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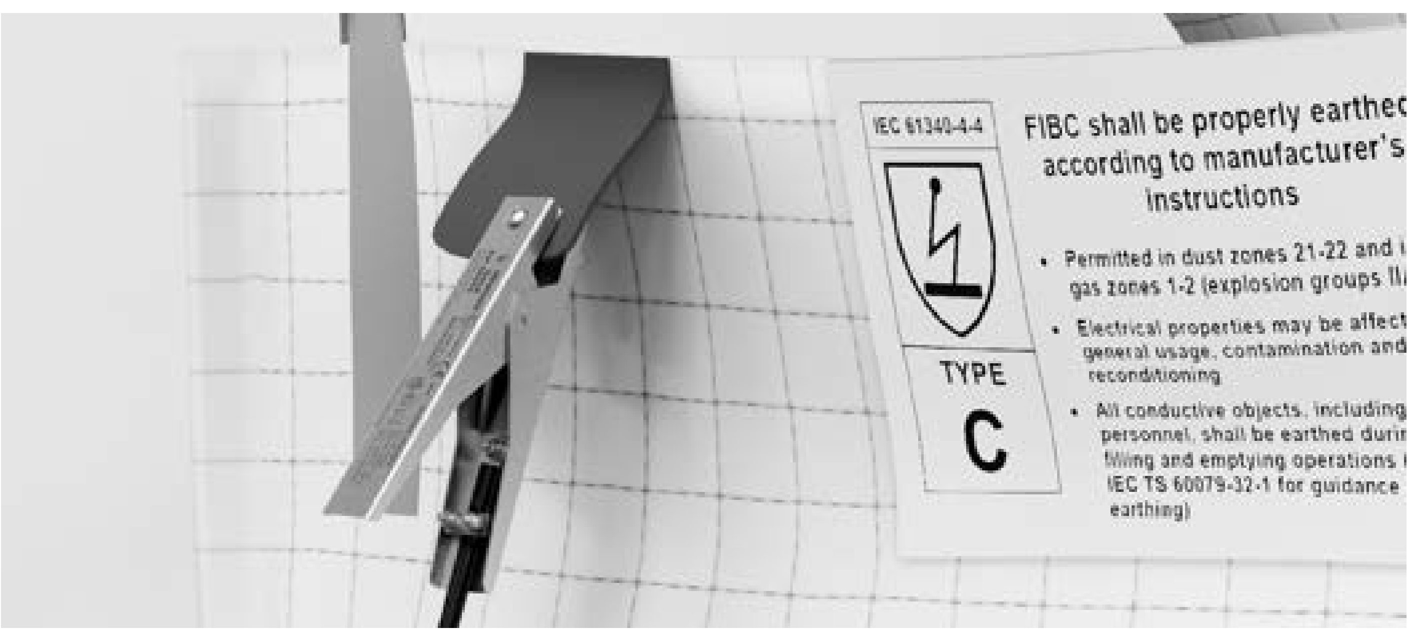
Theory and Practice of Controlling Static Electricity in FIBC Operations

Dr Tom Padden


IEC 61340-4-4
FIBC shall be properly
according to manufacturer's
instructions
Permitted in dust zones 21-22 and
gas zones 1-2 (explosion groups
Electrical properties may be
general usage, contamination and
reconditioning
All conductive objects, including
personnel, shall be earthed
filling and emptying operations
IEC TS 60079-32-1 for guidance
earthing)
TYPE
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Flexible intermediate bulk containers (FIBCs) are containers used in dry bulk product handling, storage, and transfer worldwide. While a familiar sight across non-hazardous and hazardous location operations in industries including agriculture, food processing, chemicals, petrochemicals, pharmaceuticals, and plastics, critical safety risks to personnel and facilities can arise with their use if appropriate safety measures are not taken, particularly when flammable or explosive atmospheres are present. These risks and safety measures have been the subject of extensive academic review and industry regulation, and the purpose of this article is to provide practical insights on the basis of this body of more theoretical work.

Research carried out in the Federal Republic of Germany identified a total of 426 dust explosions in the period between 1965 and 1985, with a variety of ignition sources including open flames, welding and cutting equipment, and electrostatic discharge.[1] While other safety measures can be taken with regard to other ignition sources, electrostatic discharge is a particularly important topic because it can occur without being immediately visible, requires only the presence of two moving materials in contact, and can generate spark discharges capable of igniting flammable atmospheres. Each of these points deserves to be examined more closely in turn.

1. Charge, as outlined by Chilworth Technology's Practical Guide to Industrial Electrostatics Hazards, is a phenomenon which occurs naturally in all materials made up of atoms with positively charged protons and negatively charged electrons, and that the accumulation of electrostatic charge on a particular object is the result of an excess of either positive or negative charge, which can occur through four main mechanisms: Tribocharging, streaming currents, induction charging, and corona charging.[2] A common theme in these mechanisms is that the accumulation of electrostatic charge can easily occur inadvertently while materials are being handled for other purposes, and that the charge accumulation takes place at a microscopic level, invisible to the naked eye.

2. The tribocharging mechanic is the most relevant to the topic of electrostatic charge in FIBC bulk material handling, and leads to the second point that the effect only requires the presence of two different materials rubbing against each other. At its most basic, tribocharging is the effect of friction between two materials, during which electrons from one material are transferred to the other, leaving one material negatively charged and the other positively charged. This effect led to the original discovery of static electricity itself with the observation that a piece of amber rubbed with a silk cloth could attract small particles,[3] but is also very relevant to the movement of bulk materials into and out of FIBCs, as the movement of the material through process transfer equipment or against the surfaces of the FIBC can generate electrostatic charge which, if it has nowhere else to go, can accumulate on the object.

3. This accumulation of charge then leads to the third point, which is that accumulated charge can rapidly discharge itself in the form of an electrostatic spark. While small electrostatic sparks can be nothing more than a minor annoyance in everyday life, such as a spark between a finger and a door handle after walking across a carpeted room, the presence of such a spark in a potentially flammable or explosive atmosphere can have much more serious consequences. This is expanded on in further research by Ian Pavey on electrostatic hazards in the process industries, comparing the energy from electrostatic sparks discharged from various charged objects with the energy required to ignite various flammable materials.

The upshot of this comparison is clear: electrostatic sparks discharged from larger containers, plant items, or even from the charge accumulated on an operator's body can easily reach the minimum ignition energy (MIE) not only of flammable gases and vapors, but also of flammable dust, and can easily become the ignition source of a fire or dust explosion.

Therefore, while an operator unfamiliar with comprehensive safety measures for dust atmospheres might feel confident in the safety of their FIBC transfer operations on the assumption that removing obvious and visible ignition sources such as lit cigarettes, hot surfaces, or welding and cutting equipment from the process eliminates the risk of fire or explosion, if they overlook static electricity and appropriate safety measures, they could be faced with an ignition source that is invisible, commonly occurring, and capable of causing disaster.

Table 1:
Electrostatic spark energies[4]

Object	Typical Energy (mJ)[a]
Small metal items (scoop, hose nozzle)	0.5–1
Small container (bucket, 50l drum)	0.5–5
Medium container (250–500l)	2.5–15
Major plant items (reaction vessels)	5–50
Human body	5–15

[a] Assuming an initial voltage of 10,000V.

Table 2:
Minimum ignition energies for some flammable materials[5]

Gas, Vapor or Dust	Minimum Ignition Energy (mJ)
Hydrogen	0.016
Methane	0.21
Propane	0.25
Methanol	0.14
MEK	0.53
Acetone	1.15
Sulphur	<1
Aluminum	10
Sugar	30
Wheat Flour	40

The risk posed by potentially overlooking static electricity can be compounded by an underestimation of the impact of an ignition in FIBC operations. After all, an operator might think, how dangerous can a bag of flour or plastic granulate be?

The answer, as summarized by Rolf Eckhoff in *Dust explosions in the Process Industries*, is based on a simple principle: "Any solid material that can burn in air will do so with a violence and speed that increases with increasing degree of subdivision of the material."[6] In other words, a solid material that can burn under normal circumstances can burn faster and even explode when in powder or dust form. Wheat exposed to an ignition source can burn. Wheat flour in a compacted pile exposed to an ignition source can burn faster. Wheat flour suspended in air and exposed to an ignition source can explode violently. Eckhoff expands on this with case study analyses including dust explosions in grain silos,[7] linen flax in a textile plant,[8] and aluminum processing.[9]

From this, the risk of ignition from electrostatic discharge and its consequences for personnel and facilities undertaking FIBC operations are clear, and a failure to address this risk with appropriate safety measures would be a serious mistake.

Following on from this, what then are the appropriate safety measures to take? The solution to this lies in following the relevant legislation, standards, and best practice.

As outlined in Chilworth's Practical Guide, the core legislation in Europe regarding explosive atmospheres is based on the ATEX Directive 1999/92/EC, which presents three prioritized steps in addressing the risk:

- the prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that,
- the avoidance of the ignition of explosive atmospheres, and
- the mitigation of the detrimental effects of an explosion so as to ensure the health and safety of workers.[10]

The principles of the Directive have been adopted in the national laws of European Community member states with direct relevance to static electricity as an ignition hazard, such as The Dangerous Substances and Explosive Atmospheres Regulations 2002 in the UK,[11] and the Guide notes that similar principles are applied in legislation across the rest of the world, to the point that "there is now no industrialized country where the ignition hazard arising from unwanted static electricity can be legitimately disregarded."[12] Returning to the question of dealing with static electricity in FIBC operations, it may not be possible to entirely prevent the formation of explosive atmospheres, which are inherently created by the movement of bulk products forming dust clouds. Therefore, the avoidance of the ignition of the explosive atmosphere by controlling the risk of electrostatic charge accumulation and discharge is of clear importance.

When researching how to achieve this control of electrostatic discharge as an ignition source required by the legislation, the key international technical specification is IEC TS 60079-32-1:2013, which gives a comprehensive guidance on electrostatic hazards and their management.[13] As research by Jeremy Smallwood breaks down, this technical specification provides information on assessing and managing static electricity in hazardous location operations, beginning with identifying hazardous location classification (supported by specifications IEC 60079-10-1 and IEC 60079-10-2) and gas or dust groups involved (supported by IEC 60079-0).[14] The guidance then encompasses static electricity in relation to a range of materials and applications, including – most relevantly for the current topic – powder handling operations. In terms of powder handling operations using FIBCs, Smallwood highlights three key pieces of guidance in IEC TS 60079-32-1: Firstly, that the right FIBC type is used for the right application, as outlined in Table 3.

Secondly, the research highlights limitations of Type B and D FIBCs, as the former is limited to certain zones and materials as detailed above, and the latter limited to niche applications with certain explosion groups and minimum ignition energies (MIE) ≥ 0.14mJ. This therefore leaves the Type C FIBC, constructed from fabric with interwoven conductive threads, as the key container to be used for hazardous location bulk material handling. This then leads to the third point that it is of critical importance to establish and maintain an "effective reliable ground connection" between the bag and a local grounding point before and during any product transfer to or from the FIBC.[16]

The importance of this ground connection is reinforced in a series of experiments undertaken by Ebadat and Cartwright, and reported in the IchemE Symposium. Under controlled conditions, a number of FIBC bags with and without conductive threads and with and without electrostatic grounding connections were filled and emptied in order to produce a flammable atmosphere, then subjected to conditions where an electrostatic discharge could occur. The results of these tests included consistent ignition by electrostatic discharge of the FIBCs without conductive threads, but for the Type C FIBCs the following result was observed:

> *It was not possible in the trials to ignite a propane/air mixture with a minimum ignition energy of 0.25 mJ by discharges from such FIBC's* ***provided they were earthed*** *during filling and emptying. An unearthed bag produced incendive discharges.*[17]

The observation was also made that there is a risk of parts of the FIBC becoming isolated from the conductive threads, which can be managed through control of bag design and regular monitoring of the ground connection to ensure that it stays in place.[18] From this, a clear course of action is indicated:

- A Type C FIBC is recommended for hazardous location transfer operations
- A reliable connection to a local electrostatic grounding point is required
- A continuous connection across two points on the FIBC helps to reduce the risk of parts of the bag being isolated from ground.

The final piece of the puzzle lies in the nature of the recommended connection to ground. In addition to its overview of IEC TS 60079-32-1, Smallwood's research notes the requirements of an additional standard, IEC 61340-4-4, which concerns the electrostatic classification for FIBCs. This standard details, in addition to other factors such as the classification, labelling, and test methods, confirms the requirement for Type C FIBCs to be grounded before and during transfer operations, and most importantly defines the upper resistance limit for this grounding connection as 1×10^{8} Ω (100 MΩ).[19] This is notably higher than the resistance for metallic plant equipment, for which as Chilworth's Practical Guide notes, *"it is hard to see why the resistance would even exceed 10 Ohms"*,[20] but takes into account the inherently higher resistance of the flexible material of a FIBC while still ensuring that a reliable connection to the mass of earth can be established and maintained, and is capable of dissipating electrostatic charge during operations.

As with other IEC technical specifications, IEC 61340-4-4 has been recognized and influenced national standards, having been adopted as BS EN IEC 61340-4-4:2018 in the UK,[21] and influencing the National Fire Protection Association, which in 2024 updated its recommended practice NFPA 77 to align with the same 1×10^{8} Ω (100 MΩ) maximum resistance value for FIBC grounding.[22]

Table 3: Usage of FIBC types[15]

Bulk Product in FIBC	**Surroundings**		
MIE of dust[a]	**Non flammable atmosphere**	**Dust zones 21-22**[b]	**Gas zones 1-2**[b] **(Explosion Groups IIA/IIB)**[c]
MIE > 1 000 mJ	A,B,C,D	B,C,D	C,D[d]
3 mJ < MIE ≤ 1 000 mJ	B,C,D	B,C,D	C,D[d]
MIE ≤ 3 mJ	C,D	C,D	C,D[d]

a Measured in accordance with IEC 61241-2-3, ASTM E2019 and EN 13821 with a capacitive discharge circuit (no added inductance).
b See D.2 for the definition of zones.
c See D.3 for an explanation of Explosion Groups.
d Use of Type D should be limited to Explosion Groups IIA/IIB with MIE ≥ 0,14 mJ.

NOTE 1 Additional precautions are usually necessary when a flammable gas or vapor atmosphere is present inside the FIBC, e.g. in case of solvent wet powders.

NOTE 2 Non-flammable atmosphere includes dusts having a MIE > 1 000 mJ.

NOTE 3 The MIE limit of 3 mJ is based on the incendivity of cone discharges. Cone discharges might have a much higher energy in a Type B FIBC than in a Type C or D FIBC because the wall of a Type C or D FIBC will be at close to zero potential. Based on this fact the internal field distribution will be such that in Type C or D FIBC cone discharges will at most only jump across half the diameter of the FIBC. A calculation with the formula given in A.3.7 for the largest FIBC commonly used (diameter of 1.5 m) yields 3 mJ for powder with a median size of only 0.055 mm in a Type B FIBC, whereas in Type C or D FIBC the 3 mJ limit is only reached with a coarse powder having a median size of 0,27 mm or higher. However, such coarse powders usually have a MIE higher than 3 mJ.

Having reviewed the research, regulations, and recommended practice for electrostatic hazards in FIBC operations, what are the key takeaways? In other words, where is the value in addressing the risk of static electricity as an ignition source?

The point is that electrostatic discharge is a clear and present risk in hazardous location FIBC operations, as has been shown conceptually with experiments showing that the energy of electrostatic discharges are more than enough to meet the MIE of commonly used flammable bulk materials, and empirically in research identifying electrostatic discharge as the ignition source of dozens of dust explosions in one country alone. Therefore, from a purely practical standpoint, it is clear that safety measures are required in order to control static electricity as a hazard and to protect FIBC operations, the personnel involved, and the sites at which they are carried out.

In addition to these practical considerations, the requirement to avoid, control, and mitigate electrostatic hazards are embodied in national and international legislation, standards, and recommended practice, meaning that it is also a matter of regulatory compliance to ensure that these requirements are examined and implemented. Failure to take action to control this hazard with appropriate safety measures is therefore a potential liability, as the cost of inaction may be higher than the cost of ensuring safety requirements are met.

From these appropriate safety measures, a number of points stand out from the research and from the regulatory field as particularly relevant for FIBC operations.

1. Equipment must be selected that is suitable for use in hazardous location operations, most relevantly Type C bags in the case of FIBC operations examined.

2. Effective electrostatic grounding must be in place before and during Type C FIBC transfer operations.

3. The electrostatic grounding connection must be maintained to a maximum resistance level of $1 \times 10^8\ \Omega$ (100 MΩ) in conformance to the recommended practice NFPA 77 and standard IEC 61340-4-4.

4. The grounding connection is most effective when using two connection points across the surface of the FIBC and continuously monitored in order to control the risk of parts of the FIBC being isolated from the path to ground, or the connection being interrupted.

With these principles borne in mind, the foundation of a safe and reliable means to control static electricity as a hazard in flammable atmosphere FIBC operations may be established for the improved protection of personnel, operations, and site facilities.

If you would like to find out more about static electricity as a hazard, please refer to Newson Gale's website.

Additionally, you can get in touch with Newson Gale's sales team to discuss specific requirements and solutions, and view further information on protecting Type C FIBCs against static electricity.

1 Beck, H., and A. Jeske. (1996) "Berichte über Staubexplosionen-Ergebnisse und Dokumentation." VDI-Berichte [VDI-Verlag GmbH, Dusseldorf, Germany] Nr. 1272, pp. 365-387.
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6 Eckhoff R. K. (1991) Dust explosions in the process industries, p.28
7 Ibid, p.166
8 Ibid, p.182
9 Ibid, p.192
10 Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article16(1) of Directive 89/391/EEC), Article 3
11 The Dangerous Substances and Explosive Atmospheres Regulations 2002 (SI No.2776)
12 Chilworth Technology Ltd. (2018) Practical Guide Industrial Electrostatics – Hazards, Problems and Applications, p.5
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20 Chilworth Technology Ltd. (2018) Practical Guide Industrial Electrostatics – Hazards, Problems and Applications, p.34
21 BS EN IEC 61340-4-4:2018 Electrostatics - Standard test methods for specific applications. Electrostatic classification of flexible intermediate bulk containers (FIBC)
22 NFPA 77 (2024) Recommended Practice on Static Electricity

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Chilworth Technology Ltd. (2018) *Practical Guide Industrial Electrostatics – Hazards, Problems and Applications*

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NewsonGale
HOERBIGER Safety Solutions

United Kingdom
Newson Gale Ltd
newson-gale.co.uk

Omega House
Private Road 8
Colwick, Nottingham
NG4 2JX, UK
+44 (0)115 940 7500
groundit@newson-gale.co.uk

United States
IEP Technologies, LLC
newson-gale.com

417-1 South Street
Marlborough
MA 01752
USA
+1 732 961 7610
groundit@newson-gale.com

Deutschland
IEP Technologies GmbH
newson-gale.de

Kaiserswerther Str. 85C
40878 Ratingen
Germany

+49 (0)2102 5889 0
erdung@newson-gale.de

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