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ELECTROSTATICS AND FLEXIBLE INTERMEDIATE BULK CONTAINERS (FIBCS)

By Ian Pavey of Chilworth Technology Ltd

INTRODUCTION

Flexible Intermediate Bulk Containers (FIBCs) are a convenient and useful means of storing and transporting powder and pellet materials. Typically they are cubic in shape with 1m x 1m sides formed from a woven plastic fabric sewn together. The underside has an emptying spout, usually made of the same fabric, sewn into the centre and tied when the FIBC is full. Carrying straps at the top of each side corner are formed from webbing and sewn to the main structure of the bag. The top may be open or it may be closed, in which case a filling spout will be included.

For many years FIBCs have been seen carrying sand and gravel on building sites and in garden centres. Being flexible they are collapsible when empty and take up little storage space. Typically weighing about 1000kg when full, they are readily moved by fork lift trucks using their carrying loops or, being basically cubic, they can be placed on pallets. In many situations they are also readily re-usable. Their convenience is increasingly being exploited in industrial situations wherever particulate materials have to be transported within or between sites. Problems arise because the plastic from which the fabric components are woven (generally polypropylene) is electrically very insulating.

There is hardly anyone who will not have experienced small electric shocks and sparks when removing highly insulating, man-made clothing, or after walking across some types of flooring. This type of phenomenon can also be found when filling or emptying very insulating containers, such as FIBCs. However, this apparently harmless, if annoying, effect becomes altogether more serious when it is realised that barely perceptible discharges can ignite flammable vapours and even some dust clouds. It is the fact that such sensitive materials are very commonly found in industry that gives rise to the concern regarding the use of FIBCs.

This concern is not simply speculative; there are a number of documented incidents in industrial situations which can be attributed to the use of FIBCs. Indeed, in 1993 a paper was published describing seven incidents involving FIBCs which occurred over a three-year period in the United States of America alone. This paper was not exhaustive, nor was it intended to be, but illustrative of the type of problems that could occur. The results of these incidents varied from minor burns to operators to serious injury, blast damage to buildings and prolonged fire.

This is clearly a very serious issue and various FIBC manufacturers have produced different designs aimed at eliminating the risk. Nevertheless, the infinite range of possible environments in which FIBCs may find themselves means that it is for the user to fully consider all the implications, and satisfy himself that the FIBC he has specified is appropriate for his unique application.

POTENTIAL HAZARDS

The potential hazards that must be considered are all due to the electrical discharges (sparks) which can result from charge accumulation on or in the FIBC.

The greatest risk, in that it requires the smallest spark, is ignition of flammable vapours or gases. Many common vapours and gases can be ignited by sparks with energies of as little as 0.2mJ. Of course this number alone is rather meaningless to the lay person, until it is realised that somebody receiving a spark of this energy would probably not even know it had happened; for most people in most situations this will be below their threshold of perception. Some gases, such as hydrogen, can be ignited by spark energies much lower than even this level but these must be considered special cases and will not be mentioned again here.

The next level of risk is that of ignition of dust clouds. The very nature of the use of FIBCs means that dust clouds are likely to be present in their immediate vicinity. Even apparently innocuous materials, such as flour or sugar, can explode when in the form of a dust cloud and powdered materials from many industries, from foods to pharmaceuticals, are explosible. Many are also very sensitive, sometimes requiring spark energies of less than 10mJ to ignite them - still not much above the threshold of perception.

Most peoples' intuitive concern with electricity is electric shock, although the reality is that only very rarely, and in rather special circumstances, will static lead to a discharge energy carrying the risk of physiological harm (around 10J). Much more common is a person inadvertently exposing themselves to another hazard as a result of their reaction to a lesser shock. Between about 10mJ and 200mJ, a discharge to a person becomes increasingly uncomfortable, with reactions likely to be increasingly violent. Above 200mJ, the shock will be considered "severe" even though it is still a long way from being dangerous in its own right.

ELECTROSTATIC DISCHARGES

Electrostatic discharges, commonly encountered as "sparks", can be subdivided into a number of distinct phenomena. The one thing they all have in common is that somewhere in the discharge region, the voltage gradient exceeded 30 kV per cm at which air is ionised and becomes very conducting.

Spark discharges occur when a charged conducting object discharges to another conductor. The initial voltage gradient between the two results in ionisation of the air between them which provides a conductive path across which virtually all the charge is transferred with a characteristic blue flash defining a narrow spark channel. Being conducting, there is little resistance to the charge from every extremity of the object moving to the point of spark initiation and jumping the still-conducting gap, even though the voltage may have dropped below the onset level as soon as the spark started. For a conductor discharging to earth, the spark energy depends on its voltage and capacitance and, in principle, there is virtually no limit to the energy of this type of discharge. However, in most practical situations even large isolated conductors are unlikely to produce sparks with energies greater than a few hundred milijoules.

Brush discharges occur between a conductor and a charged insulating surface. Charge cannot migrate through the insulator, and a multiplicity of very small spark channels emanate from the insulating surface. Closer to the conductor they all join into a single channel so the overall appearance is like a brush - hence the name. The energy of this type of discharge is limited as only a small part of the charge on the surface is involved at any time. Experiments with gas mixtures of known ignition energies have indicated that the maximum energy of a brush discharge is about 4mJ, easily able to ignite many flammable vapours. Although there is no confirmed record of a brush discharge igniting a dust cloud, it must also be assumed that it could if the ignition energy of the cloud were less than 4mJ.

Cone discharges occur across the surface of a "heap" of charged particles. The potential energy (voltage) of charges depends on the charge density. Charged particles in a pipe or cyclone may not have a particularly high potential owing to the low charge density. When they are dropped into a hopper (or FIBC), the charge density will increase as they settle, raising the potential, often sufficiently to produce discharges across the conical surface of the heap: hence cone discharge. The energy of this type of discharge (or whether it occurs at all) depends on particle size and conductivity, vessel diameter, and specific charge. With all these factors working together to give the worst situation the highest observed energy for a cone discharge is about 10mJ, carrying the risk of igniting flammable vapours and some dusts.

Corona is a low energy type of discharge not considered capable of igniting even vapours of common flammable solvents but is mentioned here as a means of safely transferring charge from an object. It occurs when the voltage gradient around a charged sharp object locally exceeds the discharge threshold due to surface shape, but as ionisation does not extend to a second electrode no spark occurs. One polarity of ions in the ionisation region is repelled from the charged object while the other polarity is attracted, thus neutralising it. Overall, the effect appears to be charge transferring from the charged object into its surroundings.

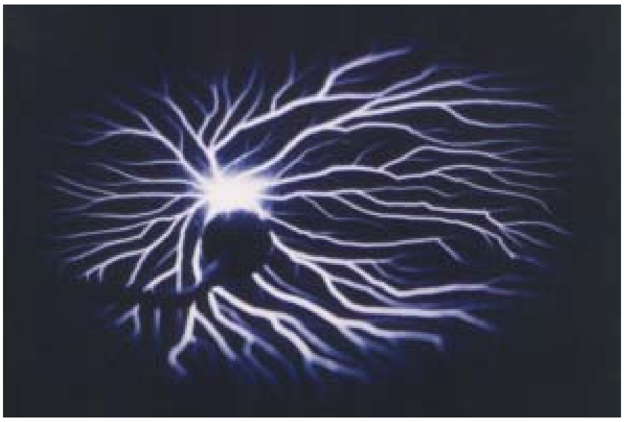

Photo 1: Propagating Brush Discharge

Propagating brush discharges are high energy discharges obtained from insulating sheet materials charged in such a way that a double layer of charge is accumulated on opposite sides of the sheet. Unfortunately, this arrangement can and does occur inadvertently with devastating consequences. One way of forming the double layer is to charge one side of the sheet while the other side is in contact with an earthed conductor (see figure 1a) which forms a kind of capacitor capable of holding large quantities of charge. When an earthed electrode approaches the surface a lightening-like discharge propagates across it as shown in figure 1b and in photograph 1. The discharge can also be initiated without an electrode if mechanical damage to the sheet provides a short air gap between opposite sides as shown in figure 1c. The amount of charge involved in this phenomenon is high and energies of several joules can readily be dissipated in discharges of this type. They can therefore ignite vapours and dusts, and this is one sort of electrostatic discharge which may be dangerous in its own right.

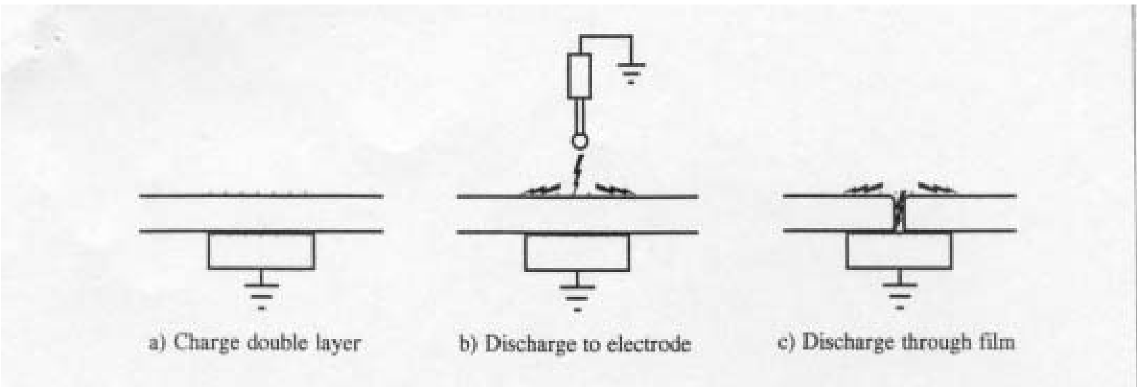

Fig.'s 1a, 1b, 1c

FIBC RISKS AND AVOIDANCE MEASURES

It is now possible to pull together the information set out in the previous three sections to explain which discharges may occur during an FIBC operation, under what circumstances, and what measures manufacturers have taken to avoid the hazard. The basic form of an FIBC was described in the Introduction. In practice this is complicated by the fact that the woven fabric from which the FIBC is manufactured is often either coated, or used in conjunction with a liner to prevent fine particles passing through the weave.

Many materials will become charged during transport to the loading station, so that during loading of the FIBC charged particulates will be accumulating inside (see figure 2a). Cone discharges may occur at this stage, either causing an ignition hazard themselves or simply transferring charge to the bag walls. Arguably, the cone discharge hazard has little to do with the bag and more to do with the loading process, so although it must never be forgotten in a complete safety assessment, it will not be considered further in this analysis. Depending upon the nature of the FIBC walls, charge deposited on them may be dissipated by corona or conduction, or it may accumulate giving rise to the risk of either brush or propagating brush discharges. If there are unearthed conducting parts to the wall (even wet patches) then discharges could be of the spark type.

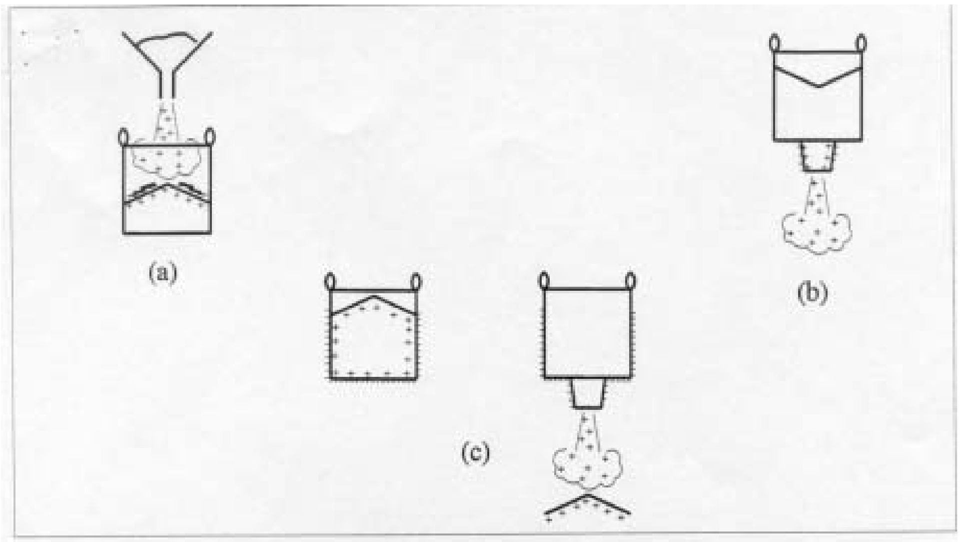

Figure 2: bag charging mechanisms

When bags are emptied, there are two mechanisms which may lead to charge appearing on the wall. Tribocharging (charging by rubbing) may occur at the sliding contact between powder and bag (fig 2b). When this happens one sign of charge is carried away with the powder whilst the opposite sign is left on the wall. Alternatively, if the contents of the bag were already charged there may be an opposite charge on the wall exactly balancing it. To an outside observer the FIBC would appear neutral, but on emptying the real situation would become apparent (fig 2c) leaving the walls of the empty bag highly charged. In both cases the possibilities for electrical discharge from the bag are as in the previous paragraph.

If no design features have been incorporated to avoid electrostatic hazards, the FIBC is commonly known as "Type A". This will usually be made only from insulating materials and there is the possibility of most of the previously described discharges occurring - even the highly energetic propagating brush discharge. Because potentially there is so much energy available, this type of bag should not be used if there is any chance that flammable gases, vapours or dusts might be present during loading or unloading.

Experiments with propagating brush discharges have shown that if potential differences of 4kV or more cannot be sustained across the insulating sheet, this type of discharge will not occur. This discharge can therefore be avoided if the FIBC fabric, its liner, or a combination of the two, are unable to withstand 4kV, and the bag is then known as "Type B". Brush discharges can still occur, so this sort of bag is not suitable for use where flammable vapours are present, but it can be used to hold all but the most ignition-sensitive powders.

The only way to avoid brush discharges, and hence make a bag suitable for use with sensitive dust clouds and in the presence of common vapours, is to ensure charge on the walls is quickly dissipated. A "Type C" bag achieves this by providing interconnected conductive paths from all sides of the bag to an earthing point. Situated close together to avoid a sufficient expanse of insulating material to allow brush discharges, this is very effective so long as the operational procedure of ensuring the earthing point is connected to earth is scrupulously applied. If the path to earth is broken through negligence or accident there is a real risk of a spark discharge capable of igniting vapours and dust clouds.

"Type D" bags dissipate the charge using corona discharge from fine, unearthed, conductive fibres. The fibres are usually included as discrete yarns in the woven fabric, but are deliberately not interconnected since their capacitance, and hence stored energy, must be kept as low as possible to minimise the incendivity af any spark discharges.

APPLICATION-SPECIFIC BAG TESTING

One of the most common questions asked by potential users of an FIBC system is: "Will it be safe in my plant and in my customers' plants?". Having read the previous section, it will be apparent that the basic principles to be used in assessing whether or not an FIBC is suitable are quite straightforward. However, it is first essential to determine the ignition sensitivity of any gases, vapours or dusts which may be present during loading and unloading.

If flammable vapours may be present, the effectiveness of the charge dissipation mechanism must be confirmed, which at its simplest means measuring the resistance from anywhere on the bag to the earthing point for a "Type C" bag. If no flammable vapours, but flammable, though not particularly sensitive, powders may be present then it is sufficient to establish that potential differences greater than 4kV from one side of a sheet to the other cannot be sustained anywhere on the bag, thus avoiding the risk of propagating brush discharge. If no flammable materials will ever come near to the bag, no particular electrostatic test is required.

Thus far, testing is straightforward although some specialist equipment and practical experience may be required. However, there are a large number of different manufacturers of the woven fabrics used to make FIBCs, all of which may be coated or uncoated. Furthermore there is an even larger choice of liners, some of which may have undergone surface treatment or even be composites of more than one material. Taken together, there is an almost infinite number of combinations which could be used to make a bag assembly. The operational complexity imparted by the use of a multiplicity of materials often means that a theoretical analysis of the safety mechanism, together with a risk assessment for the loading and unloading operations, must be carried out before a new and unique testing regime can be defined.

Nevertheless, at the end of the day, what really matters is whether a bag can generate an incendive discharge. Incendivity testing can help to support the safety mechanism analysis and physical property testing which must always provide the firm foundation of an assessment. Indeed, this test is often seen by potential users of an FIBC as an especially helpful final test because of its intuitive immediacy.

INCENDIVITY TESTING

Test equipment that is able to take a full size FIBC for loading and unloading experiments is required. It is specifically designed to investigate electrostatic effects and to that end is equipped with the means for artificially charging materials being loaded into the bag. Measurements of electric fields, potentials, charge levels and currents are informative, but gas probe tests are particularly graphic, especially to sensibly sceptical potential users of a new bag system.

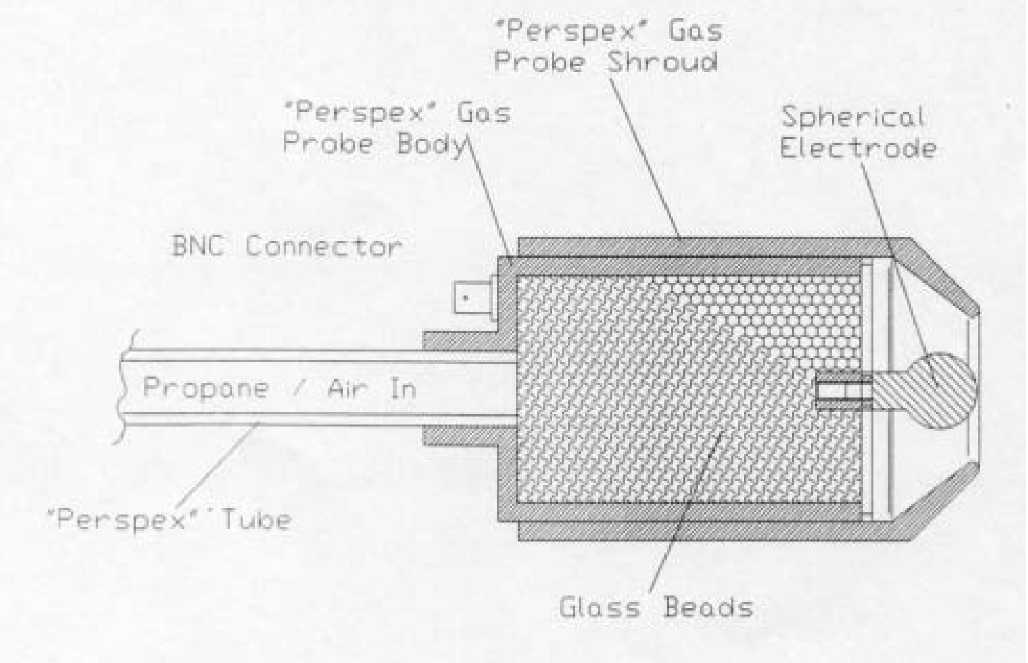

Figure 3: gas probe

Figure 3 show a diagram of the gas probe. It is an earthed electrode bathed in a gas/air mixture of a known ignition energy. The gas is usually propane and the ignition energy 0.25mJ. The rest of the probe arrangement ensures flow control and good mixing of the gases, and prevents flame propagation back through the probe to the gas line. It is used by first starting the gas flows and allowing them to stabilise for a few seconds before slowly approaching the charged surface. Photograph 3 shows an ignition due to a discharge from a stretched sample of FIBC fabric while the probe is still about 100mm from the surface. This fabric is clearly unsuitable for use in the presence of flammable vapours!

Photo 3: Gas Probe Indendivity Test

CONCLUSION

FIBCs are here to stay and will find increasing use throughout industry. In many situations the use of the wrong type of FIBC is positively dangerous. In the simplest of situations, the FIBC user may be able to obtain satisfactory assurance of the bag's suitability for his application from his supplier or the manufacturer. However, as soon as any complicating factors are added, either because of the environment of use or because of a special bag assembly, a proper understanding of the safety mechanism and an application-specific assessment must be carried out. Often it is particularly helpful to support this with full scale and/or incendivity tests.

About the author

Ian Pavey, M.Phil, BSc (hons), M.Inst.P, C.Phys, graduated from Bath University with a BSc in Chemical Engineering. After acquiring some practical experience of electrostatic hazards while working as a process development engineer, he gained an M.Phil. in applied electrostatics and thereafter specialised in electrostatic applications, problems and hazards. Ian worked for ICI for 11 years on projects involving electrostatic process research and development.

Now Group Leader of Electrostatics at Chilworth Technology Ltd, Southampton, UK, Ian is presently responsible for a variety of problem solving and research projects where electrostatics is involved. These include powder and liquid handling problems and applications. Ian has led a multi-national research programme worth 1.5 million ECU investigating powder handling and processing problems caused by static electricity in industrial processes and is currently heading a multi-national programme to develop new tests for anti-static footwear for the European Commission. Ian is a committee member of the Static Electrification Group of the Institute of Physics.

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