FIRE HAZARDS OF PLASTIC IBCs CONTAINING FLAMMABLE OR COMBUSTIBLE LIQUIDS

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INTRODUCTION

The use of plastic and composite intermediate bulk containers (IBCs) for the storage of liquids has increased rapidly during the last 10 years. They have a number of advantages over traditional steel drums, in particular; resistance to corrosion, efficient space utilisation in storage and ease of emptying when a valve is fitted.

The vast majority of IBCs are made from high-density polythene (HDPE). This material has only limited compatibility with organic solvents. Guidance on suitability of HDPE IBCs for different types of solvent is given in Reference1. Many of the liquids listed as compatible with HDPE are flammable or combustible: important examples are all the alcohols as well as most acetates and ketones. Notwithstanding the lack of complete compatibility, plastic IBCs are also commonly used in many industries for hydrocarbons — especially for waste and for fuels such as diesel.

There have been a number of serious recent fires in the UK that started or spread as the direct result of the use plastic IBCs for combustible liquids e.g. CSG (Gloucester), Distillex (North Shields) and P&R Laboratories (St Helens). A characteristic of these fires was the rapid release of liquid from IBCs, inadequacy of bunding and damage caused as a result of the unconfined flow of burning liquid.

Following HSE investigations at the scene of these fires, a research project was undertaken to provide data to allow more reliable risk assessments for premises using IBCs for liquid storage and to provide a stimulus and direction for change in IBC selection and design.

HSE also wished to respond to concerns expressed in relation to the vulnerability of such IBCs in road accidents both on-site and on public roads. It is common practice to load IBC's onto heavy goods vehicles, such as curtainsiders, with the valves facing outwards. Clearly, the rate at which a fire escalates in a road incident has a significant bearing on the outcome. Particularly so, where people are trapped or unable to leave their vehicles and the emergency services are hampered in their efforts to reach the scene by congestion, for example, after a multiple pile-up.

SPECIFIC OBJECTIVES OF HSE RESEARCH

The work has focussed on two areas:

1. The ignition resistance of different types of IBC — especially at the valve, as this is a point of weakness.
2. The rate of liquid loss when IBCs become involved in a self-accelerating fire at the valve or become engulfed in a pool fire.

The first issue is clearly relevant to the reduction in the frequency of large fires. The second is relevant to potential mitigation of such fires if they do occur; especially in the design of bunding and drainage systems to prevent escalation of incidents by unconfined flow of burning liquid.

TEST MATERIALS

Very large IBCs in excess of 3000 litres capacity are available but the vast majority in use have a capacity of around 1000 litres. The test programme was restricted to IBCs with a nominal capacity of 1000 litres. Most of the IBCs tested were manufactured by Schutz who have a high proportion of the sales of new IBCs in the UK. It should be stressed that problems of low ignition resistance and high rates of liquid loss in fire engulfment are generic problems for composite IBCs. There is no evidence that equivalent products from other manufacturers would behave in a qualitatively different manner.

Two types of liquid were used in the tests: isopropyl alcohol (a highly flammable liquid, flash point 12°C, commonly stored in IBCs and involved in several serious accidental fires) and diesel (widely stored in IBCs and commonly regarded as a low fire risk). The measured flashpoint of the diesel used was 72°C.

In all of the IBCs tested an external steel cage supported the inner HDPE receptacle. Some tests involved Schutz IBCs with anti-static screens. In these IBCs there was a thin galvanised steel sheet between the cage and the receptacle. This steel sheet is designed to provide electrostatic screening by covering larger areas of exposed plastic. It can also have a significant effect on the rate of liquid loss in the case of fire.

TEST PROGRAMME

Experimental details for eleven full-scale tests on single IBCs containing IPA or diesel are shown in Table 1. A further series of eight ignition tests on valves are detailed in Table 2.

TEST METHODS

Two types of full scale test were carried out.

1. Valve ignition test: A 60 g wooden crib (Source Number 6 from BS5852) was placed under the valve. All of the IBCs tested were vulnerable to self-accelerating fires at the valve.

Table 1. Summary of experimental conditions and results from full scale tests

Test number	Manufacturer model	Anti-static Metal sheet cover	Doghouse protection	Reinforcement type Tubing cage (TC) Wire mesh (WM)	Contents	Fill	Type of test Valve ignition (VI) Fire engulfment (FE)	Tamper seal	Leakage rate (g/s)	Potential Fire Size (MW)
TEST 1	Schütz MX (reconditioned)	N	N	TC	IPA	Half	VI	N	700	21
TEST 2	Schütz MX (reconditioned)	N	N	TC	IPA	Full	VI	N	3,400	102
TEST 3	Schütz MX	N	N	TC	IPA	Full	FE	Y	17,000	510
TEST 4	Schütz SX-EX	Y	N	TC	IPA	Half	FE	Y	650	19.5
TEST 5	Schütz SX-EX	Y	Y	TC	IPA	Full	FE	Y	650	19.5
TEST 6	Delta	N	N	WM	IPA	Full	VI	Y	1,200	36
TEST 7	Schütz SX-EX	Y	N	TC	IPA	Full	VI	Y	180	5.4
TEST 8	Schütz MX	N	N	TC	IPA	Full	VI	Y	3,000	
TEST 9	Schütz MX	N	N	TC	Diesel	Full[1]	VI	Y	9,000	360
TEST 10	Schütz MX	N	N	TC	Diesel	Full	VI	Y	25,000	1000
TEST 11	Schütz SX-EX	Y	N	TC	IPA	Full	Doghouse ignition	No valve	500	14.5

[1]320 kg of diesel used. Drums of water placed inside IBC to displace diesel to total volume 950 litres.

Table 2. Summary of results of ignition tests

	Ignition source	Valve type	Liquid	Time to uncontrolled liquid release
TEST A	Match[1]	HDPE butterfly	IPA to cap	210 s
TEST B	Match[1]	HDPE butterfly	IPA to valve	400 s
TEST C	Match[1]	HDPE ball valve	IPA to valve	450 s
TEST D	Match[1]	HDPE butterfly	Diesel to cap	220 s
TEST E	Crumpled sheet of newsprint[2]	HDPE butterfly	IPA to cap	75 s
TEST F	Absorbent granules contaminated with kerosine	HDPE butterfly	IPA to cap	100 s
TEST G	125 g wood crib[3]	Metal ball valve	Diesel to valve (no cap)	No leakage
TEST H	3000 g wood crib	Metal ball valve	Diesel to valve (no cap)	No sustained leakage

[1]Gas match from BS5852
[2]Tabloid newsprint mass of paper 9 grams
[3]Wood crib source 7 form BS5852

2. Fire engulfment test: This test reproduces the kind of fire exposure that would occur if an IBC was exposed to a spreading pool fire — perhaps from another burning IBC nearby.

The arrangement used in the tests is shown in Figure 1. A tray (size 1.8 × 2.7 m) was positioned under the IBC. In most cases this tray collected liquid draining from the IBC and defined the size of the engulfing fire in the later stages of the test. In one case (Test 10) most of the diesel was lost in a spigot flow from near the base of the IBC, which took the liquid outside the tray (Figure 2). In tests where rapid loss of liquid led to significant accumulation in the tray, a drain valve was opened to allow flow out of the tray into a sump. This allowed recovery of up to 70% of the contents of the IBC — reducing the cost and environmental impact of the tests without significantly affecting the outcomes.

In all cases load cells in the roof of the experimental enclosure were used to continuously monitor the weight of the IBC.

The experimental arrangement used in the valve ignition tests is also illustrated in Figure 1. In this case the liquid draining from the valves was caught in a tray 500 × 500 mm. The fires were extinguished after complete failure of the valves.

RESULTS

The key quantitative results from the full-scale test are the rates of liquid loss. These results are summarised in Table 1. Some typical measurements of the rate of liquid drainage are shown in detail in Figure 3.

Fire tests on water filled IBCs reported by Scheffey [Reference 2] suggest that massive releases of liquid are a rare occurrence with most breaches producing small liquid release rates. The results of the current work using solvents suggest that (for the majority of IBCs currently in use in the U.K.) catastrophic loss of liquid contents is almost inevitable, if the inner plastic bottle is full and not shielded.

Video recordings from different angles were made of all of the tests. Those interested in specific tests should contact the authors. It is intended that HSE will produce a video, including records of ignition and full-scale tests as well as footage from incidents, to improve awareness in industry and amongst regulators about the potential risks associated with storage of flammable and combustible liquids in IBCs.

DISCUSSION OF RESULTS OF FULL-SCALE TESTS

UNSHIELDED IBCs CONTAINING FLAMMABLE LIQUID

Rapid rates of loss of flammable liquid (isopropanol) were observed from plastic IBCs without any metal shielding.

- Self-accelerating leaks at the valve led to leakage rates of 3–4 kg/s
  Potential heat release per IBC 90–120 MW
  Potential size of spreading pool 45–60 m^2

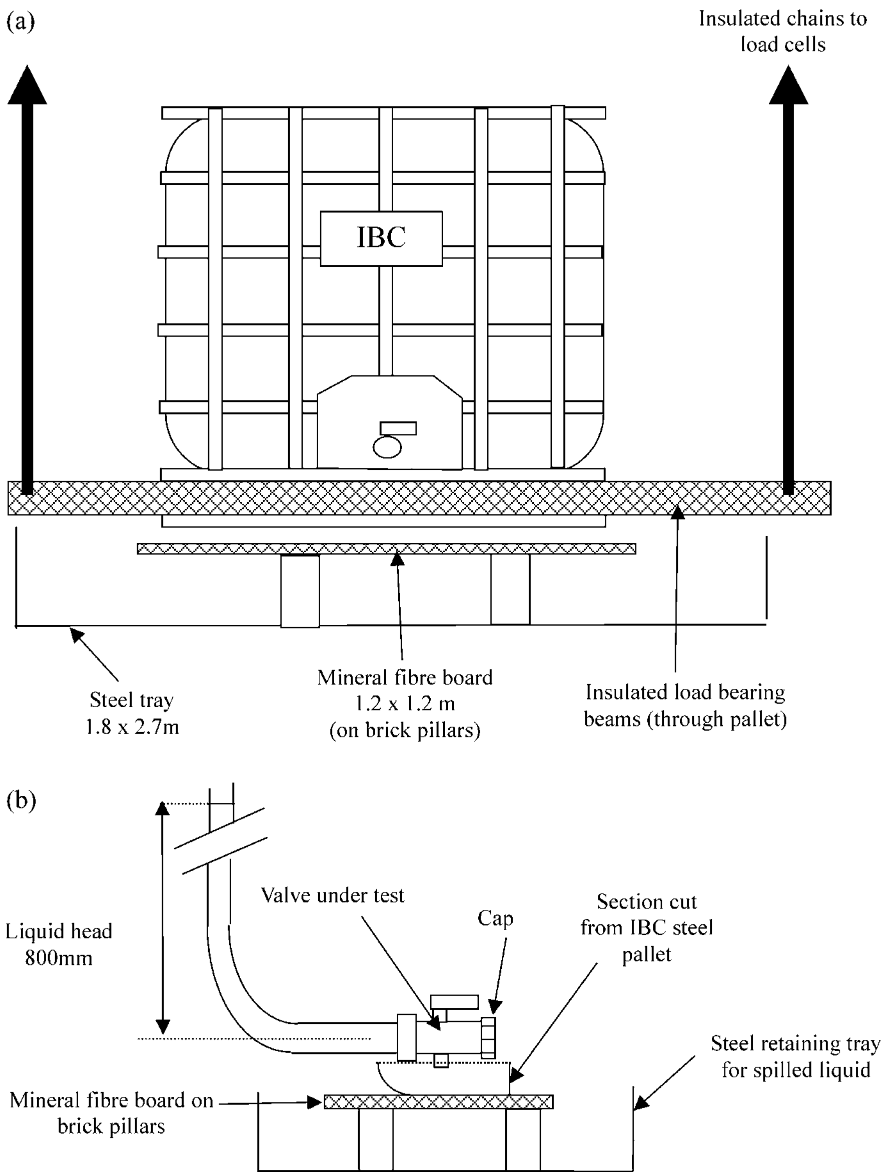


Figure 1. (a) Schematic of experimental arrangement in full scale tests. (b) Schematic of experimental arrangement in valve ignition tests

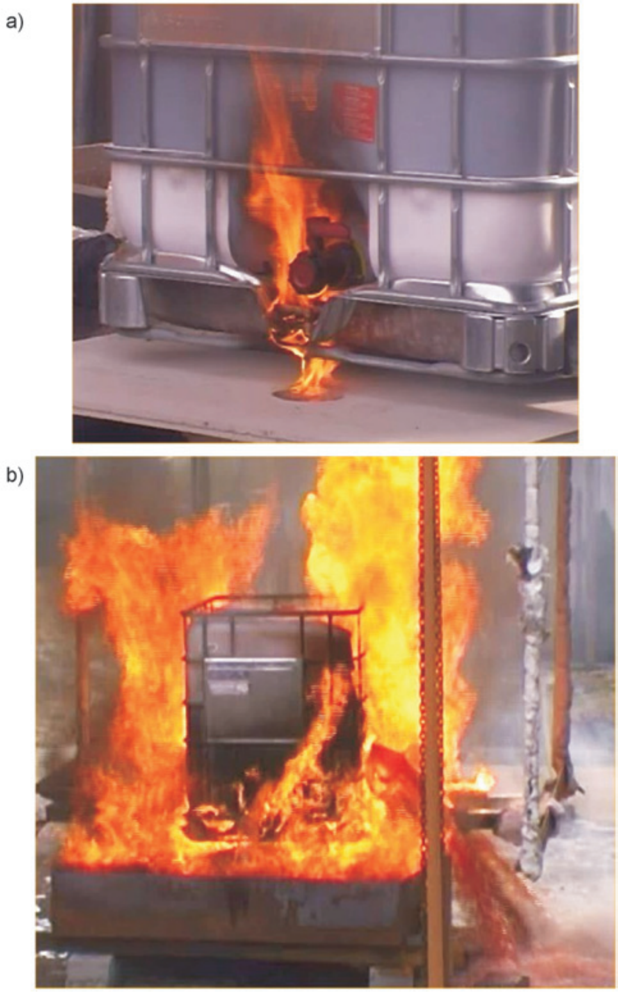


Figure 2. a) (above) Early stages of leakage of diesel from the valve. b) (below) Rapid loss of diesel causing a flood approximately 3 minutes after valve ignition — this was followed by severe and widespread pool fire

- IBCs exposed to a rapidly growing pool fire emptied at a maximum rate of 17 kg/s
  Potential heat release per IBC 500 MW
  Potential size of spreading pool 250 m^2

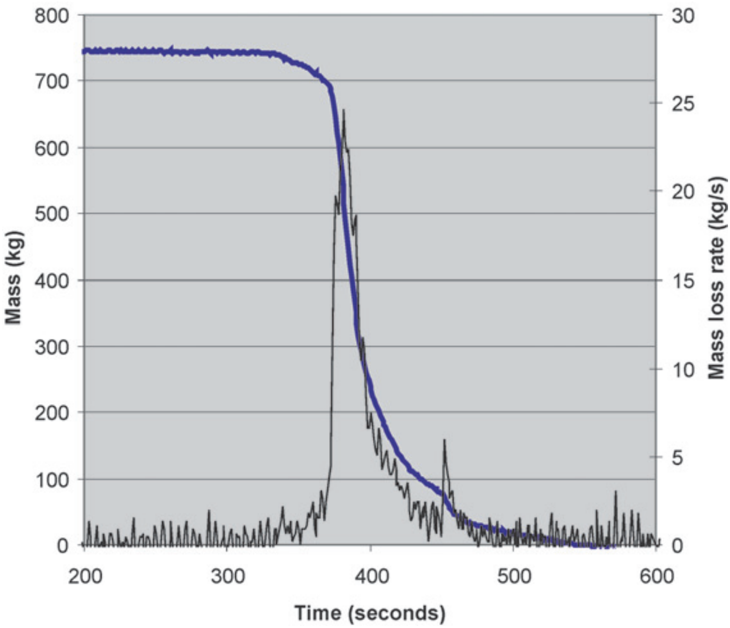


Figure 3. Mass and mass loss rate measurements for Test 10

These results give an indication of the leakage rates to be expected from the first ignited IBC and those that become involved later in a spreading fire.

UNSHIELDED IBCs CONTAINING COMBUSTIBLE LIQUID

Tests on diesel (measured flashpoint 72°C) showed that IBCs containing combustible liquids are also vulnerable to very small ignition sources.

- Self-accelerating leaks at the valve led to leakage rates of up to 25 kg/s. Potential heat release per IBC is 1000 MW.
- Catastrophic collapse of large areas of the tank wall was observed. It is likely that there was a chemical interaction between diesel and hot plastic.
- Fire engulfment tests have not been carried out but it is certain that even higher rates of leakage will be observed for IBCs engulfed by a spreading pool fire.

METAL SHIELDED IBCs CONTAINING FLAMMABLE LIQUID (IPA)

Lower rates of leakage were observed from Schutz IBCs containing IPA with an anti-static metal cover. Even in fire engulfment tests IBCs only leaked at a rate of around 0.5 to

0.7 kg/s. This corresponds to a potential heat release per IBC of around 20 MW. Such a fire would only spread to form a pool of order 10 m^2.

Use of these metal shielded IBC would be a significant risk reduction measure for IPA storage. The rate of fire spread and the final rate of burning and more importantly the outflow of flammable liquid would be reduced by at least an order of magnitude.

It is likely that the type of metal shielded IBC currently available from Schutz would not be suitable for most other liquids. Light alcohols methanol, ethanol, IPA are special because

1. HDPE is highly resistant to chemical attack by these fluids even at relatively high temperatures.
2. They are volatile. The exposed area of plastic around the doghouse (the recess in which the valve is located) is always fuel rich (cool) and the heat flux to the plastic is limited.

DISCUSSION OF RESULTS OF IGNITION TESTS

A summary of the time taken for ignition to lead to uncontrolled loss of liquid in various valves is shown in Table 2.

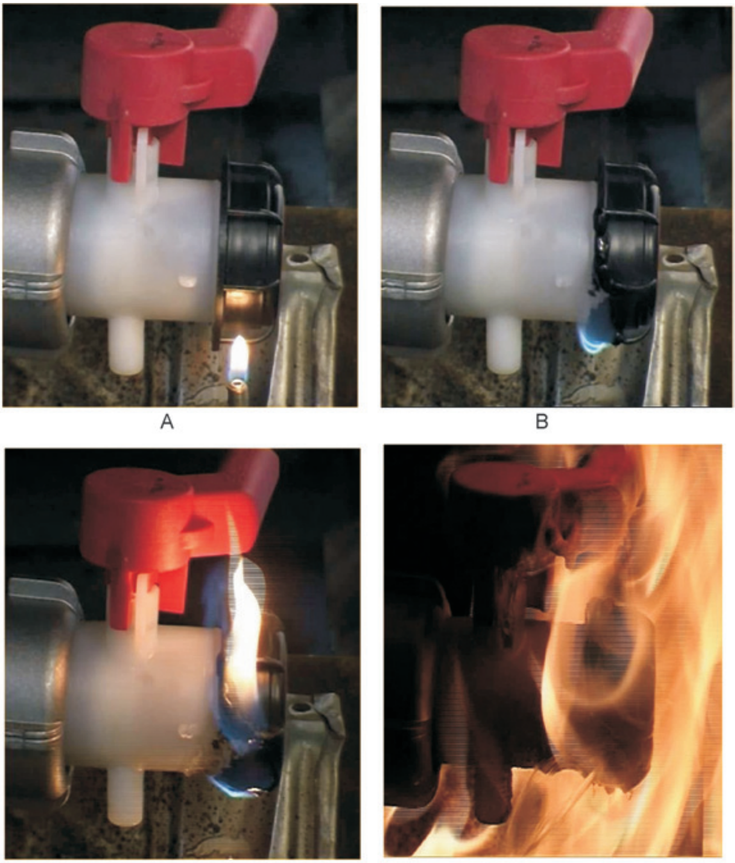
The HDPE cap and valve assembly are made from readily ignitable HDPE. A plastic fire in the cap and/or valve progresses until liquid is released (Figure 4). The plastic fire established on or under the cap or valve is a potent ignition source for liquids leaking from the IBC — even if these have high flash points. It is likely that many combustible liquids with high flashpoints (even those with flashpoints in excess of 100°C) may become fully involved following a valve ignition. These materials would not normally be considered to be readily ignitable or a fire risk in storage and are commonly co-stored with toxic or other types of hazardous materials.

Although the valves can easily be ignited with a match the fire takes several minutes to cause liquid leakage. Larger ignition sources — e.g. a 9 gram crumpled sheet of newsprint – lead to much more rapid leakage (Figure 5). IBCs are potentially vulnerable to grass fires or brands blown from bonfires. Any type of process activity that could lead to small, ignited spillages should not be carried out in IBC storage areas.

Two demonstration tests were carried on metal ball valves — without secondary closures. These valves withstand severe and prolonged fire without sustained leakage. The ignition resistance of composite IBCs could be improved by using metal valves. Such valves would have to be electrically bonded via the IBC cage to earth during any solvent transfers through the valve.

ADDITIONAL OBSERVATIONS

In all but one of the tests involving IPA there were vapour explosions causing significant overpressure when the IBC was first breached above the liquid level. In one case a sizable fireball was produced (Figure 6). This was caused by liquid being driven out of a breach in



A B C D

Figure 4. Stages of a valve fire: A = Ignition with a gas match, B = Fire spread on HDPE cap, C = Leakage of IPA vapour, D = Uncontrolled liquid leakage

the receptacle just above the liquid line. Anyone standing in front of the IBC would have been sprayed with burning liquid and would probably have been fatally burned unless wearing special clothing. Caution should be exercised in attempting to extinguish these valve fires — especially when the contents are volatile.

In another test involving a nominally full, metal-shielded Schutz IBC the internal explosion opened up a large hole in the valve area leading very rapid loss of the contents of the IBC. In a duplicate test in this programme (Number 7) a vapour explosion did not catastrophically damage the (unsupported) valve area. There a number of variables that

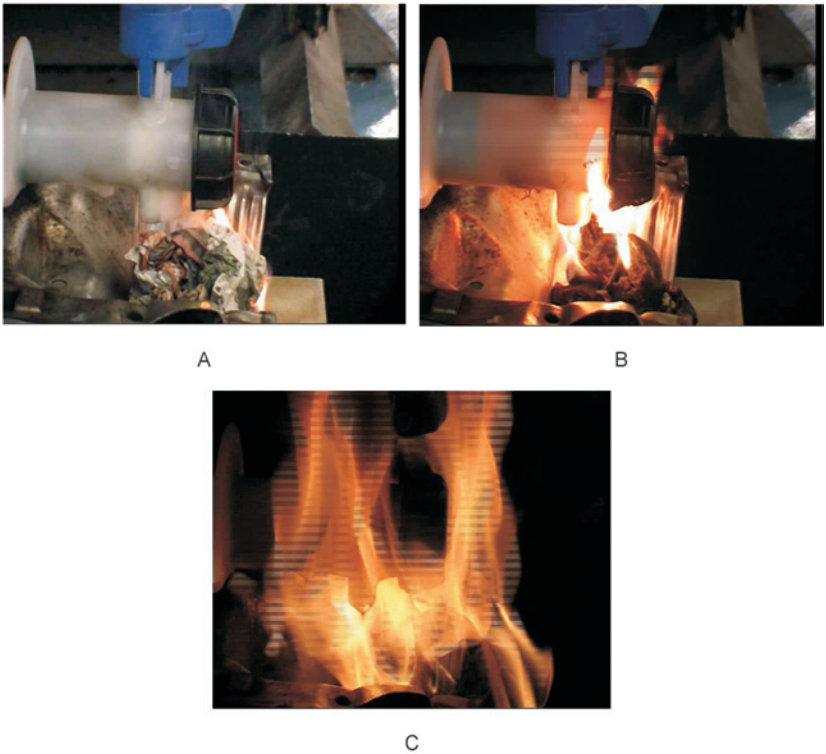


Figure 5. A crumpled sheet of newsprint causes sustained leakage at the valve in about 1 minute: A = Ignition of paper, B = Flame impingement on the valve, C = Uncontrolled leakage of IPA from valve

can affect the outcome in these circumstances: vapour concentration at the time of ignition (and the consequent overpressure), degree of preheating of the valve area, ease of venting via distortion of the cladding etc. It is currently not possible to specify the proportion of clad IBCs that will fail catastrophically during fire engulfment. The probability of such a failure for IBCs involved later in the fire is likely to be low — as the degree of preheating of the valves will be limited.

IMPLICATIONS OF TEST WORK

1. Some basic data is now available to allow assessment of the rate of liquid drainage during IBC fires. The tests show clearly that **all of the liquid** in a stock of unclad

Figure 6. Consequences of ignition of IPA vapour in the ullage of a part-full IBC

IBCs on level ground is likely to be released in a period of order 5–10 minutes. This is in line with the video records of incidents such as the Distillex fire in North Shields.

2. Current bunding arrangements in many premises would lead to uncontrolled spread of burning liquid from IBC storage areas. At Distillex streams of burning solvent flowed off site, causing fires that destroyed a large amount of nearby commercial property.
3. Combustible liquids stored in IBCs can produce spreading pool fires in exactly the same way as flammable liquids.
4. Metal cladding of the sort currently used for static protection on Schutz IBCs can reduce drainage rates significantly — for light alcohols.
5. There are strong indications that some types of liquid attack HDPE at temperatures reached in fire engulfment — this leads to particularly rapid loss of liquid. These will include all the hydrocarbons and probably many other hydrophobic organics. This issue requires further investigation.
6. The rapid escalation of fires, involving unclad IBCs fitted with a standard plastic butterfly valve, confirms the concerns as to their suitability when assessing the risks from the transport of flammable and combustible liquids.

REFERENCES

1. Solvent Industry Association Notice No.51 (2003) *Use of IBC's for oxygenated and hydrocarbon solvents.*
2. Scheffery J.L. (1997) *Status report on Fire Testing of Liquids stored in Intermediate Bulk Containers*, Proceedings of Fire Suppression and Detection Research and Applications Symposium.