FACTSHEET
Fire Protection Composite and Metal IBCs

WORKGROUP IBC (ad-hoc)

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1 Introduction

Many years now there is consensus among most experts involved in fire protection that a fire in warehouses storing flammable and combustible liquids in composite IBCs are difficult to control and extinguish. Tests with IBCs show that they fail in just over 1 minute to 11 minutes when exposes to a fire. This results in loss of containment of the 1000 – 3000 litres of flammable/combustible products which can spread over the full surface of the floor causing the fire to intensify.

A similar scenario which is initially less severe can occur when dealing with a metal IBC that is fitted with a composite tap. This tap too will fail when expose to a fire, which will result in the contents of the IBC being released in the warehouse.

Fixed fire fighting systems that comply with present standards and codes will be overpowered by such fires if spilled product is contained in the warehouse and able to spread over the full surface of the floor. The website of the Industrial Fire World shows a video (http://www.fireworld.com/ifw_articles/waxahachieFIRE.php) that helps to understand how rapid a fire involving composite IBCs and flammable liquids can spread.

The National Fire Protection Research Foundation[1]) has since published reports from three extensive projects to define the safe conditions for storing composite IBCs with flammable and combustible products in warehouses. The results of these tests are reflected in the requirements for the sprinkler system described in NFPA 30: Flammable and Combustible Liquids Code, 2012 Edition. Protected storage of IBCs containing flammable liquids is possible according to NFPA when UL 2368 listed composite IBCs are used and all requirements in Table 16.5.2.9 of NFPA 30 (2012) are met. NFPA 30 relies on early control of the fire before this fire can spread to the full surface of the warehouse.

IBCs that have UL 2368 listing/approval have been submitted to a test developed by Underwriters Laboratories. IBCs with UL listing/approval will also fail when exposed to a spill/pool fire, but this amy occur later than with some non listed/approved IBCs.

For over a decade now FM Global has also carried out tests with composite IBCs. The conditions for safe storage of IBCs are presented in Datasheet FM 7-29 Ignitable Liquid storage in Portable Containers (April 2012).

The Health and Safety Executive in the UK has carried out many tests to establish behaviour and risks of composite IBCs during a fire.

A non exhaustive enumeration of information in the public domain on the fire hazards of composite IBC's can be found in chapter two of this factsheet.

All tests show that the loss of containment of 1000 – 3000 litres of flammable or combustible liquid is the primary reason that incidents with composite IBCs become uncontrollable.
The need for more testing was expressed in the conclusions of the reports from NFPA, FM and the HSE.

In the meantime composite IBCs have become very popular. There is widespread use in many industries of these IBCs irrespective of the fact if a fire can be controlled or not. This is something we have to deal with.

[1] This Foundation is an independent nonprofit whose mission is to plan, manage and communicate research in support of the NFPA mission. http://www.nfpa.org/categoryList.asp?categoryID=242&cookie%5Ftest=1

This factsheet describes the Best Practices in provisions for constructions, for Installations fitted to control and extinguish the fire and organisational measures to be taken to store composite under safe conditions. The Best Practices are based on the currently existing references like NFPA 11, NFPA 30, FM 29 and FM 83.

2 Information in the Public Domain

The National Fire Protection Research Foundation has produced the following reports

- International Intermediate Bulk Container Fire Test Project: Scoping Tests. Fire Protection Research Foundation (September 1996)
- International Intermediate Bulk Container Fire Test Project: Required Delivered Density Test. Fire Protection Research Foundation (April 1997)
- Assessment of Hazards of Flammable and Combustible Liquids in Composite IBCs in Operations Scenarios: final Report. Fire Protection Research Foundation (October 2011)
- Rack Storage Fire Testing Of Large Liquid-Filled Containers. Hughes Associates, Inc. (February 2000)
- Plastic Drum & IBC Packaging Guideline for NFPA Code 30. Plastic Drum Institute (PDI), International Confederation of Plastic Packaging Manufacturers (ICPP), the Rigid Intermediate Bulk Container association (RIBCA) and the Reusable Industrial Packaging Association (RIPA) (January 2005)
- Static Ignition Hazards in Packaging (Power Point presentation). Jim Reppermund – Safety Consultant Bob Gravell - Process Safety Consultant – DuPont (October 2008)
- Fire performance of composite IBCs. Prepared by the Health and Safety Laboratory for the Health and Safety Executive (2007)
- Guidance for the storage of intermediate bulk containers. Chemical Business Association and Sovent Industry Association (March 2008)
- Coffee Break Training, Composite Intermediate Bulk Containers (IBCs). U.S. Fire Administration / National Fire Academy (April 2008)
- Technical Advisory Bulletin: Controlling the Increased Fire Risks of IBCs. Willis (January 2010)
- Assessment of Hazards in Flammable and Combustible Liquids in Composite IBCs in Operations Scenarios. J L Scheffey, C L Mealy, Hughes Associates, Inc., Baltimore, MD (March 2012)
- Assessment of the Hazards Associated with Flammable and Combustible Liquids in composite Intermediate Bulk containers. Presentation by Bob Bennedetti at the June 2012 NFPA Conference and Expo – Las Vegas
- FM Global IBC Project – Year 10: New Protection Options. John LeBlanc and Seth Sienkiwicz

3 What is an IBC

According to the Hazardous Materials Regulations in the US an IBC, as considered in this factsheet, consists of a rigid outer packaging enclosing a plastic inner receptacle, together with any service or structural equipment. An IBC must have a volumetric capacity between 0.45 cubic meters (450 litres, 11 9 gallons, or 15.9 cubic feet) and not more than three cubic meters (3,000 litres, 793 gallons, or 106 cubic feet) or a maximum net mass of not less than 400 kg (882 pounds).

3.1 Categories of IBC's addressed in this Factsheet based on UN approval

There are many different sorts of IBCs. This factsheet is only applicable to IBCs with the UN approvals in the following enumeration:

- UN 31A, steel;
- UN 31B, aluminium;
- UN 31N, other metal than steel or aluminium;
- UN 31H1, rigid plastic IBC fitted with a frame;
- UN 31H2, rigid IBC with no frame;
- UN 31HZ1, composite IBC with rigid inner receptacle, and
- UN 31HZ2, composite IBC with flexible inner receptacle

Images of these IBCs are shown below.
IBCs shown in images 6 and 7 are not covered by the information in this factsheet.

Image 1: Rigid composite IBC with composite butterfly or ball valve, fitted on pallet

Image 2: Rigid composite IBC in metal cage, with composite butterfly or ball valve, fitted on fixed pallet

Image 3: Rigid composite IBC with solid light weight steel cover, with composite butterfly or ball valve, on fitted steel pallet

Image 4: Rigid composite IBC with solid cover made of zinc, with composite butterfly or ball valve, on fitted pallet of zinc

Image 5: Stainless steel IBC on fitted stainless steel pallet, with composite butterfly or ball valve

Image 6: Collapsible composite IBC with flexible inner receptacle, with composite butterfly or ball valve, with fitted composite pallet

Image 7: Carton box with flexible inner receptacle and composite butterfly or ball valve, on separate wooden pallet.

4 Hazards and risks of IBCs during a fire

Tests used to list IBCs for transport of liquids are aimed at the integrity of the IBC during transport and transport incidents. It is very important to note that these tests do not address the behaviour of an IBC during a fire. There is no correlation between the UN ranking of these containers and fire protection characteristics of these containers.

In 2007 the Health and Safety Executive in England published a report with the title *Fire Performance of Composite IBCs*[2]. Extensive fire test were performed with IBCs. These test showed that various plastic and composite IBCs rapidly lose their integrity when exposed to a fire in general and specifically when the IBC is placed in a spill or pool fire. There are two reasons that this scenario can develop. The plastic or composite of the IBC wall or the composite ball or butterfly valve weakens and fails during flame impingement, resulting in loss of containment of the 1000 – 3000 litres of liquid in the IBC.
The 1000 – 3000 litres liquid can spread over the full surface of the warehouse without containment and.or diverted to a safe location.

Even when the scenario starts with no more than a puncture of the IBC without a fire being present the risk of the liquid being ignited is considerable due to the fact that plastic and composite IBCs accumulate static electricity.

The very rapid spread of such a fire can be seen in the earlier mentioned video on the website: http://www.fireworld.com/ifw_articles/waxahachieFIRE.php.

Videos showing fire tests with IBCs can be found on the following websites:

a. http://www.youtube.com/watch?v=_pfbHGxyHNc (video fire test composite IBC)
b. http://www.youtube.com/watch?v=8HX3iraAyRo (video stainless steel IBC)

It is assumed that the IBC in the test shown under b is fitted with a metal butterfly or ball valve.
If the IBC was fitted with a composite valve, the valve would probably fail when exposed to a spill or pool fire, enabling loss of containment of the liquid in the IBC.

4.1 Credible incident scenarios with IBC's

The most credible incident scenarios with the IBCs addressed in this factsheet that can occur in a warehouse for storage of these IBCs are:

1. A plastic or composite IBC which stored on the floor of the warehouse is punctured due to an external force like the forks of a forklift truck. The IBC is filled with a flammable liquid (flashpoint < 60°C). The flammable liquid is released and starts to evaporate. The vapour ignites causing a spill fire. Other IBCs with either flammable or combustible vapour are exposed to flame impingement and heat radiation caused by this fire. These IBCs fail, spreading their contents over the floor of the warehouse causing a full surface spill fire.
2. (a) A plastic or composite IBC containing flammable liquids is stored in rack at approximately 5 meter or (b) 5 of the same IBCs are pile stacked on the floor of the warehouse. The UN listing shows that these IBCs are suitable for this form of stacking.

   The in rack stored IBC (a) or the IBC at the top of the pile is punctured. Flammable liquid squirts from

[2] http://www.hse.gov.uk/research/rrhtm/rr564.htm

the IBC and splashes on the floor of the warehouse. Vaporisation of the liquid is supported by this squirting and splashing. The vapour is ignited causing a three dimensional fire as the flow of flammable liquid from the IBC is also ignited. The construction of the rack and objects in the rack can lose their integrity because they are exposed to the flames and heat radiation of this fire.
In addition the same full surface spill fire as described for scenario 1 will also be present.

3. Combustible liquids (flashpoint > 60°C) are stored in IBCs in rack or on the floor of a warehouse.
   Other products or materials stored in the same warehouse are ignited.
   An IBC with combustible liquid fails due to the radiant heat and/or flame exposure.
   The fire will spread as the spilled combustible liquid is ignited and spreads over the floor of the warehouse.
4. Metal IBC's fitted with a composite valve, containing flammable or combustible liquids is stored in a warehouse.
   Other products or materials stored in the same warehouse are ignited.
   The composite valve of the IBC fails due to the radiant heat and/or flame exposure.
   The fire will spread as the spilled flammable/combustible liquid is ignited and spreads over the floor of the warehouse.

<u>Summary</u>
A large spill with flammable or combustible liquids will be formed when a plastic/composite IBC is punctured and the spilled liquid ignites. Other plastic/composite IBCs exposed to the flames or radiant heat of this fire will rapidly loose their integrity too.

The composite valve of a metal IBC can also fail when exposed to a pool fire. The contents of this IBC will spread over the surface of the warehouse causing the fire to spread rapidly.

A spill of flammable liquids can generate sufficient ignitable vapours. The static electricity accumulated by the composite IBC, a hot surface, sparks, etc. can be the source of ignition.

Plastic/composite IBCs containing combustible liquids loose their integrity too when exposed to flames and/or intense radiant heat. The combustible liquid can be ignited when exposed to the flames and radiant heat. Therefore leak detection can be an effective line of defence to prevent fires with combustible liquids.

Unless measures are in place to detect and minimise the size of the spill, a fire will spread over the full surface of the warehouse floor. This full surface fire should be used as the credible incident scenario when designing the fire protection. This scenario is applicable for warehouses storing flammable and/or combustible liquids in plastic/composite IBCs or metal IBCs fitted with composite valves.

4.2 Reducing the risk by controlling the size of the spill

The use of IBCs for storing flammable and combustible liquids is wide spread. An IBC can contain between 1000 – 3000 litres. This amount of liquid can easily spread over the full surface of the ware house when no additional measures are in place.

Controlling the spill size for storage of IBCs at a height in racks or IBCs stacked on the floor requires a tailor made solution which is based on a profound risk analysis. Image 8 shows that a spill of liquid from a punctured IBC will spread over considerable distance.

Sprinkler systems are divided in sprinkler sections. The water supply for a sprinkler system in a warehouse storing flammable and combustible liquids is based on the water demand of all sprinklers in one section. The storage facility or storage box should be designed to secure that the size of the pool fire so it does not exceed 50% of the spray area for either the storage box or the storage facility unless (i.e., berm-mounted nozzles) foam sprinklers are also fitted in the storage box or storage facility. Further explanation on the use of floor foam sprinklers can be found in paragraph 6.1. Expertise about the development of a spill and the spill fire is required for designing such an extinguishing system.

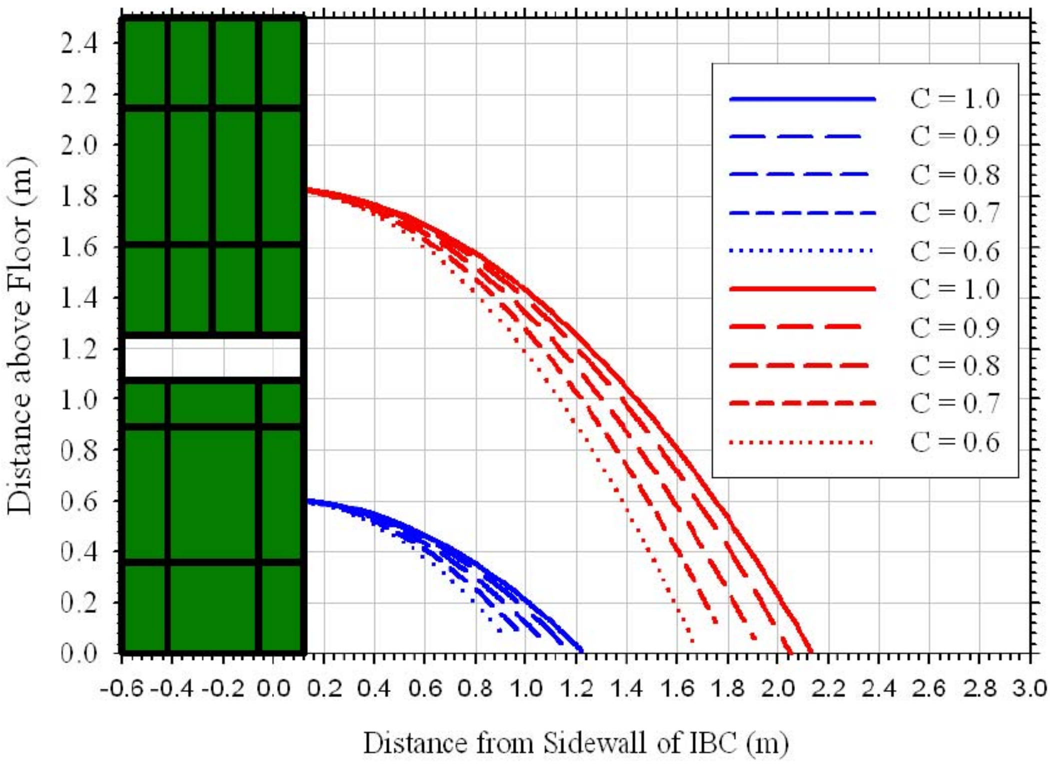

Image 8: Illustration of calculated liquid discharge distances from IBCs in both single and stacked configurations[3]

Note: The letter C in image 8 is relevant for how the liquid flows form the IBC. It is a liquid specific constant C.

Constructions, like storage racks and objects that are exposed to flames and/or radiant heat must be cooled. It is recommended to do this with the same water foam mixtures as is being used for extinguishing the spill fire on the floor of the warehouse.

Burning flowing liquids, like the liquid spilling from the punctured IBC, can not be extinguished by fire fighting foam as it is not possible to cover the liquid with foam.
But adding foam to the sprinkler system will increase the cooling properties of the water. Foam makes the water stick to vertical objects. More heat is required for the evaporation of water than for increasing the temperature of the same amount of water with one degree. Therefore the longer the water can stick to an object being exposed to flames or radiant heat the better the cooling effect will be.

[3] From the document: *Assessment of Hazards of Flammable and Combustible Liquids in Composite IBC's in Operations Scenarios Final Report*

Strategically placed leak detection (preferably at locations where liquid is collected) as an early warning mechanism for the spill in combination with structural provision to reduce the size of the spill can help to make fires with these products more controllable.

FM Data Sheet 7-83: Drainage and containment systems for ignitable liquids can be used for designing the storage warehouse. Image 9 and 10 below are derived from FM Data Sheet 7-83.

It is advised to limit the full surface are of any storage facility for composite IBCs and metal IBCs with composite valves containing flammable and combustible liquids to 2500 m^2. It is also advised to divide the warehouse in storage boxes of 300 m^2. Spill measure control as shown in image 8 is preferred. Each storage box should be surrounded by 3 fire walls with a fire resistance of at least 30 minutes.
The aisle between open sides of storage boxes should be at least 3.5 m and have a slope towards a grate to collect any spilled liquid in a gutter with discharge in a containment provision.

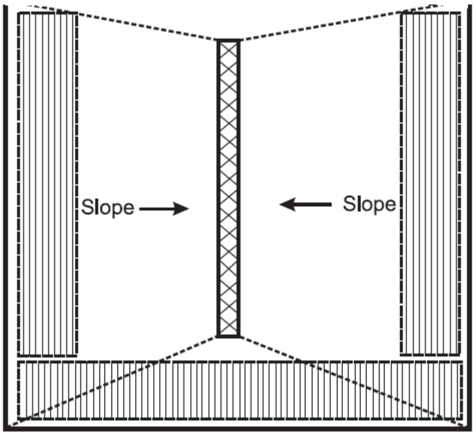

Image 9: Storage box with floor sloping to the centre of the box, where a grate is placed over gutter. The spill will flow past a flame arresting gauche in the gutter to a containment facility.

Similar provisions can be made for in rack storage of IBCs. The racks are placed against the fire wall of the box as shown in image 9. The floor slopes to a drain. The liquid passes a flame arrester and in collected in a containment facility.

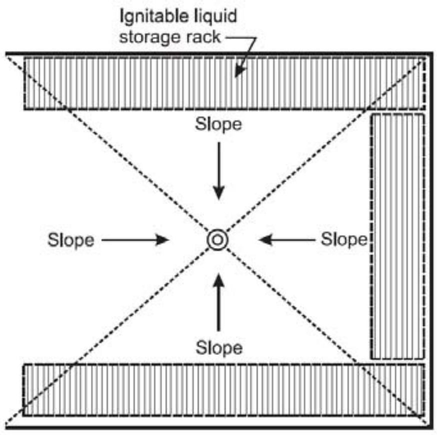

Image 10: Storage box with in rack storage of IBCs and sloping floor

The aisles in a storage facility for IBCs with flammable and or combustible liquids should also be sloping towards the middle of the aisle. The liquid should be collected through a grate over a gutter fitted with flame arresters, which is connected to the containment facility.
This construction helps to detect the fat an early stage too. Fire detectors in warehouses can have many dead angles. This can be tackled by directing the liquid to the location where the detector is mounted.

When using in rack storage – additional attention should be given to the potential compromising of the integrity of the storage compartment. An example is shown in the photos below.

Image 11A:
Domino-effect of storage racks

Image 11B:
Integrity of compartment is compromised by falling racks

5 NFPA[4] classes of flammable and combustible liquids

NFPA uses *class liquids to* differentiate between liquids. An overview of the various classes and their properties is provided in table 1.

Class liquid	Flash point °C	Boiling point °C
	Flammable liquids	
IA	<22.8	<37.8
IB	<22.8	≥37.8
IC	≥22.8 and <37.8	Not applicable
	Combustible liquids	
II	≥37.8 and <60	Not applicable
IIIA	≥60 and <93	Not applicable
IIIB	≥93	Not applicable

Table 1 Class liquids used by NFPA

[4] National Fire Protection Association – www.nfpa.org

6 Fixed fire sprinkler system for indoor storage

Sprinkler installations are suitable for extinguishing fires in warehouses storing flammable and combustible liquids in IBCs. Sprinklers can be designed and installed as described in NFPA 30: Flammable and Combustible Liquids Code, 2012 Edition.

The workgroup that wrote this document[5] suggests to store flammable and combustible liquids in plastic and composite IBCs and metal IBCs with composite valves when the following general conditions and three separate provision packages are applied in addition to the requirements already described in NFPA 30. Modified use of NFPA 30 automatic sprinkler installation. This suggestion is based on the following.

1. The spill fire caused by the 1000 – 3000 litres of hydrocarbons causes the sprinkler system to be overpowered. Early spill detection and other measures to control the size of the spill can help to make the fire controllable.
2. Adding fire fighting foam to the sprinkler system to control and extinguish the fire and improve the cooling capabilities of the water in this foam on vertical surfaces.

It its therefore suggested to apply the following general and specific provision listed in Packages 1-3 when storing flammable and combustible liquids in plastic and composite IBCs and metal IBCs with composite valves:

General provisions

- Fast working leak detection which generates an alarm;
- Fast fire detection
- Containment provision in place to minimise spill surface
- Provision to minimise spill when leaking IBC is stacked or stored in rack
- Cooling of objects when exposed to a radiant heat and flame impingement of spill fire of stacked IBC or in rack IBC
- Water/foam mixture to be discharged from all sprinkler heads
- Foam should be tested for compatibility for the products involved in the fire.

Provisions package 1: storage of Class liquids IB, IC, II, IIA & IIIB

- Storage of Class IA liquids in plastic and/or composite IBCs is not allowed. These products must be stored in full metal IBCs that are fitted with a metal valve and approved pressure relief mechanism;
- All IBCs used in the storage facility must have a UN/DOT listing for the product contained in the IBC even when the IBC is not subjected to any transport activity;
- Class IB, IC, II, IIIA and IIIB may be stored in plastic/composite IBCs if the IBC has UN/DOT listing for these products
- All sprinkler heads that have to be present according to NFPA 30 (2012 edition) § 16.5.1.6 must be fed with a water/foam mixture;
- Calculations for the water/foam supply requirements should always be based on all sprinklers that will be activated according to NFPA 30, paragraph 16.6.1.4 or paragraph 16.6.2.4);

[5] Organisations and Names of Workgroup members are listed on the title page

- Containment provisions must secure that the size of the spill and spread of the spill will always stay within the scope of the designed sprinkler section for NFPA Class liquids (NFPA 30, paragraph. 16.8.2);
- IBCs are to be stacked on the floor no higher that two IBCs, even when the IBC is approved for higher stacking, and
- Adequate containment measures to minimise the size of the spill as well as reducing the spreading of the spill, in the form of carbon steel (or other suitable material) barriers can be applied when water supply is not sufficient to meet the previous requirement for existing storage facilities. These measures are subject to approval of the AHJ;

Provision package 2: storage of Class liquids IA

When class IA liquids are stored in IBCs the following provision package should be in place on top of NFPA 30 requirements.

- Storage in a cut-off room with a fire resistance of the walls, roof and floor of 120 minutes;
- Containment provision must ensure that the spill and spread of the spill is always contained within the designed sprinkler section, and
- Restrict the total fire load of the flammable and combustible liquids stored in the warehouse to 16 MW

Provision package 3: add foam floor sprinklers to NFPA provisions

When an analysis of the scenario development shows that more than 25% of the full floor surface area of a warehouse storing IBC's, which is protected in line with a NFPA 30 sprinkler installation the following additional measures on top of provision package 1 should be in place:

- Storage in a cut-off room with a fire resistance of the walls, roof and floor of 120 minutes;
- The load baring construction must have a fire resistance of 60 minutes;
- A maximum of 4 IBCs are allowed to be stacked;
- Storage type: bulk
- Apply floor surface sprinklers (nozzles installed near the fuel surface, i.e., berm-mounted nozzles, in addition to the sprinkler installation;
- Application rate floor foam sprinklers for hydrocarbons 6.5 l/min/m^2 (NFPA 16: 7.3.2.1);
- Application rate for water miscible liquids according to suppliers recommendation;
- Application time 30 minutes(NFPA 11: 5.7.3.2)
- The full surface area of the storage facility should be covered during the activation of the floor foam sprinklers;
- System type: deluge
- Activation of the floor foam sprinklers by the fire detection system. System can stop automatically after 30 minutes.