

THE CAUSES OF IBC (INTERMEDIATE BULK CONTAINER) LEAKS AT CHEMICAL PLANTS – AN ANALYSIS OF OPERATING EXPERIENCE

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Intermediate bulk containers are in widespread use in industry for handling hazardous and non-hazardous materials. As the use of IBCs has increased, so the number of chemical leaks and fires from IBCs has increased. This paper analyses the causes of IBC leaks at a large Ciba UK manufacturing site. The analysis is based on incident reports, near miss reports, interviews with site staff and interviews with site emergency response staff. Common causes of leaks are identified. Generic leak frequencies are then calculated for IBC leaks. The analysis includes different types of operations involving IBCs including transport, temporary storage, warehouse storage, waste product storage and process applications.

KEYWORDS: Intermediate Bulk Container, Learning From Incidents.

INTRODUCTION – THE USE OF INTERMEDIATE BULK CONTAINERS IN INDUSTRY

IBCs are in common use in industry as they allow relatively small quantities of chemicals to be transported between suppliers, manufacturers and customers and around site areas efficiently. IBCs are produced in a wide range of different sizes, shapes, materials of construction and designs to suit specific user requirements. They can be purchased as standard designs as a commodity product or they can be custom built for specific uses.

Custom built designs are more expensive. They tend to be used for regular shipments of product within a site or between different sites.

Standard designs tend to be used for single or medium use duty and are often used for delivering products to customers. Suppliers will often operate a recycling scheme, picking up used IBCs when new deliveries are made. Recycled IBCs are then cleaned and checked prior to re-use.

This paper is based on a study of 1,000 litre IBCs, with a variety of different designs.

IBC DESIGN PRINCIPLES

The integrity of an IBC depends on three critical components (see Figure 1):

1. A pallet which allows the IBC to be moved easily by fork lift trucks. Pallets are commonly made of heat treated timber, plastic or steel. Timber pallets are more susceptible to mechanical damage. Plastic and metal pallets have a longer design life but have low surface friction resistance. This can cause slippage when handled by fork lift trucks.

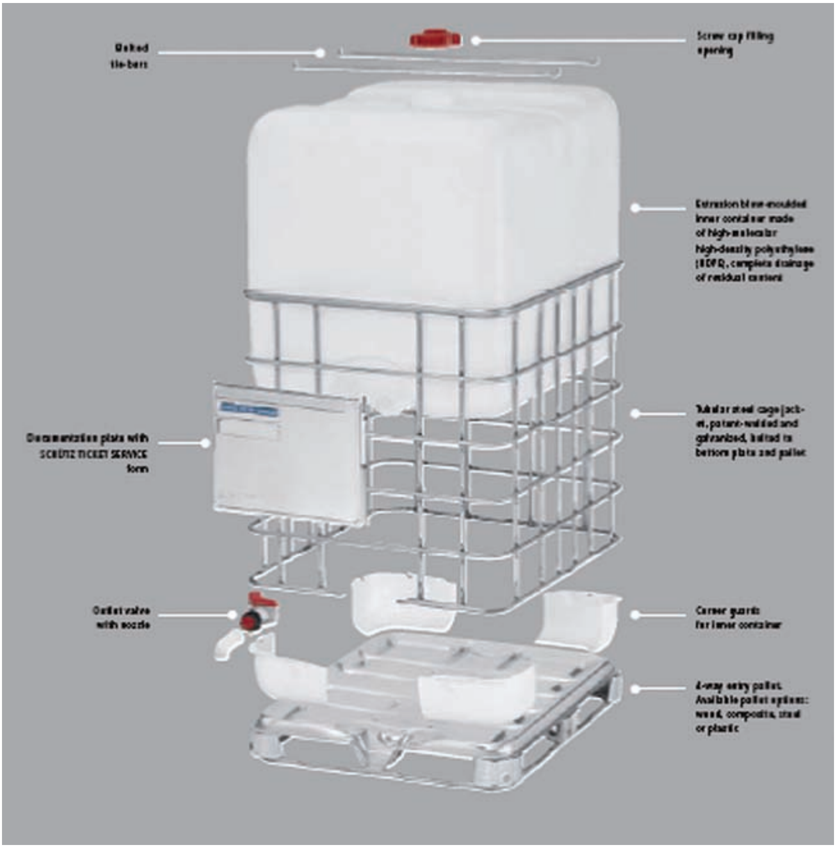

Figure 1. Typical IBC design features

Metal pallets can also cause sparks when they contact hard surfaces like concrete. The pallets are normally stamped, indicating the manufacturer and date of manufacture.

2. A container which holds the chemical. It is often made of translucent plastic, which is light, strong and easy to manufacture. Coloured plastics are also used for specific applications such as differentiating between different categories of chemical. Black plastic is used for reducing the risk of photo-initiation of monomers. White plastic is used for reducing heat input when containers are transported in hot countries. The container normally has a top screw cap which is used for filling operations. Small bore connections are normally provided, with larger bore connections for viscous liquids. An outlet valve is provided at the base of the container. This is normally recessed into the container to prevent the valve from being damaged when in transit. The valve is

normally fitted with a screw cap for additional leak integrity. Screw caps often have a tamper proof seal. Some IBCs are fitted with simple pressure relief devices which are attached at the fill point. IBCs are normally specified with an ullage space above the liquid level. If the ullage space is correctly calculated, a pressure relief device will not be required to meet normal transport requirements. For example, a 1,000 litre IBC will typically have a brimful capacity of 1.050 litres. Mistakes can be made by not calculating the ullage volume correctly or by failing to allow for the specific gravity of the product in the ullage calculation.

3. A metal cage which surrounds the container and is attached to the pallet. The cage can be manufactured with welded tubes, mesh rods or metal sides. Nameplates are attached to the cage so that the contents can be identified. The cage can be designed to provide static protection to the IBC.

The combination of pallet, container and cage provide mechanical integrity for the IBC. The mounting which holds the cage onto the pallet has to be strongly fixed. IBCs which are used for transporting hazardous chemicals often have additional and/or stronger fixings to improve integrity.

RISK DRIVERS

The following factors influence the risk of chemical leaks from IBCs:

- Safe operation is largely determined by the way that people handle IBCs.
- They are moved between different sites and reliance is placed on different companies in the supply chain.
- They are often re-used. Checks are required to ensure that the containers are clean and have not been damaged.
- Large numbers of IBCs are handled on chemical sites, often by relatively unskilled staff.
- There is a perception that they have limited hazard potential due to their relatively small size.
- They are often stored in groups in remote or unmanned site areas. Research has shown that this can allow fire incidents to spread rapidly, releasing large flammable/combustible inventories into uncontained site areas (Atkinson & Riley, 2006).

FRAMEWORK FOR ANALYSING IBC FAILURE MODES

Four consequence categories for IBC failures have been identified:

1. **Offsite chemical releases during transport** by truck, in port or on ships. These incidents are often limited to the release of relatively small inventories of chemical from one or a small number of IBCs. Releases tend to occur from poor packing/stacking, road traffic accidents or chemical reactions. These releases can cause significant nuisance and shipping delays because chemicals may be dispersed in small quantities over a wide geographic area. Particular problems occur when leaks involve toxic, sticky, odorous or environmentally sensitive chemicals.

2. **Chemical releases which do not ignite.** These releases occur frequently on sites which handle large volumes of IBCs. The consequences of release are often localised because of a combination of the relatively small inventories feeding the release, the fact that releases normally involve single or small numbers of containers and the relatively low hazard potential of many of the chemicals which are handled in IBCs. This type of release is typically seen as a low priority process safety issue at many sites.
3. **Chemical releases which ignite.** These are very rare events based on data from UK Ciba sites. IBCs are essentially small chemical storage tanks which can easily be manipulated by people and which have very limited hardware safety features. The containers may be handled where ignition sources exist; they may be stored in remote areas of the site which have limited fire detection and protection systems; and they may be stored close to other flammable or combustible containers, producing a scenario which allows rapid fire escalation.
4. **Fuel sources, causing fires in other areas of the site to escalate.** IBCs are often stored in relatively large groups in site areas such as waste storage areas, temporary container holding areas and warehouses. Research has shown that this can lead to rapid fire escalation, fed by large flammable/combustible inventories and limited pool containment systems (Atkinson & Riley, 2006).

Data about fires and fire escalations is rare. Data about unignited releases can, however, be found through staff interviews and an analysis of near miss records. The Ciba Bradford site has used a database near miss reporting system since 2001 (Beale, 2004). Database records from between 1/1/2005 and 30/9/2007 (a period of two and three quarter years) have therefore been analysed to identify reported chemical releases and near miss incidents involving IBCs. This provides a detailed profile of IBC releases over the period 2005–2007. Incidents which occurred before 2004 would only have been recorded if they were significant. These significant releases were identified from incident reports and from discussions with line managers and emergency response specialists.

All of these reported and recorded incidents have been analysed to identify IBC failure mechanisms leading to loss of containment and the relative frequency of occurrence of each type of failure mechanism.

FAILURE MODES

"IBC incidents are almost always caused by people mistreating or mishandling IBCs. They are rarely caused by mechanical or structural failure."

This is how an experienced line manager summarised his experience of failures and near misses at his site. Interviews with line managers and emergency response staff show that the following failure mechanisms have occurred:

Transport Incidents

1. IBCs are badly stacked inside trucks or the loads are badly secured. This allows movement in transit, causing IBCs to be damaged or topple.

2. Trucks are involved in road traffic accidents. IBCs are damaged and may leak inside the truck, onto roads and into drains.

Warehouse Incidents

3. Poor stacking causes IBCs at the top of a stack to fall onto other IBCs or onto the ground.
4. IBCs which are not stacked carefully into a warehouse compartment can protrude into the area where fork lift trucks operate. The next time that a fork lift truck accesses the area, it catches the protruding IBC, dislodging the IBC. This can cause the IBC to fall to the ground and can also cause the IBC to snag the warehouse racking, causing structural racking failure. Structural racking failure is most likely when tall and narrow warehouse aisles are used. Figure 2 shows an example of the aftermath of a racking failure.

Onsite Handling Incidents

5. IBCs fall off or unbalance a fork lift truck because they are not loaded carefully onto the forks, because the fork lift truck is not driven carefully or because the fork lift truck strikes an object or a pothole. The IBC is then dropped onto the ground.
6. An IBC is pierced with the fork lift truck lifting arms, puncturing the IBC and releasing it's contents. Figure 3 shows an example of a pierced IBC.
7. Fork lift trucks crash into static objects when moving IBCs. Static objects could be trucks, other fork lift trucks, stacks of IBCs, warehouse racking and warehouse walls.
8. IBCs jam or are misaligned on conveyor handling systems, causing deformation or toppling onto the ground.

Chemical Reactions

9. Containers are incorrectly labeled, often because they hold waste material, by-products or intermediate products. This can result in chemical storage in the wrong

Figure 2. Racking collapse incident

Figure 3. IBC pierced by fork lift truck

location or chemicals may be left in storage accidentally for long time periods, increasing the risk of an undesired reaction inside the container.

10. Fork lift truck operators leave IBCs in the wrong area of site. If they are stored close to incompatible chemicals, this could lead to a chemical reaction.
11. Waste material is run-off into IBCs, where it is accidentally mixed with incompatible material or it generates an unstable mixture.
12. Reactive chemicals, such as monomers, are left in IBCs and a polymerisation reaction is initiated. Typical causes would be inadequate quantities of inhibitor, contact with an impurity, lack of circulation and aged stock. IBCs are generally not fitted with pressure relief devices, so these failures tend to cause container swelling or failure. Figure 4 shows the aftermath of an IBC chemical decomposition reaction.

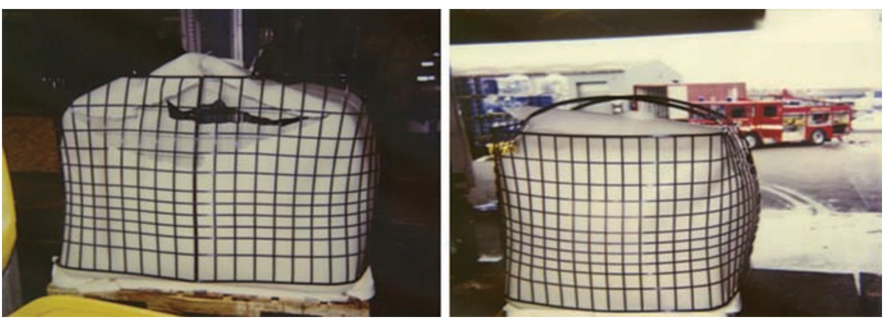

Figure 4. Chemical decomposition incident

Process Operations

13. IBCs are normally filled under operator control. They fill relatively quickly. If the operator is not concentrating or is distracted, containers can be overfilled.
14. The container is pumped out with the top cap in place, causing the IBC to be sucked in.
15. The contents of the IBC are charged to the wrong vessel or tank. This could cause an uncontrolled reaction in downstream process plant.

Mechanical Failures

16. The pallet at the base of the IBC is broken causing the container to slump. These failures are most likely with wooden pallets and rarely cause chemical leaks.
17. The outlet valve leaks. Most IBCs are fitted with external caps with tamper proof seals, thus providing an additional barrier against valve leaks.
18. Outlet valve connection leaks. This is normally caused by mechanical pressure on the top side of the valve mechanism. This causes the mechanism to bend with a failure at the connection point to the main IBC body. These failures can be prevented by fitting supports under the valve connection.
19. Deliberate tampering with the outlet cap and valve during transit or in a process area. Many IBCs have tamperproof seals to minimise this type of scenario.
20. Outlet valve left open in error causing the contents to leak to ground.

Damage To Safety Systems

21. In rack warehouse sprinkler systems are damaged when IBCs are not stored carefully. This should cause the system to operate, causing a revealed failure. This scenario is most likely when sprinkler heads are poorly located or when operators try to place multiple or large containers into a bay which is sized for a smaller container.
22. Fork lift trucks damage fire hydrants when manoeuvring around the site.

Table 1 summarises the reported causes of incidents and near misses involving IBCs for one large manufacturing site over the 33 month period. This data is based on employee generated reports using the site near miss reporting system. 107 reports for IBCs were raised in this time period. Table 2 summarises the type of site operation which was occurring when each report was made. Table 4 summarises the significant IBC incidents which were recorded in the period 1990–2003 based on incident reports and staff interviews.

FAILURE FREQUENCIES

Table 3 summarises the generic leak frequencies per year for the large manufacturing site based on incident records over the 33 month period where loss of containment was known to have occurred. It is not possible to determine the size of the leak from the reports and events could range from pinhole releases (1 mm equivalent hole diameter) to larger 75 mm hole diameter releases. Most of the releases are known to have been associated with low hazard products.

Table 1. IBC near miss and incident summary 2005–2007

Fork Lift Trucks (FLT)	**Operational Errors**
Pallet overturned in transit 9	Stored in too high a bay in warehouse 8
FLT collision with racking 5	Incorrect or no labeling 7
IBC punctured (spiered) by FLT 5	Stored in wrong area of site 5
FLT collision with IBC 4	Wrong chemical delivered to works 3
FLT collision with wall 4	Inappropriate container used 1
FLT collision with process equipment 2	
FLT collision with FLT 2	
Tried to stack 2 IBCs in 1 warehouse bay 2	
FLT damage to fire sprinkler system 1	
Container slipped off racking 1	
FLT mechanical failure 1	
FLT overbalanced 1	
Process	**Integrity**
Leak during filling 6	Container leak 11
Waste product polymerises 3	Pallet leak 2
Leak during emptying 2	Seal too big for container 2
Overfill 1	Loose outlet valve 1
Hose hit by operator 1	Warehouse support beam collapse 1
Leak during IBC switchover 1	
Supply Chain	**Automated Packing Machines**
Contamination in container 3	Snagged on packing machine 1
Lid not fastened tightly 3	Fell off packing machine 1
Load incorrectly packed in HGV 2	Set to reverse not forward 1
HGV collision with IBC 2	
Driver offloaded himself with pallet truck 1	
Filled hot, capped, cooled, imploded 1	

Note: Number of reported loss of containment events over a 33 month period, 2005–2007.

CONCLUSIONS

22 IBC failure and error mechanisms have been identified based on the experience of line managers and emergency response staff who work with IBCs. A detailed analysis of reported near misses and incidents over a 33 month period between 2005 and 2007 identified 107 records relating to IBCs. Fork lift truck movements inside warehouse areas, warehouse storage and fork lift truck movements in site areas each accounted for about 20% of the failure reports. Filling/emptying operations and process incidents each accounted for about 13% of the failure reports. 13% of the failure reports were caused by errors in the supply chain with site deliveries.

Table 2. IBC near miss and incident summary 2005–2007 by operation

Operation	Number of events	%
Receipt at goods inwards	14	13
Fork lift truck movement in warehouse	19	18
Storage in warehouse area	20	18
Fork lift truck movement around site	22	21
Filling/emptying	14	13
Process use	16	15
Packing in warehouse	2	2
TOTAL	**107**	**100**

Note: Based on reported loss of containment events over a 33 month period, 2005–2007.

Table 3. IBC leak frequency analysis

Cause of loss of containment	Number	%	Frequency/site/yr
Container leak	11	35	4.0
Leak during filling	6	20	2.2
Spiered by fork lift truck	5	17	1.8
Uncontrolled polymerisation	3	10	1.1
Leak during emptying	2	6	0.7
Container overfilled	1	3	0.4
Loose outlet valve	1	3	0.4
Spill during IBC switchover	1	3	0.4
Operator contact with hose	1	3	0.4
TOTAL	**28**	**100**	**11.3**

Note: Based on reported loss of containment events over a 33 month period, 2005–2007.

The reports suggest that the large site suffers about 11 IBC loss of containment incidents per year. These range from small pinhole leaks, such as nail penetration through base to catastrophic failures, such as polymerisation reactions. 35% of the leaks are from the container. This will include brand new containers and re-used containers. 20% are caused by leaks during filling. 17% are caused when fork lift trucks puncture the IBC with their forks. 10% are caused by uncontrolled reactions inside the IBC.

This analysis could be used to identify IBC failure modes for a risk analysis and as a source of generic frequency data for base events which could be used in a fault tree or Layer Of Protection Analysis (LOPA) study for a major accident hazard scenario. Although

Table 4. IBC incident summary 1990–2003

Date	Type	Cause	Consequence
1993	Warehouse – IBC explosion at Goods In	Truck container full of IBCs from the USA being offloaded. IBCs should have contained low hazard product but it was contaminated with hydrogen peroxide which then decomposed.	IBC exploded liberating 200 kg of product. Evidence of deformation and internal pressure build up in remaining IBCs in the container.
1994	Fork lift truck failure	Securing pin on fork lift truck failed when an IBC was being lifted.	IBC fell to floor. No loss of containment.
1996	Warehouse – fork lift truck failure	Hydraulic failure.	Damage to warehouse racking affecting low hazard product.
1996	Warehouse – racking collapse	Pallets not centered on racking support rails. Pallet fell dragging other containers with it.	16 IBCs fell, 12 from high level. Small spill of low hazard product.
1997	Fork lift truck failure	Bleed plug expelled. Loss of hydraulic pressure on fork lift truck used for accessing high levels.	Truck cab fell rapidly from height and then slowed. No injury.
1998	Warehouse – fork lift truck collided with racking.	Driver steering error. Fork lift truck crashed into racking.	Localised racking collapse affecting low hazard product.
1998	Warehouse – racking collapse	Pallet not stacked accurately in storage bay.	Localised racking collapse when pallet moved.
1998	Transport accident at major port	Tug driver pulling two containers which he believed were both empty. One was actually full. Load was unbalanced. Container toppled over at roundabout inside port area.	Container held 18 IBCs. IBC leaked low hazard liquid into container. Container had to be cleaned out.
1999	Fork lift truck failure	Lifting chain on fork lift truck collapsed.	IBC fell to floor. No loss of containment.

(*Continued*)

Table 4. Continued

Date	Type	Cause	Consequence
1999	Fork lift truck failure	Lifting chain on fork lift truck failed. Empty IBCs had just been moved.	No impact.
2000	Road traffic accident on major motorway	HGV passed too close to transit van and trailer causing trailer to jack knife. Trailer contained IBC.	Viscous material spilt on motorway. Motorway closed for long period.
2003	Warehouse – fork lift truck collided with racking.	Driver drove down narrow aisle with forks protruding about 300 mm. The forks hit the main structural frame of the warehouse racking, weakening the structure.	Localised racking collapse affecting 4 tiers of racking containing low hazard product.

the leak data from 2005–2007 is considered to be comprehensive for the site, care should be exercised because the data covers a relatively short 33 month analysis period and it is difficult to ascertain the size of the leaks which underpin the analysis.

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