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Plastic containers for flammable liquids/hazardous areas

Electrostatic risks

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Research Report

Health and Safety
Executive

Plastic containers for flammable liquids/hazardous areas

Electrostatic risks

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This report contains an assessment of the electrostatic risks associated with a selection of commonly available plastic containers ranging in size from 50 ml bottles to 1000 l Intermediate Bulk Containers, and manufactured from a variety of materials.

The containers are assessed by measuring the amount of charge transferred from their surfaces in an electrostatic discharge, after being charged by rubbing with the most suitable materials for optimum charging. The charge transfer values obtained can then be compared to maximum permitted values for different gas groups contained in EN13463-1:2001.

Incendivity tests were also conducted on the discharges from the containers, which give an indication of typical amounts of charge transfer actually required for ignition in a practical situation, as a guide for incident ignition assessments.

A description of the types and purposes of most of the various designs of IBC currently available is included, in particular those designed for zone 1 and zone 2 usages.

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EXECUTIVE SUMMARY

Flammable liquids have traditionally been stored in metal containers, however in recent years, due to a variety of commercial reasons, plastic containers of a wide variety of shape, size, type, and materials, have seen widespread adoption for the storage and transport of liquids and other free flowing materials. Unfortunately most plastics are highly electrically insulating and tend to become electrostatically charged and may result in either electrostatic or spark discharges which are capable of igniting explosive atmospheres. Recently much development has taken place in response to customer requirements in materials and design, which is likely to significantly affect the electrostatic properties and potential ignition hazards. The key project objectives were to establish appropriate test procedures for a range of container types sizes in order to evaluate the potential electrostatic hazards. The evaluation includes where appropriate, the effects of filling with liquids of different conductivities on the electrostatic behaviour inside and outside the container, and the electrostatic consequences of various construction methods.

Objectives

- Establish if standards exist for plastic containers relating to electrostatic risk.
- Develop a suitable method of measuring charge transferred.
- Determine propensity for charging for different materials applied to small plastic materials used for laboratory and pharmaceutical purposes, and relate charge transferred to ease of ignition in practice.
- Examine effects of surface on charge transferred.
- Determine charge transferred for various available types of rigid intermediate bulk containers (RIBC) including types claimed to have suitability for use in flammable atmospheres.
- To establish appropriate testing procedures that can be used to demonstrate whether or not an electrostatic ignition hazard is present for different types of plastic containers and equipment.
- To quantify the electrostatic ignition hazards from liquids with different conductivity in plastic containers of varying construction

Main Findings

- A European standard is presently being developed detailing performance and design requirements for both rigid intermediate bulk containers (RIBC) and flexible intermediate bulk containers (FIBC), but the RIBC are as yet proving more difficult to define than the FIBC, as the designs are in a constant state of development by a number of independent manufacturers. Three different designs of container claiming to have suitability for use in flammable atmospheres were tested and compared with the standard versions. The flammable atmosphere type all had labels indicating that they were certified according to CENELEC TR 50404:2003 for use in zone 1 and 2 areas, for gas groups IIA and IIB with minimum ignition energies (MIE) of 0.2 mJ and above (gas groups labelled IIA, IIB and IIC are listings of gases and vapours which conveniently fall into three categories classified accordingly to ignitabilities of gas/air mixtures). TR 50404 is in its present form, a code of practice for the avoidance of hazards due to static electricity. It refers to methods of determining incendivity of discharges including the methods described in EN 13463 annex C, and advice on the use of containers, including IBC in section 5.4.6.1.

- A test procedure was developed based on the methods in EN 13463 for measuring charge transfer, and included ignition tests in different gas groups.

- All the RIBC tested produced electrostatic discharges from some areas including caps and tap handles. Most of the discharges were in excess of the 60 nC limit for IIA gases and vapours. Many of the RIBC produced discharges in excess of 100 nC from the tank area around the tap, including both clad types which were indicated as being suitable for intended use in flammable atmospheres, or containing flammable liquids. The clad types had conducting/dissipative flaps covering the tap area, but these would need to be lifted to attach or remove pipe connections exposing the plastic.

- Discharges from containers as small as 50 ml (the smallest tested) produced charge transfer levels in excess of the limits stated in EN 13463 annex C for IIC and came close to the limit for IIB gases and vapours.

- Some containers of 100ml capacity and most containers of 250 ml capacity and above produced charge transfer levels in excess of the Standard limits for IIA gases and vapours.

- Discharges from containers as small as 60 ml produced ignitions in a IIC gas mixture (hydrogen/air).

- Discharges from almost all containers of 100 ml and above produced ignitions in a 11B gas mixture (ethylene/air)

- Discharges from a 1000 ml container produced ignitions in a IIA gas mixture (methane/air).

- The ignition test results from these small container tests, plus other ignition tests carried out previously on charged plastic objects, indicate that the limits stated in EN 163346 annex C are sufficiently low to leave a suitable safety margin compared to a typical charge transfer figures at which ignitions of the various gas groups were found to occur in practice.

Problems identified were:

- A potential ignition hazard risk exists with all plastic containers including very small ones.

- Discharges producing charge transfer levels indicating they were likely to be incendive in all gas groups, were obtained from around the tap areas of IBC certified for use in flammable atmospheres once covering flaps were lifted.

- Discharges in excess of the 60 nC limit for IIA gases and vapours were obtained from filler caps and taps on certified containers.

Recommendations

For intended use of plastic containers in flammable atmospheres: or containing flammable liquids:

- A risk assessment should be carried out before using any size of plastic container in a flammable atmosphere or to contain flammable liquids. The risk assessment needs to consider the possibility of a flammable vapour or aerosol mist being produced from the liquid, bearing in mind flashpoint and process parameters such as temperature and pressure. If a flammable atmosphere is thought possible, then the charge transfer level potential compared to the limits for the gas group as defined in EN 163346 annex C needs to be considered. Advice is given in CENELEC TR 50404:2003 section 5.4.6.1

- Only RIBC intended for use in flammable atmospheres should be employed. However it should not be presumed that they are inherently safe for use in flammable atmospheres and a process risk assessment should be carried out.

- The frame and any other conducting parts of RIBC should be electrically bonded to earth during any operation where electrostatic charging may occur, and sufficient charge relaxation time allowed before moving. They should not be stored on a highly insulating surface unless separately earthed.

- Splash filling should be avoided by bottom filling via an earthed conductive fill pipe, which will also help to dissipate charge on the liquid. With larger containers such as IBC where high fill rates are possible, then advice on recommended maximum fill rates given in CENELEC TR 50404:2003 section 5 should be followed.

- The electrical earth connection between the RIBC frame and the conducting part of the tap should be checked for integrity at regular intervals.

- Clad type RIBC, both metal and plastic, should have the cladding extended to cover all areas which can be accessed, and potentially rubbed. In particular the areas around the tap even if covered with a flap, and up to the filler cap should be addressed. This would be simple to do in practice.

- External RIBC plastic components such as taps and filler caps should be made from dissipative materials on the outside surfaces.

- Mechanical considerations such as potential puncture damage from forks etc. and potential effects of fires should also be considered in the risk assessment, and if the use of a RIBC reinforces potential dangers of use compared with more moderately sized containers.

- Consideration should be given to the variation in charge transfer obtained from nominally similar areas of exposed plastics, which may be attributable to variations in surface texture. This warrants further investigation as a potential means of inhibiting brush discharges by deliberately engineering the surface texture of the plastic.

1 INTRODUCTION

In recent years plastic containers of a wide variety of shape, size and type (including different materials), have seen widespread adoption for the storage and transport of liquids and other free flowing materials. Sizes range from a few ml up to 3000 l. Unfortunately most plastics are highly electrically insulating and tend to become electrostatically charged and may result in either electrostatic or spark discharges which are capable of igniting explosive atmospheres. Potentially incendive electrostatic discharges can occur from the surface of the plastic container, or from the surface of the insulating liquid in the container. Spark type discharges can occur from charged conducting objects (either solids or conducting liquids), that have become isolated (e.g. by the plastic) and are unable to dissipate their charge. There are two distinct ignition hazards that must be considered with plastic containers – internal ignitions of flammable contents and external ignitions of flammable atmospheres surrounding the container. In the case of the latter, the contents of the plastic container may not actually be flammable.

Intermediate Bulk Containers (IBC) have become widely used for transporting and storing large quantities of free flowing materials. Flexible Intermediate Bulk Containers (FIBC) are mainly used with powdered, flaked and granular materials and Rigid Intermediate Bulk Containers (RIBC) with liquids. These types of container are becoming increasingly used and offer a number of commercial advantages including cost, versatility, corrosion resistance, product purity, reduced weight and lower transport charges. However, these types of containers have introduced new safety hazards/issues in addition to electrostatic hazards and for more information see Holbrow 2002 (ref 1) and Atkinson 2006 (ref 2) and Atkinson and Riley 2004/2006 (ref 3 & 4).

The interest in the potential for electrostatic ignition from plastic containers is obviously very important, and has been highlighted since electrostatic hazards were specifically mentioned in the ATEX Worker Directive (See Standard EN1127 1998) (ref 5/6) and the adoption in the UK as the DSEAR Regulations. This has led to further activity in terms of standards covering electrostatic hazards both specifically (PD CLC/TR 50404:2003) (ref 7) and more generally for equipment for use in explosive atmospheres (EN13463-1:2001) (ref 8). A particular issue in relation to electrostatic testing, which is investigated in this work, is the method used, and whether charge transfer measurement is effective or if actual ignition testing should be carried out.

Since most RIBC are made of plastic materials this means that they are not permitted to be used in explosive atmospheres in classified hazardous areas (IEC 60079-10) (ref 9) unless special safety measures against electrostatic ignition hazards are taken. Various designs of both FIBC and RIBC have been developed and are available to try and overcome these issues. For FIBC four different designs have evolved, which aids the ease of classification. However the precise styles of RIBC are far less specific than for FIBC, and there is as yet no universally used approach used to describe them. This is perhaps not surprising, as the designs are in a constant state of development by a number of independent manufacturers, and many new types have recently appeared and others continue to do so. In practice, the attempts at reducing the electrostatic hazards essentially involve surrounding a HDPE (High Density Polyethylene) body with a conductive screen (either solid metal sheets or a close wire mesh) that is earthed during filling and emptying. This is also usually coupled with providing an earth contact for the liquid within the container. Other variations on this theme involve use of a conducting HDPE body or a dissipative plastic screen. Some types have also been developed for increased chemical resistance to the contents, using a fluorinated HDPE body with various external combinations, including multilayer bodies.

A European standard is presently being developed detailing performance and design requirements for both types, but the RIBC are proving more difficult to define than the FIBC.

2 CHARGE TRANSFER TESTS ON SMALL/MEDIUM SIZE CONTAINERS

The most likely ignition hazard associated with small /medium size containers is a brush discharge from the surface of the container as a result of it being charged by some sort of physical action. This might be by rubbing, removal of an adhesive label, contact with air driven particles or other mechanisms in which electrons can be physically removed. A brush discharge is analogous to a spark discharge from a conductor, but because it occurs from an insulating surface with limited electron mobility, the charge can only be gathered from a limited area of the surface and also cannot concentrate at one point. Consequently it is spacially and temporally different to a spark discharge and is not as incendive as a spark discharge of the same measured charge transfer.

2.1 BRUSH DISCHARGES

Brush discharges occur when insulating surfaces become charged and an earthed conductor is brought close to the surface. Test methods to investigate this involve measuring the level of electrical charge transferred in the discharge in order to assess its incendivity. The method used is in principle the same as that described in the standard EN13463-1:2001. To attempt to produce an electrostatic brush discharge, each container was charged and brought close to the surface of a conducting sphere. The sphere was connected to a capacitor and a high impedance voltmeter. Generally, as the charged object is brought close to the conducting sphere, initially a voltage is produced on the capacitor, which disappears if the object is moved away. This is an induced voltage, which increases as the separation between the object and the sphere electrode decreases.

If the object is sufficiently highly charged and the separation between it and the sphere small enough, then an electrostatic discharge can occur to the sphere from the plastic surface, which is indicated as a permanent reading on the voltmeter when the electrode is moved away and the induced voltage dissipates to a negligible value. The voltage on the capacitor is a measure of the charge transferred during the discharge, which can also be used to assess the igniting ability of the discharge. This technique enables very small discharges to be detected, which are difficult to see or hear but are still capable of igniting flammable atmospheres.

2.2 EN16346: 2001 ANNEX C TEST FOR INCENDIVITY OF BRUSH DISCHARGES

The standard method for whether a non-conductive material is capable of being charged to produce brush discharges and therefore can act as an ignition source for an explosive gas/air or vapour/air mixture is that described in Annex C of EN13463: 2001 This test is intended to investigate flat pieces of material (representative samples of materials that are intended for use as equipment cases etc.) and actual objects whose electrostatic properties are also shape dependant such as the containers investigated here.

Given the widespread acceptance and use of this test, it has been used as the basis of the work here. The relevant text extracted from Annex C of EN13463: 2001 is included at the top of the next page.

> "*the test should be performed with the part itself or a 225 cm2 flat sample of the material from which the equipment is constructed. The size of the flat sample is relevant because experimental evidence shows that 225 cm2 is an optimum value for the surface area in terms of charge distribution density. Other factors influencing the validity of the test results are the humidity of the test environment, which shall be kept to 30 % RH or less at 23 °C _ 2 K to minimize leakage of the electrostatic charge. Also, the size of the spark discharge electrode to produce a single spark is important. Too small electrodes can lead to multiple discharge sparks and/or corona discharging of lower energy. Therefore a spherical electrode with a radius which should be at least 10 mm radius shall be used to produce a single point discharge spark. Furthermore, the extent of the person's perspiration is also of influence.*
>
> ### *C.2 Principle of the test*
>
> *Either the actual sample or if it is not possible because of its size or shape, a 150 mm x 150 mm x 6 mm plate shaped sample of the material shall be conditioned for 24 h at 23 °C _ 2 K and a relative humidity not higher than 30 %. Its surface is then electrically charged, under the same environmental conditions as it was conditioned, by three separate methods. The first method involves rubbing the surface with a polyamide material (e.g. a polyamide cloth). The second, rubbing the same surface with a cotton cloth and the third, exposing the same surface to a high voltage spray electrode. After completion of each of the charging methods, the charge Q from a typical surface discharge is measured. This is done by discharging the sample by a spherical electrode (10 mm radius) into a known value-fixed capacitor C and measuring the voltage V across it. The charge Q is given by the formula Q = CV, where C is the value of the fixed capacitor in Farads and V is the highest voltage. This procedure is used to find the method that produces the highest measured charge to assess of the incendivity of the discharge according to C.4.2.4. Where there is a general trend of decreasing stored charges during these tests, new samples have to be used for the following tests. The highest value shall be used for the assessment procedure according to*
> *C.4.2.4.*
> *NOTE In some cases the properties of the charged material could be changed due to the discharges so that the transferred charge decreases in subsequent tests. As this kind of experiment can be influenced by, e.g. the person's perspiration, it shall be demonstrated by a*
> *calibration experiment with a reference material of PTFE that the transferred charge is at least 60 nC."*

For the testing carried out this was essentially the method used, combined with actual ignition tests with representative gas/air mixtures from the different gas groups. .

2.3 PLASTIC CONTAINERS

A selection of plastic containers were purchased ranging in size from 50 ml to 25 l manufactured from as wide a range of plastics as were readily available. The test procedure used involved deliberately charging the containers using different methods and then attempting to obtain brush discharges from the container surface.

In addition to the charging tests, material characteristics including resistivity were also measured.

2.4 CHARGING TESTS

Charging of the containers was attempted by rubbing and flicking them with various woven materials, whilst being held by the operator, which are both recognised techniques in BS5958 Part 2. The rubbing and flicking simulated direct tribo-charging. Cotton, nylon and other fabrics were used, chosen to be from opposite ends of the tribo-electric series. The tribo-electric series is a table of materials rated at their ability to become charged [1]. Charging of the containers was also attempted by spray charging using a high voltage pointed electrode to spray charge directly onto the plastic. For these tests the containers were positioned on both insulating and conducting surfaces. Electrostatic charging is strongly affected by humidity so all testing was carried out in a humidity controlled environment at a temperature of $21^o \pm 2^oC$ and a humidity of 20 ±5 % RH.

Charging and material surface resistivity are also strongly affected by contamination, so prior to and at intervals during testing the containers were cleaned with high purity n-heptane, a very low conductivity solvent which was allowed to evaporate before commencing testing. This cleaning was to remove any surface contamination such as a mould release agent, which may be present on new items. The test technique was validated by using a flat disk made of PTFE with an area of 225 cm^2 as a highly chargeable reference.

Tables on the following pages show the results from charge transfer measurements on a range of small bottles.
A total of 20 charge transfer tests were carried out on each sample, and the highest value and average of the 20 tests are shown in the tables.
In terms of the incendivity of discharges, European Standard EN13463-1:2001 Annex C gives an indication of the allowable charge transfer for the different gas groups and this is summarised below:

If the maximum transferred charge Q measured in any of the charge transfer tests is less than:

- 60 nC the non-conductive material is suitable for use with explosion Group I or IIA;
- 30 nC the non-conductive material is suitable for use with explosion Group I or IIB;
- 10 nC the non-conductive material is suitable for use with explosion Group I or IIC.

Information on the gas grouping is given in IEC/EN 160079-20

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[1] *The tribo-electric series basically lists materials in terms of their ablility to become positively or negatively charged.. The polarity of the charge is dependant on the materials ability to either lose or gain surface electrons, and the best tribo-charging occurs between materials at the opposite ends of the series.*

Table 1. Charge Transfer Results for Small Bottles

TYPE	CAPACITY ml	MATERIAL	MANUFACTURER /SUPPLER	MAXIMUM CHARGE TRANSFER nC	AVERAGE CHARGE TRANSFER nC	METHOD
Narrow round neck	1000	LDPE	Kautex Textron 301770508	98	73.5	Cotton cloth
Narrow round neck	500	LDPE	Kautex Textron 301770507	78	53.55	Cotton cloth
Narrow round neck	250	LDPE	Kautex Textron 301770506	78	55.05	Cotton cloth
Narrow round neck	100	LDPE	Kautex Textron 301770504	61	31.45	Cotton cloth
Narrow round neck	50	LDPE	Kautex Textron 301770503	29	20.35	Cotton cloth
Wide mouth	1000	HDPE	Azlon BWH 1000PN	101	83.4	Cotton cloth
Wide mouth	500	HDPE	Azlon BWH0500PN	99	63.1	Cotton cloth
Wide mouth	250	HDPE	Azlon	75	57.4	Cotton cloth
Fluorinated (white)	500	HDPE	Aeropak BTR-661-020U	90	68.4	Cotton cloth
Oblong (stores)	2000	HDPE	Nalgene	136	117.4	Cotton cloth
Fluorinated translucent	1000	Fluorinated HDPE	Aeropak HP40-005D BTR-661-030W	147	111.7	Cotton cloth
Fluorinated translucent	1000	Fluorinated HDPE	Aeropak HP40-005D BTR-661-030W	133	106.45	Wool/nylon
Wide mouth bottle fluorinated	500	FLPE	Fisher BTR-661-020U	58	42.75	Cotton cloth
Wide mouth bottle fluorinated	250	FLPE	Nalgene 2197-0008	53	32.1	Cotton cloth
Wide mouth bottle fluorinated	125	FLPE	Nalgene 2197-0004	26	15.05	Cotton cloth

Table 1. Charge Transfer Results for Small Bottles (continued)

TYPE	CAPACITY ml	MATERIAL	MANUFACTURER /SUPPLER	MAXIMUM CHARGE TRANSFER nC	AVERAGE CHARGE TRANSFER nC	METHOD
Translucent beaker	2000	PP	Azlon	83	51.6	Cotton cloth
Translucent beaker	1000	PP	Azlon	81	42.6	Cotton cloth
Translucent beaker	500	PP	Azlon	76	50.65	Cotton cloth
Translucent beaker	100	PP	Azlon	47	30.05	Cotton cloth
Wide mouth (stores)	60	PP	Azlon	79	46.15	Cotton cloth
Narrow neck conical with red stopper	1000	PP	Vitlab VITL 100694	63	34.36	Cotton cloth
Narrow neck conical with red stopper	500	PP	Vitlab VITL 100594	82	52.8	Cotton cloth
Narrow neck conical with red stopper	250	PP	Vitlab VITL 100494	62	45.55	Cotton cloth
Narrow neck conical with red stopper	100	PP	Vitlab VITL 100394	40	37.1	Cotton cloth
Narrow mouth (clear like glass)	1000	PC	Nalgene 2205-0032	107	62.75	Cotton cloth
Narrow mouth (clear like glass)	500	PC	Nalgene 2205-0016	54	34.35	Cotton cloth
Graduated beaker with handle 1223-3000	3000	PMP	Nalgene 1223-3000	63	44.9	Cotton cloth
Graduated beaker with handle 1223-1000	1000	PMP	Nalgene 1223-1000	62	53.75	Cotton cloth

Note: Fluorinated HDPE is essentially the same as FLPE and is a variation in manufacturers description.

3 IGNITION TESTS ON SMALL/MEDIUM SIZE CONTAINERS

In addition to the charge transfer testing described in Chapter 2 actual ignition testing was carried out. This testing was performed in the same manner as for the charge transfer tests, but the sphere was earthed and surrounded with a flammable gas/air mixture through which the charge transfer occurred

Tests were carried out on the discharges from the charged containers to determine their incendivity in various flammable gas/air mixtures. A gas/air mixture was used which corresponded with each of the three gas groups:

20 unsuccessful attempts were made on each container before it was classified as a non-ignition in that particular gas group.

Table 2. Optimum Test Gas Mixtures

Gas Group	Test Gas	Concentration (%)
Group IIA	Methane	8.4
Group IIB	Ethylene	7.8
Group IIC	Hydrogen	21

The maximum amount of charge allowed to be transferred for a discharge from a material to be classed as non-incendive for a particular gas group is given below-

IIA – 60 nC
IIB – 30 nC
IIC – 10 nC

Table 3. Ignition Testing Results for small bottles.

CONTAINER TYPE	CAPACITY ml	MATERIAL	HYDROGEN IGNITION	ETHYLENE IGNITION	METHANE IGNITION
Kautex Textron 301-770508 narrow round neck	1000	LDPE	Not tested	Yes	No
Kautex Textron 301770507 narrow round neck	500	LDPE	Not tested	Yes	No
Kautex Textron 301770506 narrow round neck	250	LDPE	Not tested	Yes	No
Kautex Textron 301770504 narrow round neck	100	LDPE	Not tested	Yes	No
Kautex Textron 301770503 narrow round neck	50	LDPE	No	No	Not tested

Table 3. Ignition Testing Results for small bottles (continued)

CONTAINER TYPE	CAPACITY ml	MATERIAL	HYDROGEN IGNITION	ETHYLENE IGNITION	METHANE IGNITION
Azlon wide mouth 7BWH1000N	1000	HDPE	Not tested	Yes	No
Azlon wide mouth 7BNH0500PN	500	HDPE	Not tested	Yes	No
Nalgene oblong (stores)	2000	HDPE	Not tested	Yes	No
Aeropak fluorinated (white) BTR-661-020U	500	HDPE	Not tested	Yes	No
Azlon	250	PP	Not tested	Yes	No
Azlon (stores)	60	PP	Yes	No	Not tested
Vitlab bottle narrow neck conical red stopper VITL 100694	1000	PP	Yes	No	Not tested
Vitlab bottle narrow neck conical red stopper VITL 100594	500	PP	Yes	No	Not tested
Vitlab bottle narrow neck conical red stopper VITL 100494u	250	PP	Not tested	Yes	No
Nalgene clear plastic bottle narrow mouth	500	PC	Yes	No	Not tested

Table 3. Ignition Testing Results for small bottles (continued)

CONTAINER TYPE	CAPACITY ml	MATERIAL	HYDROGEN IGNITION	ETHYLENE IGNITION	METHANE IGNITION
Nalgene graduated beaker with handle 1223-3000	3000	PMP	Not tested	Yes	No
Nalgene beaker graduated with handle 1223-1000	1000	PMP	Not tested	Yes	No
Aeropak narrow top fluorinated BTR-661-030W	1000	Fluorinated HDPE	Not tested	Yes	Yes
Nalgene wide mouth bottle fluorinated 2197-0008	250	FLPE	Not tested	Yes	No
Nalgene wide mouth bottle fluorinated 2197-0004	125	FLPE	Not tested	Yes	No

Note: Fluorinated HDPE is essentially the same as FLPE and is a variation in manufacturers description

4 CHARGE TRANSFER TESTS ON RIGID INTERMEDIATE BULK CONTAINERS (RIBC)

4.1 RIBC TYPES TESTED

Schutz general-purpose type (figs 1-4) with open framework allowing easy access at top and sides for potential rubbing and placement of conducting objects on top. This is typical of the common type of RIBC made by a variety of manufacturers. Whilst they are not intended for use in zoned areas they are often used for the storage of flammable liquids.

Fig 1

Fig 2

Fig 3

Fig 4

Schutz metal clad type (Figs 5-10). Plastic body is fully covered with sheet metal inside outer metal cage. Cladding prevents major access to plastic surface, but has a plastic cap and a small uncovered area around the cap. There is a larger uncovered plastic area above the tap once a metal cover flap is lifted for access. The flap is easily detached and quite likely to be lost in practice. The yellow label indicates that the RIBC is certified for use in zones 1 and 2 according to CENELEC TR 50404:2003.

Fig 5

Fig 6

Fig 7

Zertifiziert für Ex-Zonen 1+2 nach CENELEC TR 50404:2003

SICHERHEITSHINWEISE

- Der IBC darf für Flüssigkeiten der Explosionsgruppe IIA und IIB (entsprechend EN 50014) mit einer Mindestzündenergie von: ≥ 0,2 mJ benutzt werden
- Der IBC darf nicht in Zone 0 benutzt werden
- Misch- und Rührvorgänge sowie schnelle wiederholende Befüllvorgänge sind zu vermeiden
- Der IBC sollte nicht direkt nach dem Reinigen wiederbefüllt werden
- Während dem Befüllen und Entleeren muß der IBC geerdet werden

Certified for Ex-Zones 1+2 according to CENELEC TR 50404:2003

Safety instructions

- The IBC can be used for liquids of the explosion group IIA and IIB (according to EN 50014) with a minimum ignition energy of ≥ 0,2 mJ
- The IBC shoulr not be used in zone 0
- Mixing, stirring, and rapid repeated fillings should be avoided
- The IBC should not be filled immediately after cleaning
- During filling and emptying operations the IBC has to be earthed

Fig 8


¡Atención!
¡Antes de abrir la válvula suelten el tornillo de seguridad!
200
100

Fig 9


¡Antes de abrir la válvula suelten el tornillo de seguridad!

Fig 10

Mauser Repaltainer (Figs 11-14). This has a steel mesh cage at the sides with a plastic (recycled PE) pallet and top cover, not intended for use in zoned areas.

Fig 11

Fig 12

Fig 13


31HA1 /Y/ 10 03 /D/ BAM 5752 -M
4300/2050/ 82 KG /1050 l/ /100 k
IBC
COLLECT
MIPI
Bitte setzen Sie sich mit uns in Verbindung.
Please contact us. · SVP contactez nous.
Por favor, contactar nos. · Prego contattare nos.
+49 (0) 180 1 IBC COLLECT
+49 (0) 180 1 422 2655328
FAX
+49 (0) 180 3 IBC COLLECT
+49 (0) 180 3 422 2655328
eMail ibc-collect@mipi.com
www.ibc-collect.de
for global inquiry
MAUSER

Fig 14

Mauser type EL Exemplary Conduct (Figs 15-20). This is nominally the same as the Mauser Repaltainer, with recycled plastic top and base but with the addition of a corrugated black plastic covering over the areas of exposed inner tank preventing access. This is similar in principle to the Schutz metal clad. It has closer fitting cover around the cap than the Schutz, but a similar exposed area around the tap covered by a black plastic flap. Both have earthing wires linking the frame to the tap pivot spindle. This is intended to prevent the conducting parts of the tap becoming electrically isolated and help dissipate charge on the contents of the RIBC.

Fig 15

Fig 16

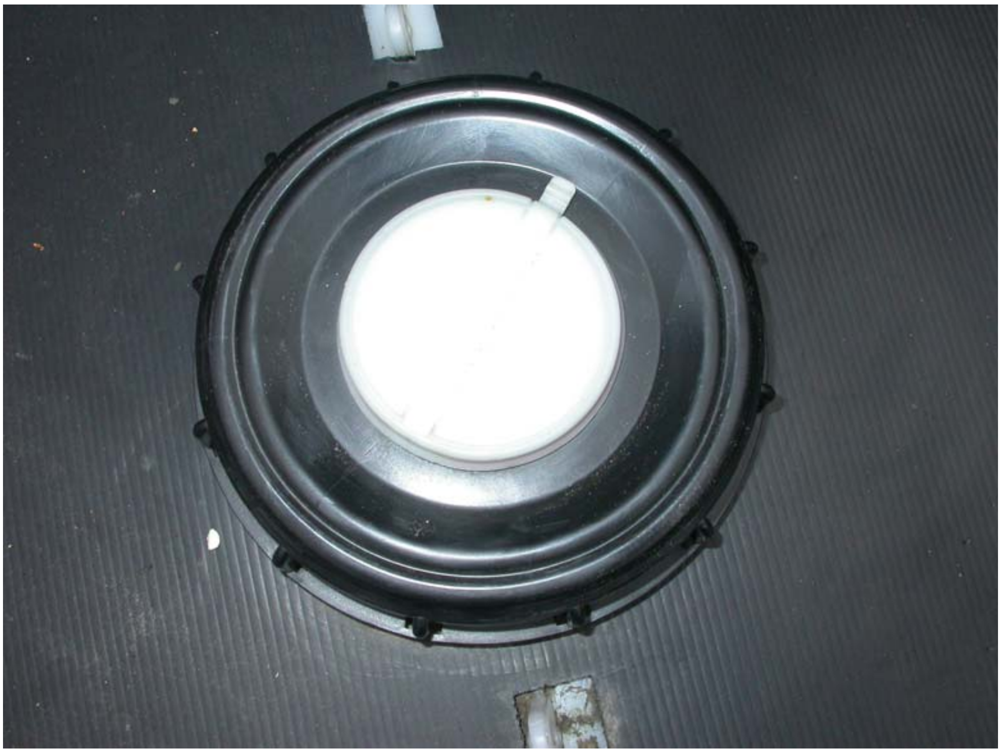

Fig 17

Zertifiziert für den Einsatz in Ex-Zonen 1 + 2 nach
CENELEC TR50404:2003, BGR 132

SICHERHEITSHINWEISE

- Der IBC darf nur für Flüssigkeiten der Explosionsgruppe IIA und solche der Gruppe IIB verwendet werden, welche eine minimale Zündenergie von gleich oder mehr als 0.20 mJ aufweisen (entsprechend EN50014).
- Der IBC darf NICHT in Ex-Zone 0 benutzt werden.
- Schnelle, wiederholende Füllvorgänge sind zu vermeiden. Andere stark aufladende Vorgänge, wie z.B. der Einsatz von Rührwerken, bedürfen zusätzlicher (erdender) Sicherungsmaßnahmen.
- Der IBC sollte nicht direkt nach dem Reinigen wiederbefüllt werden.
- Während des Befüllens und Entleerens muß der IBC geerdet werden.

Certified for use in Ex-Zones 1 + 2 according to
CENELEC TR50404:2003, BGR 132

SAFETY INSTRUCTIONS

- The IBC may only be used for liquids classified as explosion group IIA and those of IIB which have a minimum ignition energy value of equal or more than 0.20 mJ (according to EN50014).
- The IBC should NOT be used in Ex-Zone 0.
- Rapid, repeated fillings are to be avoided. Other high charging processes, like e.g. use of stirring equipment, need additional (earthening) safety meassures.
- The IBC should not be filled immediately after cleaning.
- During filling and emptying operations the IBC is to be earthened.

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Fig 18

Fig 19

Fig 20

Mauser TC1000EC–(Figs 21-22) dissipative HDPE moulding. Zone 1 and 2 usage.

Frame connected by wire to metal parts of tap.

Fig 21

Fig 22

4.2 CHARGE TRANSFER MEASUREMENTS

Charge transfer measurements were carried out on a selection of different types of 1000 litre RIBC, using the same methods of charging and discharge collection and measurement described in part 1 for the smaller containers. Because it was not possible to fit a standard 1000 litre size RIBC in the temperature and humidity controlled room used for the previous tests, a dehumidifier and control system was incorporated in a more suitable situation. The humidity was monitored during the tests and was maintained at 20-±5 % RH. When the humidity rose over 25% due to activity such as the rubbing it was allowed to reduce again before recommencing testing.

Table 4. Charge Transfer Measurements for RIBC

Schutz general-purpose type with open framework

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER nC	AVERAGE CHARGE TRANSFER nC	METHOD
Common type with open cage	HDPE	Top cap (red coloured)	Schutz	63	37.8	Cotton cloth
Common type with open cage	HDPE	Bottom tap area	Schutz	145	113	Cotton cloth
Common type with open cage	HDPE	Plastic reinforcement at bottom corner	Schutz	60	32.3	Cotton cloth
Common type with open cage	HDPE	Large open area on top	Schutz	None obtained (Some corona)	0	Cotton cloth

Schutz general-purpose type with open framework
(same as previous test but with smoother surface)

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER nC	AVERAGE CHARGE TRANSFER nC	METHOD
Common type as above smoother surface	Top cap (red coloured)	HDPE	Schultz	50	50	Cotton cloth
Common type as above smoother surface	Panel side above tap	HDPE	Schultz	79	56.2	Cotton cloth
Common type as above smoother surface	Near tap	HDPE	Schultz	127	88.5	Cotton cloth
Common type as above smoother surface	Large open area on top	HDPE	Schultz	None obtained (some corona)	0	Cotton cloth

Mauser ex type – similar to repaltainer but clad with black dissipative plastic

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER C	AVERAGE CHARGE TRANSFER nC	METHOD
31MAI/ Y/0105/ D/BAM Covered with black plastic	Cap (black coloured)	HDPE inner/ black plastic outer	Mauser EX ZONE 1&2	2	3.5	Cotton cloth
31MAI/ Y/0105/ D/BAM Covered with black plastic	Area near tap under plastic flap	HDPE inner/ black plastic outer	Mauser EX ZONE 1&2	21	64.3	Cotton cloth
31MAI/ Y/0105/ D/BAM Covered with black plastic	Black plastic areas	HDPE inner/ black plastic outer	Mauser EX ZONE 1&2	None	0	Cotton cloth

Mauser standard use IBC using black recycled plastic top and base with metal open frame

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER C	AVERAGE CHARGE TRANSFER nC	METHOD
31HAI/1003/0/BAM 5752-MC/4300/2050	Cap (black coloured, red centre))	HDPE inner/ black plastic top and bottom	Mauser repaltainer	76	4	Cotton cloth
31HAI/1003/0/BAM 5752-MC/4300/2050	White plastic near top corner	HDPE inner/ black plastic top and bottom	Mauser repaltainer	62	38.1	Cotton cloth
31HAI/1003/0/BAM 5752-MC/4300/2050	White plastic on top	HDPE inner/ black plastic top and bottom	Mauser repaltainer	150	68.4	Cotton cloth
31HAI/1003/0/BAM 5752-MC/4300/2050	Area near tap	HDPE inner/ black plastic top and bottom	Mauser repaltainer	None (some corona)	0	Cotton cloth

Schutz ex type clad with metal sheet

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER nC	AVERAGE CHARGE TRANSFER nC	METHOD
SCHUET 23/5230/1 728 Metal clad	Area near tap	HDPE	Schutz EX ZONE 1&2	160	108.8	Cotton cloth
SCHUET 23/5230/1 728 Metal clad	Plastic tap handle	HDPE	Schutz EX ZONE 1&2	85	51.1	Wool/nylon
SCHUET 23/5230/1 728 Metal clad	Plastic tap handle	HDPE	Schutz EX ZONE 1&2	75	49.3	Cotton cloth
SCHUET 23/5230/1 728 Metal clad	Cap centre lid	HDPE	Schutz EX ZONE 1&2	71	56.6	Cotton cloth
SCHUET 23/5230/1 728 Metal clad	Inside rim lid	HDPE	Schutz EX ZONE 1&2	37	28.9	Cotton cloth

Mauser TC100EC dissipative HDPE moulding – Zone 1 & 2 usage

TYPE	MATERIAL	AREA TESTED	MANUFACTURER	MAXIMUM CHARGE TRANSFER C	AVERAGE CHARGE TRANSFER nC	METHOD
TC1000 EL	Large open area on top	HDPE/ dissipative HDPE composite	Mauser	None	0	Cotton cloth
TC1000 EL	Near tap	HDPE/ dissipative HDPE composite	Mauser	None	0	Cotton cloth
TC1000 EL	Cap (black coloured, red centre)	HDPE/ dissipative HDPE composite	Mauser	None but evidence of charging	0	Cotton cloth
TC1000 EL	Plastic tap handle	HDPE/ dissipative HDPE composite	Mauser	27	23.25	Cotton cloth
TC1000 EL	Black plastic reinforcing near pallet	HDPE/ dissipative HDPE composite	Mauser	None	0	Cotton cloth

5 FLUID TRANSFER TESTS ON RIBC

Fluid transfer tests were carried out using both a high and low conductivity liquid. Because of the risk of an ignition of the liquids if substantial charging occurred, an important criteria in choosing which liquids to use were that they were ideally non-flammable. Water was used for the high conductivity liquid for this reason and also convenience, but any low conductivity liquids, which are readily and economically available in quantity, tend to be flammable. Consequently a series of low conductivity, but high flashpoint liquids, were measured to find one with a suitable value. All the liquids tested were variations on light petroleum products – diesel/kerosene

Table 5 – Conductivity measurements on potential liquids

Liquid type	Measured conductivity pS/m
Zero sulphur diesel	4.9
Light kerosene oil central heating fuel	18.6
Ultra low sulphur pump diesel fuel	250

It is accepted that liquids with conductivities greater than 50 pS/m, provided they are single phase, are unlikely to produce electrostatic charging hazards in most circumstances. Consequently a liquid with conductivity significantly lower than 50 pS/m is required for the tests, but if the conductivity is very low (<1pS/m) then although it will retain charge for long periods, there are also not many charge carriers present to produce charging. Either the zero sulphur diesel or the heating oil should have been a reasonable compromise between the two extremes and the heating oil was chosen because it was readily available at low cost.

Tests were carried out by pumping the low conductivity Kerosene liquid between the two standard Schutz RIBC, and by pumping water between the Mauser standard and the repaltainer Schutz metal clad RIBC as used for the rubbing tests. A fieldmill meter, which gives an indication of the electric field produced by a charged body, was placed at a set distance above the liquid surface after the liquid transfers were completed. A selection of metal plates 100 mm, 200 mm and 300 mm square were placed on the plastic area on the RIBC top surface to act as isolated conductors in order to measure any charge that may be induced from the charged liquid. A capacitor was connected to the plate to limit the voltage induced in the plate, the charge being calculated using $Q = CV$, where Q is the charge, C the plate capacitance, and V the charged voltage. Attempts were made to measure charge transfer from the plastic parts of the RIBC using the same measuring arrangements and techniques as with the small centre tests. Various tests were carried out at different flow rates, with and without the frame earthed, but stood on metal and concrete, and also with the RIBC completely isolated from ground. 10 m lengths of nylon reinforced PVC pipe were used to transfer the fluids, which were allowed to splash feed centrally from just below the top of the RIBC. A hole was cut to allow this as the normal hole provided was used to mount the fieldmill centrally.

Table 6 – Charge measurement due to fluid transfer

Liquid type	Pumping times	Amount transferred l	Pipe diameter mm	Flow rate l/s	Linear velocity m/s	Conditions	Fieldmeter reading kV/m	Plate voltage V	Charge transferred nC
Kerosene	217	920	50	4.24	2.16	Std Schutz RIBC to Std Schutz RIBC earthed chassis	+1200	None recorded	None recorded
Kerosene	340	880	25	2.59	5.29	Std Schutz RIBC to Std Schutz RIBC (transferred back) earthed chassis	-1000	None recorded	None recorded
Water	121	1000	50	8.26	4.2	Schutz metal clad to Mauser repaltainer earthed chassis	zero	None recorded	None recorded
Water	124	1000	50	8.06	4.11	Schutz metal clad to Mauser repaltainer unearthed chassis	zero	None recorded	None recorded
Water	117	1000	50	8.56	4.36	Schutz metal clad to Mauser repaltainer chassis isolated from earth	zero	None recorded	None recorded

6 DISCUSSION

6.1 DISCHARGE AND IGNITION TESTING OF SMALL CONTAINERS

Figure A shows the results for charge transfers obtained from different types of small plastic container. A number of general observations from these results are:

i. Based on the charge transfer measurements, even some of the smallest containers tested (50 ml capacity) produce charge transfers, which could be incendive for IIC atmospheres (> 10nC) and are even close to the limit for IIB atmospheres (30nC). In terms of the incendivity for Group IIA atmospheres (60nC), one container of 60 ml capacity, some containers of 100ml capacity and most containers of 250 ml capacity and above produced discharges above this level. Figure 1 summarises some of the results for LDPE.

ii. During the actual ignition testing, discharges from containers of 60ml capacity were shown to ignite hydrogen (IIC); containers of 125 ml capacity and above ignited ethylene (IIB) and a 1000 ml capacity container ignited methane (Gas Groups IIA/I).

iii. In terms of the different materials, Fluorinated HDPE shows the maximum charge transfer values as shown in Figure B, which summarises the results for 1000 ml containers of different types.

Clearly from these observations there are general points regarding the risk of ignition from different types of containers if used in explosive atmospheres.

- Containers as small as 50 ml produced charge transfers in excess of the 60 nC limit for IIA gases and vapours.
- The ignition testing demonstrates that electrostatic discharges from even very small plastic containers (60 to 125 ml) can ignite IIB and IIC flammable atmospheres.
- Fluorinated plastics generally charged readily, and produced greater charge transfer than untreated containers of the same size and material

There is a debate at the moment amongst members of the BSI electrostatic committee about the origin and hence the validity of the figures for the maximum allowable charge transfer given in European Standard EN13463-1:2001 Annex C (BSI GEL 601 electrostatics meeting 21/11/06 at Avecia, Blackley), but the results from these tests, plus other ignition tests carried out previously, indicate that the figures are sufficiently low to leave a suitable safety margin compared to typical charge transfer figures at which ignitions of the various gas groups occur in practice irrespective of their validity.

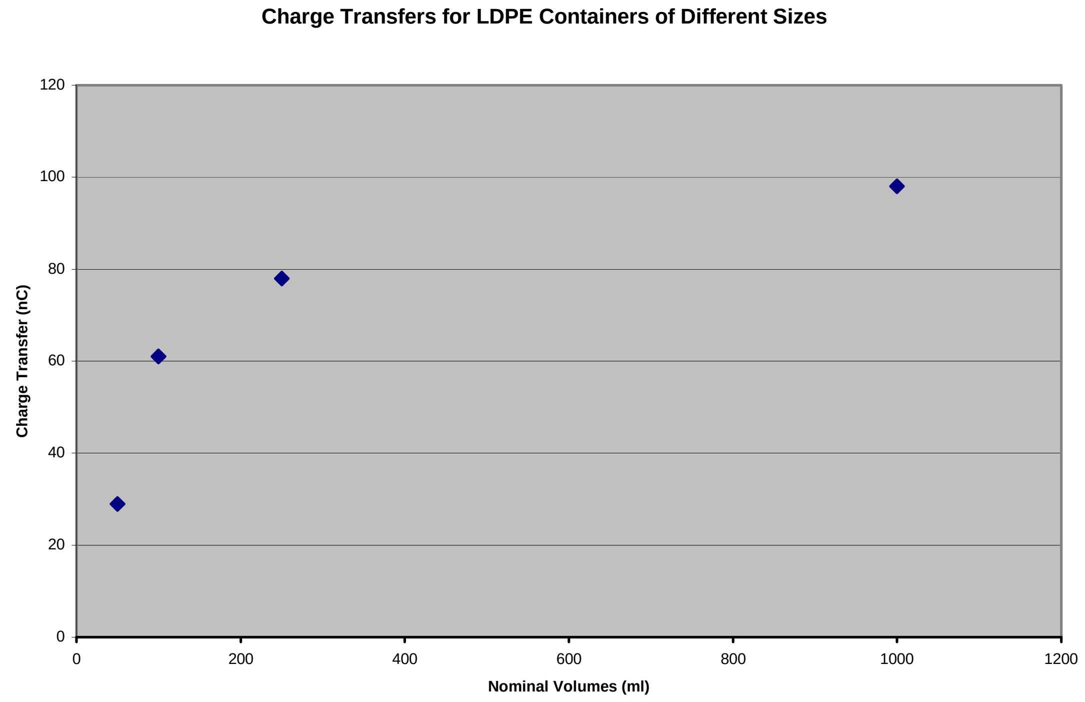

Figure A.

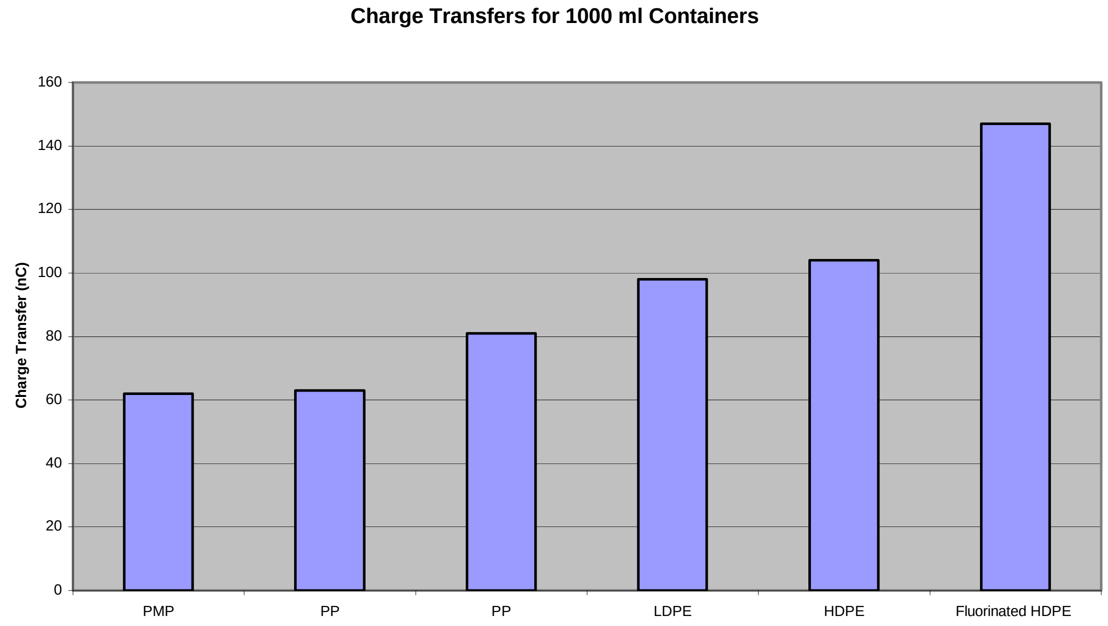

Figure B.

6.2 DISCHARGE TESTING OF LARGE CONTAINERS (RIBC)

Charge transfer considerations

Charge transfer tests on the various RIBC showed very mixed results. The standard common type open framed container (Figs 1-4) first tested failed to produce any brush discharges from most of the outer plastic surfaces and especially the top surface, which is very easily accessible for rubbing, although there was evidence that considerable charging was occurring. The first RIBC tested had a fairly rough outside surface with a blotched pattern possibly caused by water being present during the moulding process.

The level of induced charge on the measuring sphere suggests that the surface charged readily, and the permanent charge level slowly increased when the sphere was brought close. No distinct brush discharges were observed and any charge transferred was likely due to a corona discharge effect as a result of the surface roughness. Corona discharges occur around objects with edges of small radius of curvature around which the electric field, which is radius dependant, is sufficiently high to cause localised breakdown of the air. This type of discharge is commonly observed as the visible light seen when certain types of clothing are removed and is non-incendive. Because of this lack of distinct discharges with the first container, a second of the same type, both manufactured by Schutz, was tested which had a smoother surface than the first, but however gave very similar results. However both did produce substantial discharges from the area around the tap, well in excess of the 60 nC set limit, and at a similar level to that which actually ignited a IIA gas in the ignition tests using the smaller containers.

The Mauser repaltainer (figs 11-14) was in principle similar to the two standard type Schutz containers intended for common usage, but using a recycled plastic pallet and top section. It had a substantial open area of plastic on the top surface, which in this case produced substantial discharges again of likely IIA incendive levels, but had a mesh around the sides with smaller spacing than the more open Schutz design. The finer mesh made rubbing difficult and may offer better, but not complete protection, against mechanical puncture damage by forks etc. The plastic inners on both types, and similar offerings from other manufacturers, are nominally of the same material (HDPE) and as the Mauser demonstrated can potentially produce incendive discharges. The fact that some areas on the Schutz did not when they might have been expected to suggests that the surface texture is very important, and this effect should probably be investigated as a means to reduce the likelihood of brush discharge occurring. Some plastic petrol containers previously tested appeared to be deliberately produced in this way, and were effective in inhibiting discharges compared to smooth finished containers of the same material.

A further hazard present with containers having large exposed areas of plastic particularly on the top surface, is that they are a convenient place to leave tools and other conducting objects whilst working in the vicinity. This leaves an isolated conducting object, which can then become charged by induction from the charged liquid contents of the RIBC following a filling operation. This can produce a spark discharge with a potentially higher charge transfer value than a brush discharge from the plastic surface. Also a spark discharge is temporally and spatially different to a brush discharge, and is more incendive for the same value of charge transfer. The tests on the smaller containers also showed variations in the incendivity of the brush discharges for similar values of charge transfer from different materials. For example a 500 ml polycarbonate bottle was very easy to charge and gave obvious clearly audible discharges, which from observation and comparison would have been expected to have a higher charge transfer value than the 54 nC measured. A 250 ml fluorinated HDPE bottle had a similar charge transfer value of 53 nC but the discharge was short and barely audible. However the discharges from the fluorinated vessel easily ignited ethylene while those from the PC bottle had difficulty in igniting hydrogen. The PC discharges were much longer, up to 50 mm in comparison to approximately 10 mm for the fluorinated HDPE and hence spatially less concentrated which may account for the difference in incendivity.

The two types of clad containers are similar in principle in that the cladding prevents access to the inner tank, for both rubbing and the placement of conducting objects, and are claimed by the manufacturers, as stated on a safety instruction label to be certified for use in Ex zones 1 and 2 according to CENELEC TR 50404:2003. The label also states that they can be used for liquids of the explosion group IIA and group IIB provided its minimum ignition energy is >= to 20 mJ. They both carry instructions that the frame should be connected to earth during filling and emptying. Both types had a possible design flaw in that an area of inner tank surrounding the tap was exposed once covers had been lifted to access the tap. Discharges were obtained around the tap area with similar charge transfer values to those measured in a similar place on the standard types tested. The action of screwing an outlet connection onto the tap could produce rubbing in practice. Again these charge transfer values are well in excess of the 60 nC set limit, and at a similar level to that which actually ignited a IIA gas in the ignition tests using the smaller containers. It should be borne in mind that the charge transfer values obtained in all these tests were erring towards the worst case conditions of low humidity, together with a rubbing technique developed by practice to give efficient charging. The charging levels obtained by accidentally rubbing are in the most case likely to be less than this, but could potentially be similar or slightly higher in exceptional circumstances. This potential problem could be easily rectified in both designs by extending the cladding to cover this area.

The other type of container tested, Mauser 7C 1000EC Figs 21,22 has a different approach, in that rather than covering the inner tank to prevent access, the tank is constructed from a multilayer of HDPE modified to give desirable characteristics. The variation in construction of these seems to vary between manufacturers and development is in progress and precise information difficult to obtain. However in general the outer layer is modified to give electrical dissipative properties, but may not be suitable for contact with some chemicals, so the inner is either standard HDPE or may be fluorinated to give extra chemical resistance. An interim layer of standard HDPE may be included in the latter case. The principle of the dissipative outer layer is to prevent electrostatic build up and provides a sufficiently low resistance path to prevent isolated conductors due to objects left on top. As in the clad type, the frame needs to be earthed to ensure they are effective. In practice standing on most common surfaces would provide a good enough earth path, but this cannot be relied on due to paint or other insulating surfaces so an earth strap is necessary.

Tests on one of the metal clad RIBC were carried out to investigate the worst-case condition of it being stood on an insulating surface, unearthed, and being externally charged. This could happen as a result of it being bombarded externally by dust or liquid droplets, and there are even examples of snow causing significant charging. Filling the RIBC with a highly charged liquid will cause the outer conducting layer to become charged by induction and very high-energy spark discharges are possible due to either internal or external charging. These effects are likely to be more significant with a metal clad RIBC as there is far greater surface area to be affected by the charging mechanism than with a metal framed or mesh covered type of RIBC. If the conducting cladding becomes charged by some external means there is also the possibility of a charge being induced on the inside plastic surface and a brush discharge occurring to the liquid surface and igniting an internal flammable vapour.

No significant charging was obtained by rubbing methods, but spraying on charge using a high voltage power supply from a point source at 30 kV for 1 minute produced a very large spark discharge. The charge transfer measured from the spark was 5590 nC, which assuming the capacitance of the isolated RIBC was fully charged in this time, the spark energy can be calculated.

Using $Q = CV$ where Q is the charge, C the RIBC capacitance, and V the charged voltage

$C = Q/V = 186$ pF

Using $E = 0.5\ CV^2$ where E is the spark energy

$E = 83\ mJ$

A spark of this energy would be sufficient to very easily ignite all gases and vapours, and a significant number of dusts. For use in potential flammable atmospheres or when containing flammable liquids it is therefore very important that the RIBC frame is reliably earthed during any situation where a charging mechanism may be present.

Fluid movement considerations

Electrostatic charging occurs as a result of electrons being transferred by physical interaction from one material to another, resulting in a net charge on the materials of either positive or negative polarity depending if they have lost or gained electrons Charging occurs as in this case when flowable materials (liquids and dusts) are passed through pipes, and physical interaction occurs between the flowing material and the pipe wall, and in all other situations where relative motion occurs. The highest rates of charge transfer occur between materials whose atomic structure is such that one can easily lose electrons and one can easily gain electrons ie. at opposite ends of the triboelectric series as discussed previously. This effect occurs with all motion and materials, but the effects are not usually apparent, unless very high resistance materials are involved, any charge formed recombines very quickly and its effect is unnoticed. The electrical resistance or its reciprocal-conductivity, is in effect a measure on the abilities of electrons to move within the material. The higher the resistance (lower the conductivity) then the more difficult it is for electron movement and the longer time taken for displaced electrons to recombine in order that the material becomes electrically neutral again. If the rate of displacement of electrons due to the physical interaction during relative movement is greater than the rate of recombination, then electrostatic charging now occurs. The charged material is then deposited in an isolating RIBC tank and is unable to dissipate quickly. This difference between displacement and recombination will become greater as the flow speed increases or if the flow becomes turbulent (also usually speed related).

In addition to the potential charging of the material as a result of interaction with the pipe walls, if the liquid is allowed to fall into the container such that the liquid surface is agitated (splash filling) then additional charging can also occur. The mechanism is different (and complex) and also occurs in high conductivity liquids. The charge polarity can be different depending on conditions and impurities, and hence may reinforce or diminish charge acquired in pipework.

None of the liquid transfer tests conducted produced substantial charging. This is to be expected with the high conductivity liquid (water) and with the chassis earthed (either deliberately or standing on a reasonably conducting surface such as concrete in this case), with the modified RIBC as these have a deliberate wire connection between the liquid at the tap and the chassis. This connection will quickly dissipate a high conductivity liquid via the chassis to earth. This earth lead is not present in the standard types not intended for flammable atmosphere use, and if the liquid acquires charge as a result of pumping and filling there is the potential for a charged liquid to be isolated in the container tank, provided the tank material resistance is sufficiently high that charge dissipation through the walls is slow. In practice the Mauser repaltainer used for the water tests despite lack of earth wire proved to have a resistance of 400 M Ohms measured from the filler neck to the frame which is low enough to dissipate any charge on the liquid quickly, so any charge developed by splash filling would not be apparent.

During the low conductivity liquid tests (kerosene) the fieldmill meter indicated that some charge was present on the liquid surface after filling, but the polarity of the charge was opposite when transferred back to the original RIBC with a change in pipe diameter. It is not clear why this polarity reversal occurred, but it may be due to the effects of a fairly moderate charge due flow in the pipe being cancelled by charge of opposite polarity due to splash filling. In the test using the larger 50 mm pipe, flow was quite smooth with little liquid surface disturbance, whilst there was more turbulence using the smaller 25 mm pipe. However the kerosene was rather too viscous to break up in the manner that slightly less viscous liquids would do at similar flow rates. Unfortunately both for the tests and in practice, the lower flashpoint hydrocarbon liquids which have less carbon atoms in their molecular chain, being less viscous, tend to produce more turbulence and hence greater charging during splash filling. These characteristics makes them too dangerous to use for the tests, although desirable for their charging ability.

Mechanical considerations such as potential puncture damage from forks etc. and potential effects of fires should also be considered in conducting a risk assessment, and if the use of a RIBC reinforces potential dangers of using compared with more moderately sized containers. It was observed that the metal clad containers tested had a relatively thin plastic body compared with the standard type, and the cladding was also of light guage. Consequently this may render them less physically robust then the standard type, and one of the test metal clad IBC was found to be punctured when received (probably fork damage).

7 CONCLUSIONS

- Discharges from containers as small as 50 ml produced charge transfer levels in excess of the limits stated in EN 163346 annex C for IIC and came close to the limit for IIB gases and vapours.

- Some containers of 100ml capacity and most containers of 250 ml capacity and above produced charge transfer levels in excess of the Standard limits for IIA gases and vapours.

- Discharges from containers as small as 60 ml produced ignitions in a IIC gas (hydrogen).

- Discharges from containers of almost all containers of 100 ml and above produced ignitions in a 11B gas mixture (ethylene)

- Discharges from a 1000 ml container produced ignitions in a IIA gas (methane).

- The results from these small container tests plus other ignition tests carried out previously on charged plastic objects, indicate that the limits stated in EN 163346 annex C are sufficiently low to leave a suitable safety margin compared to typical charge transfer figures at which ignitions of the various gas groups occur in practice.

- All the RIBC tested produced electrostatic discharges from some areas including caps and tap handles. Most of the discharges were in excess of the 60 nC limit for IIA gases and vapours. Many of the RIBC produced discharges in excess of 100 nC from the tank area around the tap, including both clad types which were indicated as being suitable for Ex zones 1 and 2, and for containing liquids of the explosion group IIA, and group IIB provided its minimum ignition energy is >= to 20 mJ. Based on the ignition tests on the smaller containers it is likely that these discharges from the tap area would be incendive for both these gas groups.

- Based on the charge transfer values obtained from the clad type containers, although much has been done to reduce the likelihood of an electrostatic ignition compared with the standard RIBC, neither can be presumed in their present form to be inherently safe for use in flammable atmospheres. A process risk assessment should be carried out with a view to potential charging mechanisms before they are used in flammable atmospheres or to contain flammable liquids. Tests on the RIBC with the dissipative outer plastic tank suggest that this design has advantages over the clad type from an electrostatic point of view, but this is only based on one example and more would need to be tested to determine if this is a representative sample. It is very important with all designs that the frame and any other conducting parts are electrically bonded to earth during any operation where electrostatic charging may occur and that they should not be stored on a highly insulating surface unless separately earthed. The risk assessment needs to consider filling rates and methods as recommended in CLC/TR 50404 and needs to consider the requirement of additional safety earthing measures if other operations other than normal filling such as mixing or stirring are carried out.

8 RECOMMENDATIONS

For intended use of plastic containers in flammable atmospheres: or containing flammable liquids:

- A risk assessment should be carried out before using any size of plastic container in a flammable atmosphere or to contain flammable liquids. The risk assessment needs to consider the possibility of a flammable vapour or aerosol mist being produced from the liquid, bearing in mind flashpoint and process parameters such as temperature and pressure. If a flammable atmosphere is thought possible, then the charge transfer level potential compared to the limits for the gas group as defined in EN 163346 annex C needs to be considered. Advice given in CENELEC TR 50404:2003 section 5.4.6.1

- Only RIBC intended for use in flammable atmospheres should be employed. However it should not be presumed that they are inherently safe for use in flammable atmospheres and a process risk assessment should be carried out.

- The frame and any other conducting parts of RIBC should be electrically bonded to earth during any operation where electrostatic charging may occur, and sufficient charge relaxation time allowed before moving. They should not be stored on a highly insulating surface unless separately earthed.

- The electrical earth connection between the RIBC frame and the conducting part of the tap should be checked for integrity at regular intervals.

- Splash filling should be avoided by bottom filling via an earthed conductive fill pipe, which will also help to dissipate charge on the liquid. With larger containers such as IBC where high fill rates are possible, then advice on recommended maximum fill rates given in CENELEC TR 50404:2003 section 5 should be followed.

- The electrical earth connection between the RIBC frame and the conducting part of the tap should be checked for integrity at regular intervals.

- Clad type RIBC, both metal and plastic, should have the cladding extended to cover all areas which can be accessed, and potentially rubbed. In particular the areas around the tap even if covered with a flap, and up to the filler cap should be addressed. This would be simple to do in practice.

- External RIBC plastic components such as taps and filler caps should be made from dissipative materials on the outside surface.

- Mechanical considerations such as potential puncture damage from forks etc. and potential effects of fires should also be considered in the risk assessment, and if the use of a RIBC reinforces potential dangers of use compared with more moderately sized containers.

- Consideration should be given to the variation in charge transfer obtained from nominally similar areas of exposed plastics, which may be attributable to variations in surface texture. This warrants further investigation as a potential means of inhibiting brush discharges by deliberately engineering the surface texture of the plastic.

9 REFERENCES

1. P Holbrow, "Control of explosion hazards in intermediate bulk containers - a literature review", HSL Report No EC/01/69 by P Holbrow, Issued November 2002
2. Graham Atkinson "Fire performance of composite IBCs: Final report" HSL Report No FR/05/09, 05/06/06
3. Atkinson G. and Riley, N. "Controlling risks from composite IBCs" (2006), IChemE Hazards XIX Conference (UMIST).
4. Atkinson G. and Riley, N. "Fire hazards of plastic IBCs containing flammable or combustible liquids" (2004), IChemE Hazards XVIII Conference (UMIST).
5. Directive 94/9/EC of the European Parliament and the Council of 23 March 1994, on the approximation of the laws of the member states concerning equipment and protective systems intended for use in potentially explosive atmospheres, O.J. L100 of 19/04/1994, page 1.
6. BSEN1127-1:1998 "Explosive atmospheres – Explosion prevention and protection: Part 1. Basic concepts and methodology."
7. CENELEC (2003), Electrostatics – Code of practice for the avoidance of hazards due to static electricity, PD CLC/TR 50404:2003.
8. EN13463-1:2001, Non-electrical equipment for potentially explosive atmospheres. Basic method and requirements" ISBN058039414 X, 27/03/2002
9. IEC 60079-10:1995 Electrical apparatus for explosive gas atmospheres. Classification of hazardous areas.
10. BS5958-1:1991 Code of practice for control of undesirable static electricity. General considerations
11. G P Ackroyd & G P Newton (2002), "Flash Fire During IBC Filling", Loss Prevention Bulletin 165 (IChemE), p13
12. G P Ackroyd (2003) "An Investigation of the Electrostatic Ignition Risks Associated with Plastic Coated Metal", Inst. Phys. Conf. Ser. No 178, 11th Int. Conf. on Electrostatics (Edinburgh 2003), p25
13. G P Ackroyd & P Caine (2005) "Electrostatic Testing of a Rigid Intermediate Bulk Container (RIBC) Intended for use in Explosive Atmospheres", J. Electrostatics 63 (2005), p509

10 GLOSSARY

ATEX - **AT**mosphères **EX**plosibles
DSEAR - Dangerous Substances and Explosive Atmospheres Regulations
IBC – Intermediate bulk containers
FIBC – flexible intermediate bulk containers
RIBC – rigid intermediate bulk containers
RH - relative humidity
HDPE - high-density polyethylene
LDPE - low-density polyethylene
FLPE - fluorinated high-density polyethylene
PP - polypropylene
PC - polycarbonate
PMP - polymethylpentene

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Health and Safety
Executive

Plastic containers for flammable liquids/hazardous areas

Electrostatic risks

This report contains an assessment of the electrostatic risks associated with a selection of commonly available plastic containers ranging in size from 50 ml bottles to 1000 l Intermediate Bulk Containers, and manufactured from a variety of materials.

The containers are assessed by measuring the amount of charge transferred from their surfaces in an electrostatic discharge, after being charged by rubbing with the most suitable materials for optimum charging. The charge transfer values obtained can then be compared to maximum permitted values for different gas groups contained in EN13463-1:2001.

Incendivity tests were also conducted on the discharges from the containers, which give an indication of typical amounts of charge transfer actually required for ignition in a practical situation, as a guide for incident ignition assessments.

A description of the types and purposes of most of the various designs of IBC currently available is included, in particular those designed for zone 1 and zone 2 usages.

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