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TECHNICAL ARTICLE

Controlling the risk of electrostatic ignitions in chemical operations

This article is designed to aid engineers, operations managers and safety professionals in understanding the root causes of static electricity and why it can be a potential ignition source in daily operations. The article will also provide a general overview of legislation and industry guidance relevant to static electricity and then outline practical methods around how it can be managed.

High levels of safety awareness in the intermediate and specialty chemical industry have been in place for decades and the management and mitigation of ignition source risk has always been a major practice for safety professionals, operations managers and engineers.

Static as an ignition source

Static electricity is just one of several sources of ignition regularly identified as being responsible for the ignition of combustible atmospheres (Gas and/or Dust) and there are a range of site wide operations that can result in the generation of static electricity. Whether the operation involves filling, dispensing flammables or conveying/tipping powders into vessels, static electricity can be generated just through the movement of the material being processed or handled.

Because static electricity has long been known to present an ignition source in hazardous area operations, it is highlighted in legislation.

In **Annex II of the ATEX Directive 2014/34/EU** it states the following:

Section 1.3.2 "Hazards arising from static electricity"

- ***"Electrostatic charges capable of resulting in dangerous discharges must be prevented by means of appropriate measures."***

In carrying out the obligations laid down in **Articles 6 and 9 of Directive 89/391/EEC** the employer shall assess the specific risks arising from explosive atmospheres, taking account at least of:

- ***"the likelihood that explosive atmospheres will occur and their persistence,***
- ***the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective,***
- ***the installations, substances used, processes, and their possible interactions,***
- ***the scale of the anticipated effects."***

Explosion risks shall be assessed overall.

Getting to grips with static electricity

Although it is easy to understand why static electricity can be perceived as a mysterious topic to get to grips with, the principles around which static electricity can present an ignition source risk are relatively straightforward.

One common denominator is the interaction of electrically insulating materials (materials that have a low conductivity, e.g. toluene) with electrically conductive materials (e.g. plant equipment constructed from metals).

When an insulating material like toluene comes into contact with metal plant equipment, whether it's flowing in piping, through a filter or being deposited into a drum the toluene attracts electrons from the metal surface of the equipment it is in dynamic contact with.

Static accumulating liquids	Static accumulating powders
Benzene	PTFE
Diesel	Polyethylene
Gasoline	PMMA
Light crude	Wood
Crude/Gas condensates	Polyuerthane
Jet fuel	PVC
Kerosene	Pyrex
Toluene	Neoprene
Xylene	Nylon
Hexane	Polypropylene
Heptane	Polystyrene

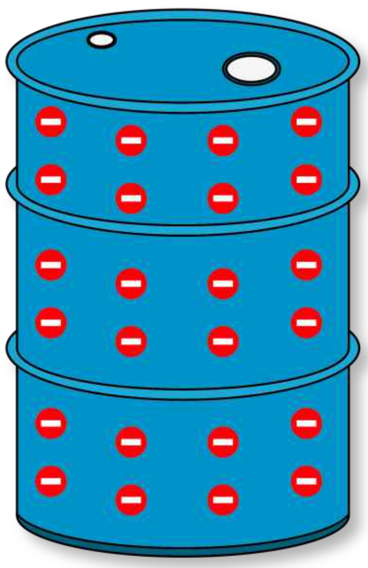
Table 1 – Examples of static accumulating materials

The net result of this interaction is that the toluene is rapidly building a negative electrical charge, as it is attracting negatively charged electrons from the conductive metal, while the metal equipment is rapidly building a positive electrical charge.

The problem with this situation, if it is allowed to continue, is that the voltage of both materials will rise rapidly if both materials are "isolated" from the earth.

Any object isolated from the earth can be described as possessing an "electrical capacitance" which is denoted with the symbol "C" and is measured in Farads.

If we take the example of the toluene building a continuous negative charge as it flows through the metal piping system and gets deposited into an object like a metal drum, which, in this example, is isolated from earth, the drum will build a negative charge on its outside surface. The reason for this is that the negative voltage of the toluene forces the electrons in the drum to the outside surface of the drum. This is caused by the "rule-of-thumb" principle that like charges repel and unlike charges attract.



Negative electrical charges distributed on external surface

The problem with this scenario is that the voltage of the drum will rise based on the amount of negative charge residing on its outer surface relative to its own value of capacitance.

The more charge, the higher the voltage. **This scenario can be best explained through the formula:**

$$V = \frac{Q}{C}$$

Where:
V = voltage of charged object (Volts)
Q = total quantity of charge on the object (Coulombs)
C = capacitance of charged object (Farad)

*(Source: **NFPA 77: 6.3.1**)*

As more charge is deposited on the isolated object there is a constant voltage rise. In our example, this is the outside surface of the drum as it is being filled with the toluene.

Value of capacitances for typical conductors	
Object	**Capacitance pF***
Small metal items (scoop, hose nozzle)	10 to 20
Small containers (bucket, 50 l drum)	10 to 100
Medium containers (250 l to 500 l)	50 to 300
Major plant items (reaction vessles) immediately surrounded by earthed structure	100 to 1000
Human body	100 to 200
*1 pF = 1 x 10^{-12} F	

*Table 2: Capacitance of objects routinely used in the movement and containment of hazardous products. (Source: **IEC TS 60079-32-1 "Explosive atmospheres, Part 32-1: Electrostatic hazards, guidance" – Table A.2**)*

As the voltage rapidly rises and the electrical field strength around the surface of the drum passes 3000 volts per millimeter (the breakdown voltage of air at ambient conditions) then there is a real risk that an electrostatic spark will be discharged from the surface of the drum into the potentially combustible atmosphere. In order to initiate combustion of the atmosphere, assuming it is within its ignitable range, the energy of the resulting spark must exceed the minimum ignition energy (MIE) of the surrounding flammable atmosphere.

The potential energy of an electrostatic spark discharge can be illustrated in the formula:

$$W = 0.5CV^2$$

Where:
W = spark energy (joules)
C = capacitance of isolated object (farad)
V = voltage of isolated objects (volts)

*(Source: **NFPA 77: 6.3.1**)*

If it is assumed that the voltage of the object has exceeded the breakdown voltage of the surrounding atmosphere and is charged to a voltage of, say, 10,000 volts at the moment when there is a spark discharge to another object in close proximity to the drum, the potential energy of the resulting spark would be approximately 2.5 mJ. This assumes the drum has a minimum capacitance of 50 pF as indicated in Table 2. If we are assuming that the flammable mixture surrounding the drum is a toluene-air vapour the minimum ignition energy would be in the region of 0.24 mJ (Source: **Table B1 of NFPA 77 "Recommended Practice on Static Electricity" (2024)**), then the resulting energy from the spark would be capable of initiating combustion of the vapour.

Charge generation is not just limited to liquids. Powder processing operations can produce electrostatic charging rates well in excess of liquids and gases.

Processes capable of generating static electricity

In the intermediate and specialty chemicals sector there are many processes that can result in the generation of static electricity as a natural by-product of the process in question. Such examples include but are not limited to:

- Bulk material transfer into or out of **road tankers and railcars.**
- **Ex IBC and drums** that are being filled, emptied, or being used as mixing and blending vessels.
- Transferring liquids and powders via hoses.
- Filling or emptying vessels and **FIBC with powders.**
- Even people, if they are wearing **insulating footwear** or are walking on insulating surfaces, can accumulate large voltages on their body without even sensing it.

Bulk material transfer

Ex IBC and drum filling

FIBC Type C bag powder filling

Railcar grounding

Charge build up on powders	
Operation	**Mass charge density (μC kg^{1})**
Triboelectrical powder coating	10 000 to 1 000
Pneumatic conveying	1 000 to 0.1
Micronizing	100 to 0.1
Grinding	1 to 0.1
Scroll feed transfer	1 to 0.01
Pouring	1 to 0.001
Sieving	0.001 to 0.000 01

Table 3 – Charge build up on powders through different processing techniques and the quantity of charge typically carried per kilogram of powder.

*(Source: **CLC/TR 60079-32-1 "Explosive atmospheres, Part 32-1: Electrostatic hazards, guidance" – Table A.1).***

However, the vast majority of these situations can be managed by ensuring the objects at risk of static charge accumulation are not isolated from earth. Because fixed plant like large storage tanks and vessels should be earthed via the plant structure, the risk of static spark discharges is most pronounced for moveable objects ranging from road tankers to people.

Table 4 highlights some of the sources of electrical isolation on moveable equipment. If the objects are connected to earth then the charge imbalance on the object is neutralized which mitigates the risk of a static spark with enough energy to ignite potentially combustible atmospheres.

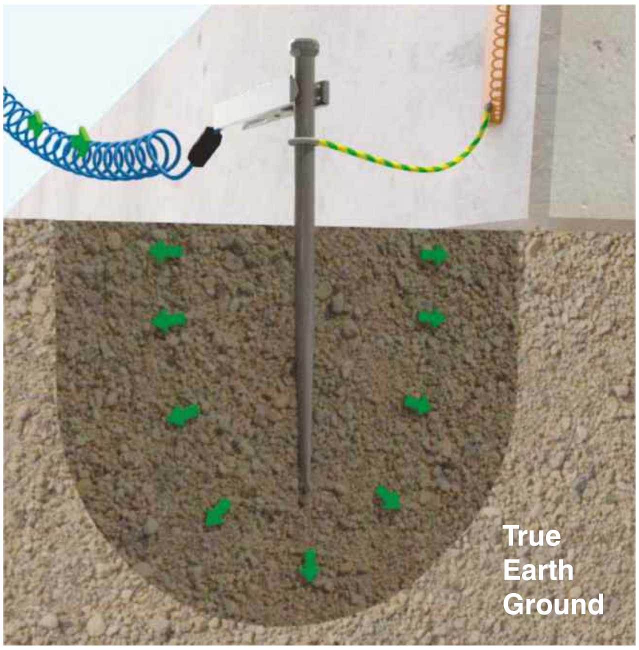
Objects	What causes capacitance?
Portable drums	Protective coatings, product deposits, rust
Road tankers	Rubber tyres
Piping	Rubber and plastic seals, anti-vibration pads and gaskets
Railer Tankers	Grease, vibration pads isolating tank from rail cars. Rails isolated from loading gantry
People	Soles of footwear
Scoops	Rubber gloves
Hoses	Broken internal helixes and bonding connectors
FIBC	Non-conductive fabric / damaged static dissipative threads

Table 4 – Examples of why process equipment and people can be isolated from earth

Sole-Mate™ static dissipative footwear testing

Grounding and bonding systems

Grounding potentially isolated equipment should be regarded as a compulsory safety function in any process and area where combustible products are handled and processed. It is the most practical and effective way of mitigating the accumulation of static electricity on equipment (and people). However, having objects in contact with ground is not grounding. For example, resting a drum on concrete or using drag chains on road tankers does not provide an effective and reliable means of preventing static charge accumulation.



"True Earth Ground" - a connection to the general mass of the earth that has been measured and verified to be below 10 ohms

So what does "grounding" really mean? In effect, if we can connect our potentially isolated equipment to a verified "true earth ground" i.e. a connection to the general mass of the earth that has been measured and verified to be below 10 ohms, in accordance with a standard like the **EN 62305** standard for grounding lightning protection systems, we can be confident that connecting to installed ground networks like the local lightning and electrical earthing protection system will enable static charges dissipate safely from the process equipment. The bus-bar network that feeds out from the ground rods (installed ground network) can provide a means of grounding our process equipment.

Bonding is different to grounding in that it ensures that two bonded objects at risk of static charge accumulation are at the same electrical potential, however, it does not mean they have no charge, i.e. are at ground potential (0 volts). Bonding ensures there is no risk of static spark discharges between the bonded objects. It does not mean they are not capable of discharging sparks to objects at a lower electrical potential.

For movable metal objects this extract from **IEC TS 60079-32-1 "Explosive atmospheres, Electrostatic hazards, guidance"** recommends the following:

Section 13.4 "The establishment and monitoring of earthing systems":

13.4.1 Design

"Permanent bonding or earthing connections should be made in a way to provide low resistance during its lifetime, e.g. by brazing or welding. Temporary connections can be made using bolts, pressure-type earth clamps, or other special clamps. Pressure-type clamps should have sufficient pressure to penetrate any protective coating, rust, or spilled material to ensure contact with the base metal with an interface resistance of less than 10 Ω."

A resistance of 10 ohms or less refers to the resistance between the object requiring static grounding protection and the local ground network.

Any resistance higher than this value would indicate loose connections or corrosion (see NFPA 77 ref. below) which could limit the dissipation of electrostatic charges from the equipment undergoing electrification. The challenge, however, is to ensure we implement a consistent and reliable means of connecting to these networks, especially since most of the equipment we are dealing with is portable and will not have a permanent connection to the site's local ground network.

Section 7.4.1.3.1 of NFPA 77 (2019ed), "Recommended Practice on Static Electricity"

"Where the **bonding/grounding system is all metal, resistance in continuous ground paths typically is less than 10 Ohms. Such systems include those having multiple components. Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion. A permanent or fixed grounding system that is acceptable for power circuits or for lightning protection is more than adequate for a static electricity grounding system."**

Implementing practical grounding solutions

The implementation of a consistent and repeatable way of grounding mobile equipment needs to take into account the characteristics of the process, who the responsible people are for performing the grounding and bonding safety function on a daily basis and other factors like environmental conditions and the classification of the hazardous area.

Whatever method is adopted it is critical to ensure that the person (people) responsible for performing the safety function of grounding it and that the grounding activity itself it is kept relatively simple. There are many cases where sites with good grounding practices have been caught out either due to forgetfulness on the part of an operator or because a minor flaw in the process has been missed.

Industrial grade grounding clamps

Grounding clamps are the most "traditional" means of connecting mobile plant equipment to verified grounding points. However equipment specifiers need to be aware of the difference between clamps like alligator clips as compared with static grounding clamps that have been designed for repeated use in harsh industrial environments.

Clamps like alligator clips are designed to be attached to clean surfaces like battery terminals. They are not designed to penetrate industrial grade protective coatings or product deposits on equipment that would otherwise not permit static charges to pass through them. So even though the clamp may be attached to the object it does not mean it is effectively grounding it.

Clamps that combine a strong spring pressure with sharp rugged teeth have a greater chance of penetrating surfaces that would otherwise prevent a reliable electrical and mechanical connection to the equipment undergoing electrification by electrostatic charging.

Camps that carry the **FM approval** mark will have passed a range of functional tests that demonstrate key functional performance characteristics to operate successfully.

These tests include:

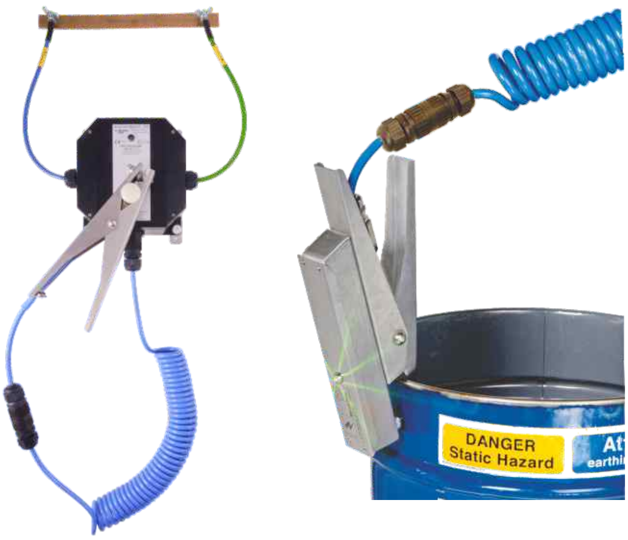
- Clamp pressure testing
- Pull resistance testing
- Electrical continuity testing (less than 1 ohm)
- Clamp connection testing in response to a range of vibrating frequencies

Although the use of a basic grounding clamp will not verify a low resistance connection to equipment for the operator, selecting a grounding clamp that combines FM approval with a set of sharp teeth capable of penetrating layers that would otherwise inhibit static charge transfer will enhance the likelihood of repeatable and reliable ground connections to plant equipment.

Verifying a positive ground connection

Combining certified grounding clamps with a ground monitoring system adds the benefit of providing positive confirmation to operators that a 10 ohm or less connection to the plant equipment requiring static grounding protection has been achieved after they have attached the grounding clamp. This effectively removes the "guesswork" out of knowing whether or not the equipment is grounded. Once a connection of 10 ohms or less has been verified by the system, an indicator like a flashing green LED will let the operator know that he/she can proceed with the operation (e.g. filling or mixing operation).

The benefit of the flashing green LED principle is that it lets people in the area know that the system is continuously monitoring the health and effectiveness of the grounding circuit and that should the resistance rise above 10 ohms, or the clamp's connection to the equipment be compromised in any way, that the LED will switch off. This will notify people working in the area that the process should be halted or if it cannot be halted that the equipment not be approached until an adequate charge relaxation time period has been adhered to after the process has finished.



Bond-Rite® ground circuit monitoring units

The use of a ground circuit monitoring system with an indicator has the added benefit of becoming a core step in the operator's Standard Operating Procedures (SOP) so that if the green light is not obtained the process should not begin. It also enhances the site's ability to demonstrate compliance with the recommendations of **IEC TS 60079-32-1** and **NFPA 77** by ensuring the process does not start unless a verified 10 ohm or less connection has been achieved.

Ground verification with interlocks

If the process that causes charge generation is automated an alternative option is to specify a **grounding system** that will not only verify and indicate a ground connection resistance of 10 ohms or less, but through its volt free contacts, control the process (e.g. **road tanker loading operation**).

Unless the grounding system detects a 10 ohm or less connection it will not permit the process to begin.

It should be borne in mind that if the grounding system is interlocked with devices to control the flow/movement of material that although the device causing material movement (e.g. pump) may have stopped (e.g. through accidental removal of the clamp mid-transfer) there could be a period of time before the flow or movement of material stops completely.

It is the responsibility of the customer to determine what measures need to be in place to manage scenarios where static charge could still be present. Likewise, if the clamp's connection or the grounding circuit should be compromised during the process, the grounding system will automatically detect this situation and halt the process, thereby stopping the further generation and accumulation of static electricity on the process equipment.

The benefit of this type of system is that it really enforces the Standard Operating Procedures (SOP) of grounding the object prior to process initiation.

Earth-Rite® RTR and MULTIPOINT monitoring units with interlock capabilities

Again, what needs to be borne in mind is that the person tasked with ensuring the safety function of grounding the equipment is actioned via an easy and repeatable way of grounding the equipment. The most effective way of getting acceptance and engagement from the operator is to keep the visual indication and mode of operation as simple as possible. A simple red “NO-GO”, green “GO” method of indication is a simple but effective concept for people to engage with.

This in line with a simple action of connecting the grounding clamp to the object requiring grounding, without any additional need to interface with switches and dials, simplifies the procedure.

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