White Paper

You don't need to be a rocket scientist – to safeguard against the hazards of static electricity

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For any person responsible for the safety of employees, colleagues, plant equipment and plant property, one of the most potentially confusing aspects of providing a safe operating environment is trying to determine if that site's manufacturing or handling processes have the potential to discharge static sparks into flammable or combustible atmospheres.

Electrostatics is a detailed subject area that, for most of us, appears to be a black art accessible only to academics and experienced process safety consultants. Because static ignition hazards occur at the "nuclear level", it is naturally difficult to visualise how and why static electricity is a hazard in industries where flammable and combustible products are regularly processed. There are so many variables that have a role to play in electrostatics, it is almost impossible to predict the net effects of these parameters, in a hazardous prevention context, without feeling the need to conduct controlled laboratory testing to determine if a specific process could produce incendive electrostatic discharges.

If you consider that a walking across a carpet can generate 35,000 volts (35 KV) on a person, it is easy to see how normal everyday processes can generate potentials well in excess of 10,000 volts (10 KV). For a small object like a metal bucket, which has a typical capacitance of 20 pico-farads, the total energy available for discharge at 10 KV is 1mJ. This is higher than most flammable vapour minimum ignition energies (MIE's). Scaling up, the ignition energy available on a human, at 10 KV, would be around 10mJ. In powder conveying operations voltages of the order of 1000 KV can easily be generated on parts of the conveying system. Road tankers undergoing loading can carry as much as 2000 mJ of ignition energy.

It can be time-consuming, and expensive, to investigate and determine the level of voltage that can arise as a result of these charging mechanisms. Complicating matters further, ignitable electrostatic discharges can occur in many forms ranging from spark discharges, propagating brush discharges, bulking brush discharges, to corona discharges. The effort required to assess, determine and combine these variables into a cohesive audit of a potential hazard is, by no means, easy.

Which standards should I follow to control static electricity in ignitable atmospheres?

Fortunately, there are several internationally recognised standards that provide guidance on ways to limit electrostatic hazards enabling those responsible for worker health and safety minimise the risk of incendive static discharges. Hazardous area operators who can demonstrate compliance with these standards will go a long way to providing a safe working environment and preventing the ignition of ignitable atmospheres. The most comprehensive standards are:

NFPA 77: Recommended Practice on Static Electricity (2007).

CENELEC CLC/TR 60079-32-1: "Explosive atmospheres - Part 32-1: Electrostatic hazards, guidance" (2015).

API RP 2003: Protection against Ignitions Arising out of Static, Lightning and Stray Currents (2008).

API RP 2219: Safe Operation of Vacuum Trucks in Petroleum Service (2005).

The standards, particularly NFPA 77 and CLC/TR: 60079-32-1, describe a range of processes where static charges can be generated including flow in pipes and hoses; loading & unloading of road tankers; railcar loading & unloading; filling and dispensing portable tanks, drums and containers; storage tank filling and cleaning; mixing, blending and agitation operations; the conveying of powders and other operations. The API RP 2003 standard focuses on road tanker loading and railcar filling operations, storage tank filling and general operations involving petroleum products. API RP 2219 provides detailed guidance on protecting vacuum trucks from electrostatic hazards.

These standards outline what factors can be identified and controlled to limit electrostatic hazards and these controls typically depend on:

- Preventing the accumulation of electrostatic charges on plant equipment, people and the material transferred.
- Controlling the process to minimise the generation of electrostatic charges.

NFPA 77 (5.1.10) states that the transfer of just one electron in 500,000 atoms is required to generate voltages with enough energy to ignite flammable atmospheres.

Effective earthing and bonding is presented in the standards as the primary means of protection from electrostatic hazards and is the most straight forward, secure and cost-effective means of ensuring static hazards are managed and controlled correctly. Eliminating the accumulation of static charges will eliminate the static hazard.

Earthing and Bonding - What are the key benchmarks?

The earth has an infinite capacity to absorb charges and "earthing" (grounding) is the act of connecting a body to an electrode (or other buried structure) that has a verified contact resistance to the ground, typically less than 25 ohms. Earthing provides a path for static charges to rapidly flow to earth, reducing the voltage of the object to zero and thereby eliminating the presence of an ignition source. "Bonding" connects objects so that they are at the same electrical potential preventing discharges when they are positioned in close proximity to each other. If bonding is carried out, it is important to ensure that one of the bonded objects is connected to earth, thereby ensuring all parts of the bonded system are at zero potential.

Static Hazard = Situation where the rate of charge accumulation exceeds the rate of charge dissipation

Given that earthing is the primary source of static hazard prevention it is important to understand what parameters can be identified as providing a satisfactory level of protection. The key to static hazard protection is ensuring that the path between the charged object and earth is of a sufficient quality to dissipate the static charges safely and rapidly.

The majority of plant equipment at risk of static charge accumulation is made of metal. Metals are excellent conductors and the natural resistive properties of metals ranging from copper through to steel means that electrical resistance to the transfer of charges from the body is low, provided that the body has good contact with earth. If the metal body is not earthed, this positive characteristic can quickly become a negative as isolated metal conductors are the primary source of static spark ignition hazards.

Material	Typical Volume Resistivity	Resistance to Charge Transfer
Copper	1.7×10^{-8} Ω.m	Low
Steel	4.52×10^{-7} Ω.m	Low
Carbon	10×10^{-8} Ω.m	Low
Glass	1×10^{10} Ω.m	High
Polymers	10^{15} to 10^{22} Ω.m	High

Resistivities of different material properties

To illustrate, a 10 m length (32 feet) of 2 mm diameter steel cable, in good condition, should have an overall resistance approximating to 1.44 ohms over its entire length (see table below).

The maximum value of resistance present in metal circuits, which includes the body at risk of static charge accumulation, should be equal to or less than 10 ohms and is the benchmark value of resistance recommended by all four standards. If a resistance of 10 ohms or more is detected then there is a likelihood that the earthing circuit has been compromised and should be checked for corrosion or breakages.

2mm diameter cable	25 metres (82 feet)	10 metres (32 feet)	5 metres (16 feet)
Copper	0.13 ohms	0.05 ohms	0.027 ohm
Steel	3.6 ohms	1.44 ohms	0.72 ohms

Resistance values for a range of cable lengths

	NFPA 77	API 2003	API 2219	CLCTR 50404
Metal Circuits	10 ohms	10 ohms	10 ohms	10 or 100 ohms
Type 'C' FIBC	must be grounded	no reference	no reference	1×10^{8} ohms

Resistance values recommended by the standards for static earthing and bonding circuits

The table above outlines the maximum resistance levels for static dissipation circuits recommended by the standards for static control in potentially ignitable atmospheres. It is important to ensure that the static dissipative path, the path that channels the charging current to earth, is 10 ohms or less, and stays that way for the duration of the process.

How to Audit your processes for static hazards:

Figure 6.1.2 in NFPA 77 provides a decision tree flow chart which helps define a simple and effective way to help decide whether or not conductive objects should be earthed. It shows that the first step in an audit is to determine if there ***"is the potential to create an ignitable mixture"***. If there is a potential for this to occur the next step states ***"bond and ground all conductive equipment"***. There are further steps that query whether or not ***"electrostatic energy"*** can be generated and accumulate. As stated earlier, the process of determining these factors can be time consuming and require the expertise of process safety consultants. Very often, it is more cost-effective to earth the object, particularly if it is made of conductive metal, when it is known that materials with different properties come into contact. In order to provide a basic audit of processes NFPA 77 (Fig. 6.1.2) lists the following scenarios where charge can be generated:

Can charge generate?
Does process include:
- Flow of material?
- Agitation or atomization?
- Powders or solids?
- Interaction with personnel?
- Filtration?
- Settling?
- Bubbles rising?

If YES, can charge accumulate?
Does process include:
- Insulated equipment?
- Insulating materials?
- Isolated conductive equipment?
- Interaction with personnel?
- Nonconductive liquids?
- Mists or clouds?

When the answer to these questions is "YES", it states that the potential MIE should be calculated to determine if it exceeds the MIE of the atmosphere present. This will probably be the hardest thing to calculate so the best advice is to earth the equipment as there may not be an opportunity to change the material being processed or the equipment, through which it is pumped, conveyed or handled.

What do the standards recommend for specific applications?

Road Tankers: NFPA 77, CLC/TR: 60079-32-1 and **API RP 2003** recommend that the first procedure in road tanker material transfer operations is to earth the tanker prior to any other operation being carried out by the driver. Interlocking static earthing systems, with earth status indicators, should also be specified so that if the road tanker is not protected from static discharges due to incorrect earthing, the system will not permit the flow of product thereby eliminating the generation of electrostatic charges. The static earthing system should monitor the resistance in the earthing circuit ensuring it does not rise above 10 ohms. **CLC/TR: 60079-32-1** specifies 10 ohms or 100 ohms as being suitable for convenience in monitoring, however 10 ohms would be the established standard for large companies with a good track record in static control safety.

Earthing of road tanker is critical to ensuring static charges do not accumulate on the container (barrel).

Railcars: API RP 2003 and **NFPA 77** identify parts of the railcar that could become isolated from the railway tracks. Non-conductive wear pads and bearings can be located between the barrel and the chassis and it is recommended that the barrel is earthed prior to and during, the material transfer process. This will prevent the accumulation of static charges on the barrel and eliminate the risk of discharges from the barrel to the fill pipe, and discharges to people or other grounded bodies. NFPA 77 **(8.8.2)** states:

"Many tank cars are equipped with nonconductive bearings and nonconductive wear pads located between the car itself and the trucks (wheel assemblies)….. Therefore, bonding of the tank car body to the fill system piping is necessary to protect against charge accumulation".

Vacuum Trucks: API 2219 provides guidance on the protection of vacuum trucks when they are used to suck up flammable or combustible products. Examples include waste collection during storage tank cleaning operations and the suction of combustible powders from dust collection chambers. Of the many recommendations outlined in API 2219, the most relevant instruction is to fully ground the truck by connecting it to "a designated, proven ground source", before commencing with transfer operations. The "ground source" describes an object with a low resistance connection to earth (ground). The standard also states the importance of confirming that the connection resistance between the truck and the designated grounding point is less than 10 ohms and that this resistance should be verified with the use of an ohm meter (or some other type of measurement device).

People: As highlighted earlier, people, through regular movement, can generate large potential differences on their bodies and the accumulation of static charges should be minimised so that operators do not discharge sparks in the presence of ignitable atmospheres. The advice in the standards is to ensure hazardous area floors are conductive and that operator's working in these areas should be wearing static dissipative shoes to prevent charge accumulation on their body. **CLC/TR: 60079-32-1** states the shoes should be tested prior to entry into the zoned (classified) area:

"All personnel should be earthed by means of conducting floors and footwear (see 9.2 and 9.3). A personnel resistance monitor should be installed at every entrance to any area where such footwear is required."

Portable containers: When portable metal containers like IBCs and drums are being filled or dispensed from the advice in all standards is to earth and bond all of the filling system and the receiving vessels. **NFPA 77 (8.13.3.2)** states that:

"Bonding should be done with a clamp that has hardened steel points that will penetrate paint, corrosion products, and accumulated material using either screw force or a strong spring."

There is some guidance in the standards regarding the use of plastic lined metal containers. **NFPA 77** states that a metal container, with a plastic of lining of 2mm, or less, can be treated as a metal drum. **CLC/TR: 60079-32-1** contains a table with the maximum recommended lining thicknesses and emphasises the importance of ensuring that their interaction with conductive objects does not promote high energy propagating brush discharges. In general, filling insulating plastic containers is not recommended. If a conductive liquid is being processed it may be possible to dissipate charges using a conductive dip tube, however, the use of dip tubes carry extra precautionary measures.

FIBCs: CLC/TR: 60079-32-1 provides the clearest guidance in respect of resistance values that should be maintained when filling or discharging from FIBC Type C bags. **NFPA 77** states that the bag should be grounded but does not specify a maximum resistance value. **CLC/TR: 60079-32-1** states:

"The conductive fabric and the conductive threads or filaments shall have a resistance of the earthing point on the FIBC of less than (1 x) $10^8\ \Omega$."

Type D bags are designed to dissipate charges from bags through "low energy" corona discharges. The potential drawback, however, is that the bag could induce charges on surrounding conductive objects. **CLC/TR: 60079-32-1** states:

"any conductive items that may not normally be earthed (e.g. drums on pallets) should either be earthed or removed from the vicinity of the FIBC Type D. In addition, conductive items (e.g. working tools, bolts and clips) shall not be placed or stored on the FIBC."

Summary

Identifying and controlling electrostatic hazards can be a challenging process for those of us responsible for ensuring our colleagues, employees, equipment and property are fully protected from electrostatic ignition hazards. There are many factors that can contribute to the presence of a static hazard but if the examples of earthing and bonding protection outlined above can be followed, the majority of processes at risk of static discharge will be controlled and accounted for. When an audit of a process or procedure has identified an electrostatic ignition hazard, it is important to specify earthing and bonding systems that can demonstrate compliance with the standards. Where possible, static earthing instruments that can demonstrate resistance levels recommended by the standards will ensure companies are protected from this ever-present and hazardous ignition source.

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NG UK White Paper 21 070918