

## Assessment of Hazards in Flammable and Combustible Liquids in Composite IBCs in Operations Scenarios

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NFPA 30 *Flammable and Combustible Liquids Code* provides specific guidance for both containment and fire protection of Listed Intermediate Bulk Containers (IBCs) containing flammable and combustible liquids in storage configurations. However, a common usage scenario involves the use of non-Listed, composite IBCs containing flammable/combustible liquids in operations scenarios. The code does not provide specific fire protection criteria for these applications. The only guidance provided, to date, relates to the quantities of liquids that are permitted in such scenarios. Historically, the protection schemes prescribed in NFPA 30 have been based on experimental testing and engineering analysis. As such, the goal of this work is to identify protection strategies that can be evaluated in accordance with Appendix E of NFPA 30. If adequate performance is identified, it might be implemented into the code.

This assessment was limited to the hazards associated with the use of both flammable and combustible liquids (i.e., Class IB–IIIB) in non-Listed/Approved IBCs (i.e., Type 31HA1\Y). The IBCs were considered as being out in the open (i.e., no enclosure) under 3.1–9.1 m (10–30 ft) ceilings. The liquids considered included heptane, isopropyl alcohol, and mineral seal oil. The discharge rate and projection of leaks were estimated. Using these variables, a fire hazard analysis was performed to identify the range of fire scenarios and associated hazards that could occur. In this analysis, maximum fire size, ceiling temperatures, sprinkler activation times, and radiant heat fluxes were calculated for five IBC configurations and ten fire scenarios.

Predicted fire sizes from 0.7–160 MW were calculated for the confined scenarios and from 2.7–6600 MW were calculated for unconfined scenarios. Maximum exposure durations to prevent structural collapse of the overhead ceiling structure were calculated. Minimum separation distances for both ignition of adjacent combustibles and human pain were also calculated. Depending on the fuel and exposure duration, these distances ranged from unlimited for relatively small, contained isopropyl alcohol fires to a minimum of 14 m (45 ft) for a contained, unprotected heptane release. Different levels of protection were identified for the various IBC configurations based on predicted thermal exposures to the structure and adjacent combustibles. Containment was determined to be essential for all scenarios considered, given the potential for leaks in the IBC.

A range of viable strategies to contain, detect, and suppress these events was explored. The emphasis was on existing building scenarios, not new construction. A total of three containment, six detection, and seven suppression systems were considered, as shown in Table 1. The advantages and disadvantages with respect to system cost, performance, and impact on logistics/ITM were considered. A summary of these findings is provided in Table 2.

The primary factor influencing the severity of the fire hazard was the required area of containment. Two approaches to containment were explored: the use of large containment areas to capture ejected liquids; or the use of enclosed, raised sumps to reduce the required containment area while still preventing liquid release outside the containment area.

In configurations with enclosed, raised sump containment of one or two side-by-side IBCs or IBCs containing alcohol based fuels (e.g., IPA), no additional protection other than fire resistive

containment and adequate separation may be needed. This assumes that the facility, in accordance with insurer/fire code requirements, will at a minimum have an overhead water sprinkler system designed for an ordinary hazard scenario. This also assumes that the performance of the fire resistive containment system being used has been verified.

Table 1 — Summary of Mitigation/Protection Strategies Considered

<b>Containment Systems</b>	<b>Detection Systems</b>	<b>Suppression Systems</b>
Raised Sump Fixed Berm/Raised Sill HazMat Storage Locker	Overhead Thermal Link Local Thermal Link Local Linear Heat Detection Optical Flame Detection Video Fire Detection Liquid Detection	Overhead Sprinklers Overhead Foam–Water Sprinklers Pre-engineered Dry Chemical Low-level AFFF Foam Compressed Air Foam (CAFS) Local Application Water Mist Aerosol Generators

For scenarios where the hazard is large enough to threaten the steel overhead or where adequate separation distance is not provided, it is recommended that the local suppression systems described in this assessment be considered in addition to the fire resistive containment. A variety of systems were considered in this analysis with some (i.e., water mist, dry chemical, CAFS) having proven performance (i.e., FM Approvals) for similar scenarios. Other systems (i.e., aerosol, low-level AFFF, passive protection) have potential, but have not yet been Approved or Listed for the application. The performance of the suppression system should be verified via full-scale fire testing in a configuration comparable to that expected in an operations scenario.

In addition to the active fire suppression system options, a passive fire suppression (PFS) method was also explored. An inorganic, closed-cell, cellular glass insulation material might be used to provide a simple and reliable method to effectively reduce the total area of fuel available for combustion. When installed within a spill containment area (steel pan), it may provide a means of reducing the burning area and burning rate of a pool fire which in turn would reduce the thermal insult produced by the fire. In the event of a liquid release, the material will float on top of the liquid surface to form a protective layer.

For detection, the type of system required was primarily dependent on the available separation distances. Scenarios where adequate separation distance is not available require that local, automatic detection equipment be installed to activate the suppression system quickly. In cases where adequate separation distance is provided but the threat to the overhead is still present, the use of manual activation could be permitted, but the equipment should be installed at appropriate distances (i.e., separation distance greater than that required to prevent pain to humans).

The project technical panel decided to conduct hazard verification tests and investigate passive measures. Puncture tests will be performed with water to verify leak discharge rate/distance assumptions. Background burns of representative contained flammable liquids will be performed to verify calculated heat flux threats. Reduced scale (25 sq ft) testing will then be performed on the capabilities and viability of the passive fire suppression material. Variables will include fuel type, PFS material arrangement/construction, and the impact of obstructions on the ability of the PFS material to suppress a liquid fuel fire. If the PFS material substantially reduces the fire threat, scaled up tests which would include an overhead sprinkler system are planned.

Table 2 — Comparison of Advantages/Disadvantages of Fire Suppression Systems

	<b>Water Usage Efficiency<sup>1</sup></b>	<b>Suppression of 3D Fire</b>	<b>Inherent Protection of Neighboring Combustibles</b>	<b>Protection against Re-ignition/Burn-back</b>	<b>Obstructs Movement in Containment Area</b>	<b>Low-Level Piping Req.</b>	<b>Insp., Testing, and Maint.</b>	<b>Requires Local Detection System</b>	<b>UL Listed or FM Approved System</b>	<b>Requires Dev. or Veri. Testing<sup>3</sup></b>
Overhead Sprinkler	1.00	No	Yes	No	No	No	Minimal	No	Yes	Veri.
Overhead AFFF	0.75 or less	No	Yes	Yes	No	No	Moderate	No	Yes	Veri.
Low-level Application of AFFF	0.17	No	No	Yes	Yes, Minimal	Yes	Moderate	Yes	No	Dev.
Compressed Air Foam	0.11	No	Yes/No	Yes	No	Yes, Minimal	Moderate	Yes	Yes	Veri.
Pre-Engineered Dry Chemical	N/A	Potentially yes, Re-flash possible	No	No	Yes, Minimal	Yes	Moderate	Yes	Yes	Veri.
Aerosol Generators		Potentially yes, Re-flash possible	No	Unlikely	No	No	Very Low	Yes	No	Dev.
Local Application Water Mist	0.06 <sup>2</sup>	Yes, potentially	No	Yes, for duration of discharge	Yes, Minimal	Yes	Moderate	Yes	Yes	Veri.
Passive Pool Fire Suppression	N/A	No	Yes	N/A	Yes	N/A	Essentially None	N/A	N/A	Veri.

1 – Water usage efficiencies were normalized with respect to the system with the highest liquid volume discharge (i.e., overhead sprinkler system) over ten minutes duration. Over this duration, the sprinkler system would have discharged approximately 8600 L (2300 gal.) over a 35 m<sup>2</sup> (380 ft<sup>2</sup>) coverage area.

2 – Water mist water usage efficiency based on 5 minute discharge duration.

3 – Dev. – Development / Veri. – Verification