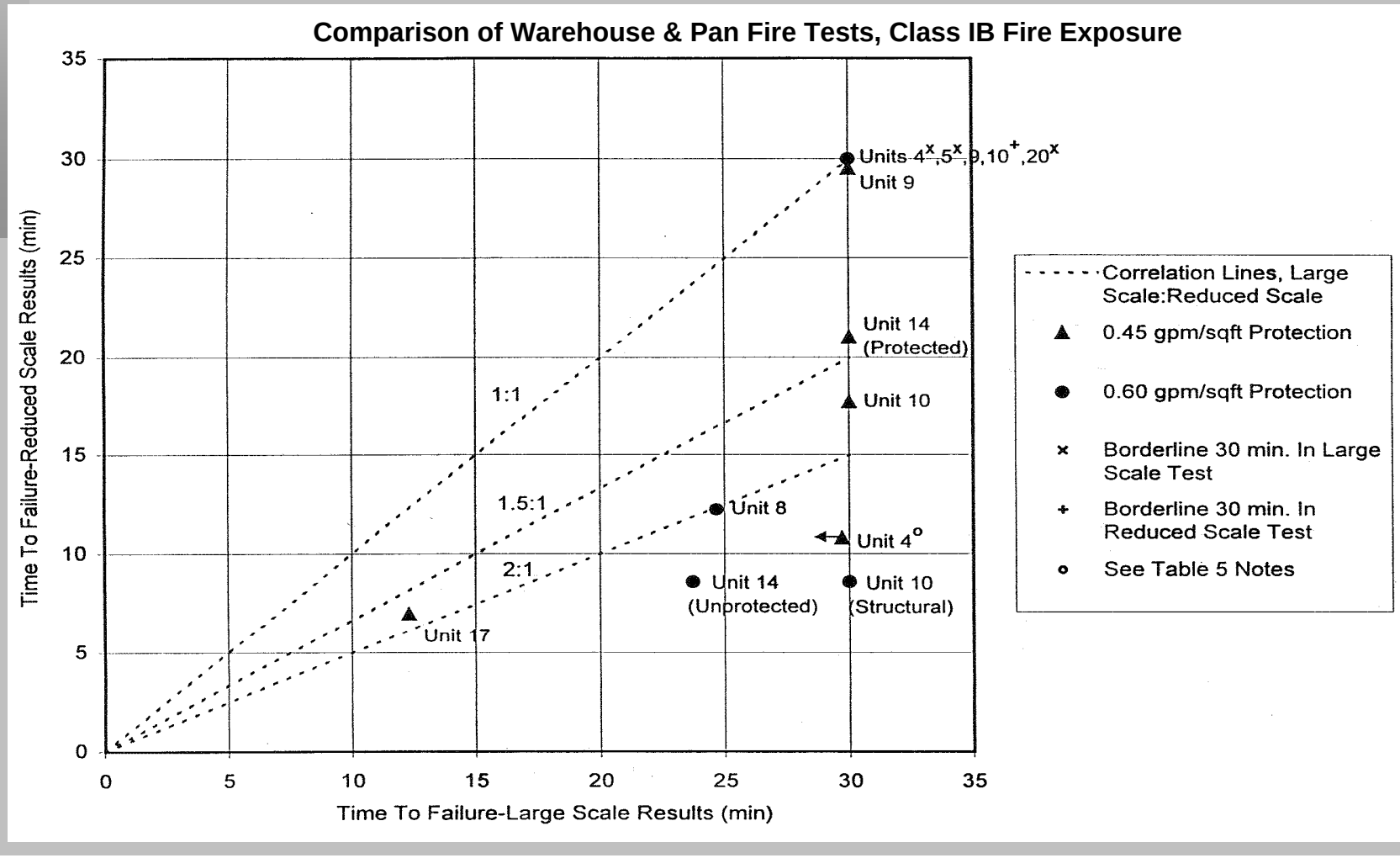
Conclusions – 14X14 Pan not Equivalent to UL Large Scale Test



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Phase II – Conclusions

- Liquid ladening – no significant differences observed
- Test 3 mineral oil IBC performance consistent with original IBC assessment
  - IBC hardening plus cooling from sprinklers is needed to prevent container breeching.
- Construction of “as delivered” Listed IBCs needs improvement
  - Improved corner design;
  - Ceramic paper must cover over all surfaces; and
  - Observed breaches seemed to coincide to areas where insulation coverage was suspect (edges and overlap).

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Part 4 – Summary and Conclusions

- Large pan fire exposures provide a greater fire threat to CIBCs than scenarios previously tested.
- Water will not suppress a well-established flue fire, particularly in the pan fire scenario.
- No significant performance differences were observed between water and mineral oil ladening (Phase II, Tests 2 vs. 3).
- A hardened CIBC plus suppression is required to provide protection for a floor fire scenario.

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Summarizing Key Fire Protection Issues

- NFPA 30 serves as a mandatory Flammable & Combustible Liquid rule in many jurisdictions.
- Occupancies using Composite IBCs are subject to the limitations of Unprotected Storage, unless:
  - The Containers are Listed and Labeled;
  - Approved Storage Configurations are used; and
  - Adequate Fire Sprinkler capacity is available.

  Note: Facilities classified as Liquid Warehouses have some additional flexibility.
- Current fire codes do not allow storage of Class I Flammable Liquids in Composite IBCs.

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Summarizing Key Fire Protection Issues (Cont'd)

- Continued fire testing and field experience may change the method for how containers are Classified (Listed) and what protection criteria is specified.
- The key is for fire professionals to stay informed on this important topic.

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