White Paper

Static grounding protection for Tank Cars.

Author Details:

Mike O’Brien, Head of Marketing and Sales for Newson Gale

If you have any questions relating to the topics discussed in this article, you can contact Mike directly at:
mike.obrien@hoerbiger.com

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The transportation of flammable products by rail, whether that be as a result of the shale driven boom in crude by rail or the transportation of chemicals from petrochemical manufacturing centres to end user markets, is still one of the most flexible and cost effective methods by which to move flammable products across the continent of North America in bulk quantities. And while this industry has a host of safety and environmental regulations to contend with, one area of safety that is often misinterpreted or misunderstood, is the ignition hazard associated with static electricity and the measures that can be put into practice to control this risk.

Static electricity: what’s the big deal?

Let’s start with static electricity itself. The clue is in the term. Static electricity is, essentially, electricity that is static. It is electricity that is temporarily “stuck” in the same position. It’s made of the same “stuff” that powers your refrigerator or lighting, but its characteristics are different to the line power delivered to your home or place of work.

In the hazardous process industries, more commonly referred to as the HAZLOC industries, static electricity is generated virtually all of the time. Various grades of crude oil, refined petroleum products like LPG, and a host of chemicals fall into a category of materials that are often referred to as “static accumulators”. What this term means is that materials in this category are known to be powerful attractors of electrons from other materials and resist “letting go” of electrons they come into contact with. They “accumulate” static charge.

In a typical Lease Automatic Custody Transfer unit (LACT) or rack loading operation, the static accumulating product is transferred from, say, a truck, via the LACT unit or from a storage tank via a rack loading system into a receiving tank car. We can refer to the equipment involved in the transfer of product collectively as the product "transfer system". As the product makes its way through the transfer system to the customer side of the transfer, the molecules in the product become electrostatically charged.

If the tank car is not grounded contact with the charged product will cause it to become electrified. If this situation is allowed to exist and persist throughout the transfer operation, it will present a potentially serious source of ignition in the presence of flammable atmospheres.

As the tank car builds up electrostatic charges on its surface, the voltage present on the tank car rises dramatically in a very short space of time. Because the tank car is at a high voltage, it is seeking to find ways of discharging this excess potential energy and the most efficient way of doing this is to discharge the excess electrons to objects at a lower potential in the form of a spark. The best object to discharge to is the Earth or an object with a direct connection to it, i.e. something that is **grounded**. This is because the Earth can absorb an infinite amount of charge due its size and mass. This is what happens during an electrical storm, where lightning strikes result from huge potential differences that are present between the Earth and the layer of storm clouds above its surface. Static electricity is no different; it's the same stuff, the only difference being the amount of electrons being discharged via a static spark or via a lightning strike.

Energy discharged in static sparks.

Grounded objects that are in close proximity to charged objects are good targets for electrostatic sparks and permitting the uncontrolled accumulation of static electricity in a HAZLOC atmosphere is no different to having an engine's spark plug exposed to a potentially flammable atmosphere.

The magnitude of the energy present during the discharge of a static spark is a product of the capacitance of the tank car and the voltage present on the tank car at the time the spark is discharged. The electrostatic voltage that is present on the tank car is a combination of the charging current generated by the flow of the liquid, the capacitance of the tank car and the tank car's isolation from ground.

Increased flow rates and turbulence can increase the size of the charging current, but even when safe recommended flow rates are taken into consideration, if the transfer system is not grounded, the electrostatic voltage of the tank car can build up to hazardous levels in less than 20 seconds. Table 1 illustrates how much energy can be discharged by a spark from a tank car charged to 20,000 volts.

TankCar charged to 20,000 volts	Potential Spark Energy (mJ)
Tank car	1000

Table 1. Potential energy of sparks from Tank Cars

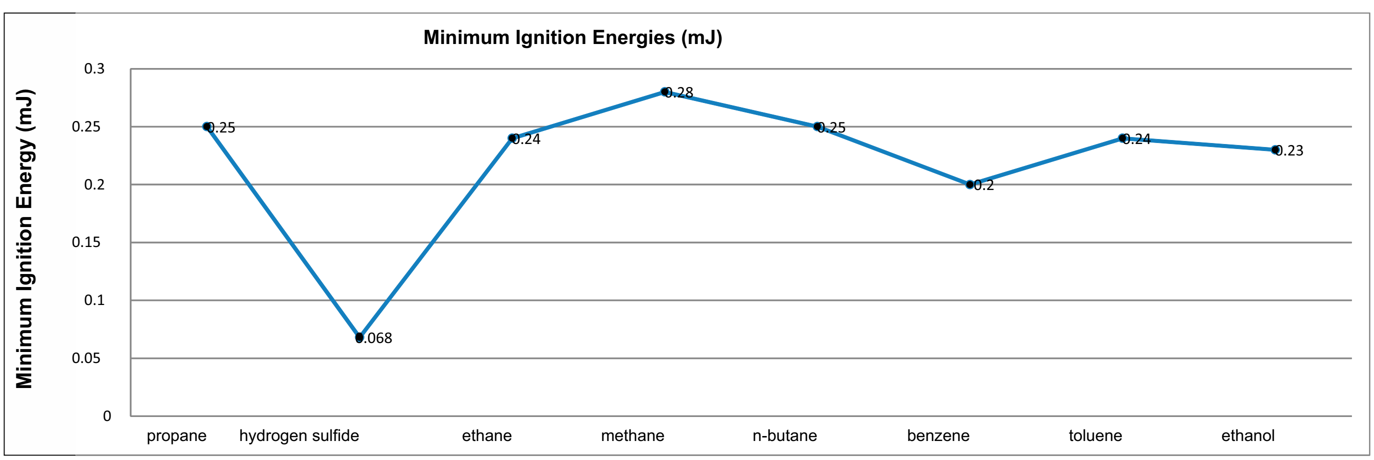

Fig. 1 The MIEs of common petroleum products. (Source: NFPA 497)

When the energy of the sparks discharged by static electricity is compared with the minimum ignition energies of a wide range of both raw and refined petroleum sourced products, it's easy to see why the tank car and any equipment connected to it, like flexible hoses and piping, should be bonded and grounded.

As can be seen in Table 1, isolated tank cars can discharge sparks with a huge amount of energy. At these static spark energy levels the prevention of electrostatic shocks to workers is an important safety consideration. Involuntary physiological reactions caused by electrostatic shocks could lead to trips and falls and could be particularly hazardous when personnel are working above ground level.

Of the several factors that contribute to static charging, the one variable that must definitely be controlled is the grounding of the tank car. Grounding the tank car ensures that the tank car's resistance to the general mass of the earth is maintained at a level that does not impede the safe transfer of static charges from the tank car to ground.

Grounding and bonding is not simply achieved by connecting alligator clips on wires back to the loading rack or LACT unit. Because of the serious ignition hazard static electricity presents to a wide range of HAZLOC operations, there are industry guidelines in place designed to control the risk of fires and explosions caused by static electricity.

Industry codes of practice related to the static grounding of tank cars in HAZLOC atmospheres:

Grounding is the act of ensuring the tank car is connected to an object that has a verified connection to the general mass of the earth. Article 250 of NFPA 70, the National Electrical Code, describes these points as "ground electrodes". Typical ground electrodes are objects that encompass metal rods buried up to 8 ft. in the ground, pipes in direct and continuous contact with the earth for more than 20 ft. and building structures, like loading racks, which should be grounded for electrical fault protection and lightning protection purposes. Grounding provides a continuous and uninhibited path for charges generated during the transfer operation to flow to Earth, via the object performing the function of a ground electrode.

The National Fire Protection Association and the American Petroleum Institute each publish codes of practice for controlling the risks associated with static electricity in hazardous locations. **NFPA 77 "Recommended Practice on Static Electricity"** (2014) and **API RP 2003 "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents"** (2008) are publications written by committees of HAZLOC industry professionals who are recognised experts in the area of static control for hazardous locations. Understanding and implementing the recommendations of these guidance documents will ensure the risk and liability attached to static hazards is well controlled.

What is clear from the recommendations of NFPA 77 and API RP 2003 (see extracts below) is that 10 ohms in the grounding and bonding circuit is the maximum resistance recommended for equipment at risk of electrostatic charging in HAZLOC atmospheres. While API RP 2003 goes one step further in recommending 1 ohm or less, if a grounding system with signal lights is in use, 10 ohms is satisfactory. This is because the grounding system is continuously monitoring the resistance in the grounding circuit, so that if it rises above 10 ohms, the grounding system can signal this potential hazard to the operator of the loading rack or LACT unit. Another important recommendation is to use interlocks wherever possible, to ensure the transfer does not take place if grounding is not present. By halting the movement of product, the charge generation source is eliminated thus preventing additional charging of the tank car. The relevant recommended practice extracts from both codes of practice are provided below.

NFPA 77, section 7.4.1.3.1, "Charge dissipation" states:

> "Where the bonding/grounding system is all metal, resistance in continuous ground paths typically is less than 10 ohms…..Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion".

NFPA 77, sections 10.1.1 and 10.1.2., "Metal Piping Systems" state:

> "All parts of continuous all-metal piping systems should have a resistance to ground that does not exceed 10 ohms".
>
> "Bonding wires might be needed around flexible, swivel, or sliding joints. Test and experience have shown that resistance in these joints is normally below 10 ohms, which is low enough to prevent accumulation of static charges."

API RP 2003, section 4.3.2 "Tank Car Loading" states the following:

> "Many tank cars are equipped with nonconductive bearings and nonconductive wear pads located between the rail car and chassis. As a result, the resistance from the tank car compartment to ground through the rails may not be low enough to prevent the accumulation of an electrostatic charge on the tank car body. Therefore, bonding of the tank car body to the fill system piping is necessary for protection against static accumulation."

NFPA 77, section 12.4.2 "Railroad Tank Cars" reflects the guidance in section 4.3.2 of API RP 2003 but provides the additional recommendation:

> "In general, the precautions for railroad tank cars are similar to those for tank vehicles specified in Section 12.2."

NFPA 77, section 12.2 "Summary of Precautions for Loading Tank Vehicles" states:

> "Bonding and Grounding. Tank trucks should be bonded to the fill system, and all bonding and grounding should be in place prior to starting operations. Ground indicators, often interlocked with the filling system, frequently are used to ensure bonding is in place."

API RP 2003, section 4.2.2 "Bonding and Grounding" states the following:

> "The entire bond circuit, including clamps and connectors, should be included in the continuity test. Bond circuit resistance should typically be 1 ohm or less. Resistances less than 10 ohms may function satisfactorily, but test results showing resistances over 1 ohm may be a "warning sign" to prompt further testing or physical examination to ensure that there are no incipient bonding discontinuities (such as damaged wire, loose connection or paint under a bonding screw). Bond or ground indication instruments are available for installation at truck loading racks to monitor the bond connection. These systems can be operated in conjunction with signal lights or can be electrically interlocked with the control circuits to prevent the loading pumps from being started when a good bond is not present."

In summary the precautions recommended for grounding tank cars should be similar to the recommendations for grounding tank trucks.

Specifying a Static Grounding System for your operations.

One of the main problems with static electricity is that it is not something the operators can see, smell or hear. This characteristic of static electricity can, unfortunately, promote an attitude of *"it can't happen to me"* or *"it doesn't exist"* amongst personnel operating LACT units and loading rack systems. A grounding system that combines a simple visual "GO / NO GO" communication via a traffic light model of indication with interlock control capability is the most effective means of controlling the risk of ignitions caused by static electricity during tank car product transfer operations. Interlocking the transfer system with the grounding system is probably the ultimate layer of protection equipment specifiers and designers can take to ensure the tank car is grounded.

To demonstrate compliance with NFPA 77 and API RP 2003 source grounding systems that:

1. Monitor the grounding circuit to 10 ohms or less.
2. Provide operators with a visual reference that indicate a "GO / NO GO" action via RED and GREEN indicators.
3. Provide dry contacts to interlock the grounding system with the LACT unit / loading rack pumps or PLCs.
4. Display the full range of HAZLOC approvals with the mark of a recognised NRTL.

Point 4 is of particular importance to the HAZLOC professional tasked with protecting workers and the business from fires caused by static electricity. When a grounding system is to be specified it is important to anticipate what gases and vapors could be present at the grounding system's installation. Grounding systems that display Class I, Div.1 approvals for gas groups A, B, C, D are systems that can be mounted in any hazardous location.

Be careful to differentiate where the XP controller can be installed and where the ground monitoring circuit, delivered by the clamp, is approved for use. Specifiers can easily misinterpret HAZLOC Certificates of Compliance (CoCs) and think that because the ground monitoring circuit is certified as being suitable for all gas groups, the same applies to the XP controller. Very often, this is not the case as the XP controller can only be mounted in lower gas group atmospheres, e.g. groups C and D.

Newson Gale recommends the Earth-Rite® PLUS for bonding tank cars to LACT units and loading rack superstructures. Along with demonstrating the full range of Class I, Div. 1 approvals for all gas and liquid vapor groups, it also ensures there is a 10 ohm, or less, connection between the tank car and the product transfer system. This provides equipment specifiers with the ability to demonstrate full compliance with the recommendations of NFPA 77 and API RP 2003. By simply connecting the grounding clamp to the tank car the Earth-Rite® PLUS automatically verifies if the tank car is connected to the LACT unit or loading rack by delivering an Intrinsically Safe monitoring circuit to the system's Factory Mutual approved grounding clamp. The Factory Mutual approved stainless steel heavy duty grounding clamp ensures that a strong initial connection, via a pair of tungsten carbide teeth, is made to the tank car, and is then maintained for the duration of the product transfer operation, resisting movement caused by vibration or accidental dislodging.

Unlike standard grounding systems that rely on the their non-monitored electrical ground connection to dissipate the static charges generated by the transfer, the Earth-Rite® PLUS ensures that its dedicated static grounding connection to the LACT unit or loading rack is always monitored, via the static ground connections G1 and G2 (ref. Fig. 2). This ensures there is a monitored connection directly between the tank car and the LACT unit or loading rack. This is an important feature as we are depending on the LACT unit / loading rack's verified ground connection to dissipate static charges from the tank car to the general mass of earth.

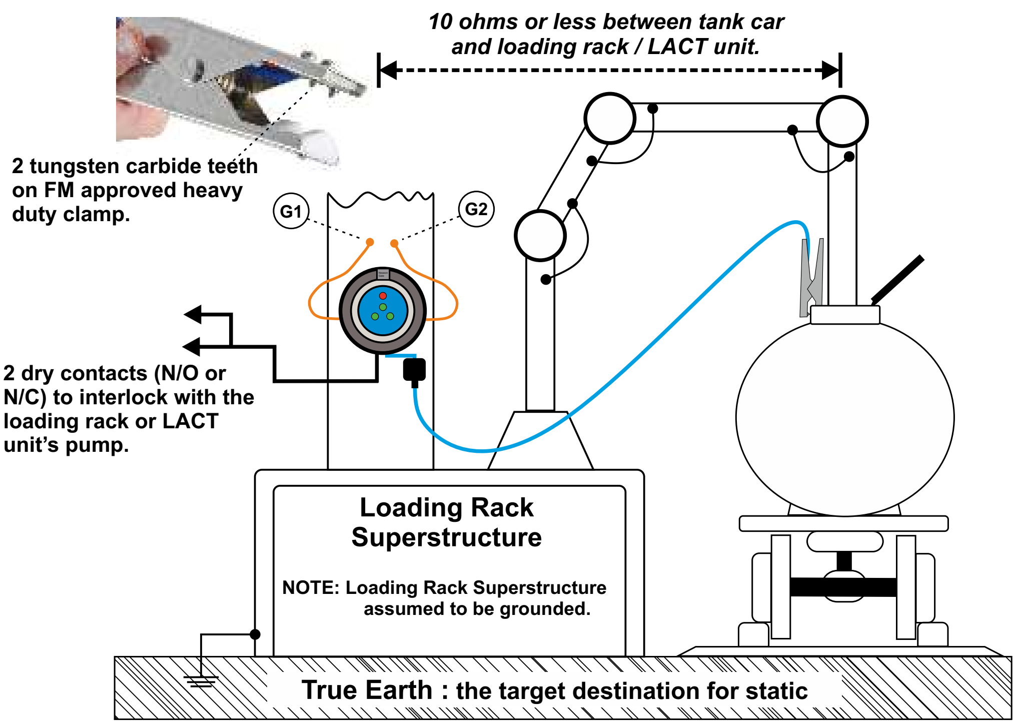

Fig. 2 Typical Earth-Rite® PLUS tank car loading rack installation. The tungsten carbide teeth on the grounding clamp are the contact points for the signal that verifies if the tank car is bonded to the loading rack (orLACT unit) to 10 ohms or less.

When the Earth-Rite® PLUS verifies the tank car is bonded to the LACT unit or loading rack superstructure, a cluster of attention grabbing green LEDs pulse continuously to inform the operator that the system is actively monitoring the integrity of the ground loop.

A pair of dry contacts can be interlocked with the power delivered to the pump or PLCs to halt the product transfer operation if the Earth-Rite® PLUS detects a resistance of more than 10 ohms in the ground loop between the tank car and the product transfer system.

The Earth-Rite® PLUS can be powered off a 110 or 230 volt AC source or 24 volt / 12 volt DC source and is cCSAus approved Class I, Div.1 for gas groups A, B, C, D and all combustible dust and fibre groups.

Fig. 3 Earth-Rite® PLUS ground status indicators pulse continuously when grounding is in place.

Codes of Practice:

NFPA 70, the National Electrical Code.

NFPA 77, Recommended Practice on Static Electricity.

API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.

United States
Newson Gale Inc
460 Faraday Avenue
Bldg C
Jackson, NJ 08527
USA
+1 732 961 7610
groundit@newson-gale.com

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

Deutschland
Newson Gale GmbH
Ruhrallee 185
45136 Essen
Deutschland
+49 (0)201 89 45 245
erdung@newson-gale.de

South East Asia
Newson Gale S.E.A. Pte Ltd
136 Joo Seng Road, #03-01
Singapore
368360
+65 6704 9461
ngsea@newson-gale.com

www.newson-gale.com