SMARTTECH WHITEPAPER:

Static Electricity Hazards and the Handling of Petroleum Products

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In this whitepaper, you will learn about the latest industry terminology & standards, the causes of static charges and the recognized preventative measures.
Introduction
Static electricity in one form or another is a phenomenon of nature and often results in electrostatic discharges that can cause fires and explosions. The term static describes electricity that is trapped on a body that is said to be charged. While most of the expertise to reduce these hazards is based on research, a great deal is based on industry experience as related to safety precautions used for handling petroleum liquids. This paper addresses a basic understanding of static electricity and commonly used precautions in the operation of tank trucks, rail cars and storage tanks.

General
The generation of electric charges, their accumulation on material, and the uncontrolled process of dissipating these accumulated charges cause static electricity hazards. Sparks from static electricity are a significant source of ignition. For an electrostatic charge to be a source of ignition, four conditions must be present:

1. A means of generating an electrostatic charge.
2. A means of accumulating an electrostatic charge capable of producing an incendiary spark.
3. A spark gap.
4. An ignitable vapor-air mixture in the spark gap.

Ignition hazards from static sparks can be eliminated by controlling the generation, accumulation or dissipation of static charges, or by eliminating a flammable mixture where static electricity may be discharged. The risk of ignition can also be reduced if spark promoters are avoided in areas of potentially high electric field.

Charge Generation
A static electrical charge may be either positive (+) or negative (-) and is manifested when some force has separated the negative electrons from the positive protons of an atom. It is only necessary to transfer about one electron for each 500,000 atoms to produce a condition that can lead to a static electric discharge. Surface contaminants at very low concentrations can play a significant role in charge separation at the interface of materials. Typical forces in petroleum operations include flowing, mixing, pouring, pumping, filtering or agitating materials where there is the forceful separation of two like or unlike materials. Static generation is common with petroleum operations involving the movement of liquid hydrocarbons. The static electric charging rate is increased greatly by increasing the speed of separation (i.e. flow rate and turbulence), low conductivity materials (e.g., hydrocarbon liquids) and surface area of the interface (e.g., pipe or hose length, and micropore filters).

The very nature of petroleum operations involves the transport of various types of petroleum products. This movement of product in itself generates a static charge within the product. It involves the separation or pulling apart of surfaces that are in intimate contact with each other. This is also referred to as frictional charging. When two bodies of dissimilar materials are in close physical contact with one another there is often a transfer of free electrons. If one or both of the materials are poor conductors, uneven charges cannot quickly recombine. A sudden separation will leave the excess electrons on one of the bodies and a deficiency of electrons on the other. If the two bodies are then insulated from their surroundings, they will tend to accumulate equal and opposite charges. The body having the excess electrons will be negatively charged and the one with an electron deficiency will be positively charged. The electrical potential difference between the charged bodies can easily reach several thousand volts.

Some common examples of separation or frictional generation of static electricity in petroleum industry are:
- Separation of liquid or gas from a hose, nozzle, faucet, or pouring spout.
- The movement of liquids, gases or solid particles relative to other materials, such as occurs commonly in operations involving flow through pipes, mixing, pouring, pumping, filtering, agitating, or other types of fluids handling.
- Turbulent contact of dissimilar fluids, such as water or gas flowing through a liquid hydrocarbon.
- Air, gas, or vapors containing solid particles (e.g., dust, rust, etc.) or droplets being discharged from a pipe or jet.

Charge Accumulation & Relaxation
Electrostatic charges tend to leak away from a charged body because the excessive charges are not stable, and they are under the attraction of an equal but opposite charge. Thus, most static sparks are produced only while the generating mechanism is active, or there is no proper pathway for dissipation. The mechanism of dissipation starts as soon as a charge is generated and can continue after generation has stopped. Electrostatic charges accumulate when they are generated at a higher rate than they dissipate. Also, some refined petroleum products have insulating qualities and the
charges generated during movement will remain for a short period of time after the product has stopped moving. This accumulation, rather than dissipation, is influenced by how well the bodies are insulated with respect to each other. Since air or air/vapor mixtures are often the insulating body between the opposite charges, both temperature and humidity are factors in this insulation. Thus, very low or high temperatures, with resulting low humidity, will increase the accumulation of the electrostatic charge both while it is being generated and during the normal relaxation period.

The ability of a charge to dissipate from a liquid is a function of the following:
   a. The conductivity of the product being handled.
   b. The conductivity of the container.
   c. The ability of the container to bleed a charge to ground.

In a grounded conductive container, the ability of a liquid to dissipate a charge is governed by the liquid’s conductivity. The higher the conductivity, the faster the charge dissipates. Generally, liquids with conductivity greater than 50 pS/m (50 C.U.) do not accumulate static charges provided the material is handled in a grounded conductive container. Above 50 pS/m, charges will dissipate as fast as they are generated.

For liquids with conductivity greater than 1 pS/m the charge relaxation follows an exponential decay proportional to the relaxation time constant. Liquids with lower conductivity follow a hyperbolic decay. This may create dissipation times shorter than predicted by exponential decay.

Charges can also accumulate regardless of the conductivity of the fluid if the container being filled is made of low-conductivity (nonconductive) material (e.g., a plastic bucket), or if the container is conductive but is inadequately grounded. A metallic (conductive) fuel container resting on a plastic bed liner of a pick-up truck) is an example.

**Flammability of Vapor-Air Mixtures**

The flammability of a hydrocarbon vapor-air mixture depends on its vapor pressure, flash point and temperature. These properties are used to classify petroleum products whose electrical resistivities are high enough to enable them to accumulate significant electrostatic charges under certain handling conditions.

Following are the three petroleum product Vapor Pressure Classifications, including common examples:

**Low:** Those with a closed cup flash point above 100°F (38°C).

These products do not develop flammable vapors under normal handling conditions. However, conditions for ignition may exist, if the products are handled at temperatures above their flash points, are contaminated with higher vapor-pressure materials, or are transferred into containers where vapors are at concentrations at or above those necessary to produce a flammable mixture.

*Examples: #2 Fuel Oil; Kerosene, Diesel, Jet Fuel A (commercial), Motor Oil and Asphalt.*

**Intermediate:** Those with a closed-cup flash point below 100°F (38°C).

These products may create a flammable mixture in the vapor space at ambient temperatures.

*Examples: Xylene, Benzene, Toluene, Jet B (commercial) and JP-4 (military)*

**High:** Those with a Reid Vapor pressure above 4.5 psi absolute (31 kilopascals).

These products, under normal handling temperatures in a closed vapor space, will rapidly produce a mixture too rich to be flammable. However, in some areas, a vapor space may pass through the flammable range before becoming too rich.

*Examples: Motor and Aviation Gasoline’s, and high vapor pressure Naphtha’s*
Control of Electrostatic Charge Generation in Tank truck filling operations:

GENERAL
Bonding and grounding provide no protection from brush discharges generated from the surface of a low conductivity liquid, particularly if there is a spark promoter present. The conductivity of many refined petroleum products can be well below, 50 pS/m, and accumulation of electrostatic charge is likely. Charge accumulation is even more likely for ultra-low conductivity (less than 5 pS/m) hydrocarbons.

The following four primary electrostatic charge generation mechanisms relate to tank truck filling operations:
1. Product flow through filters and screens.
2. Product flow through piping.
3. Splash loading.
4. Multiphase flow.

FLOW-THROUGH FILTERS AND SCREENS
Flow-through filters and screens can produce a high electrostatic charge. The degree of hazard depends on the size of the openings within the filter or screen. In general, when product conductivity is less than 50 pS/m an adequate residence time should be provided downstream of the filter or screen to permit sufficient charge relaxation. The need for relaxation time increases as the conductivity decreases.

FLOW-THROUGH PIPING
The flow of liquid through piping generates static charge. The magnitude of the charge is a complex function of a fluid's composition, piping material and the rate of product flow. A simple empirical formula relating the maximum recommended linear velocity to minimize charge generation as a function of loading arm diameter has been developed for tank trucks:

\[ v_d < 0.5 \text{ m}/\text{sec} (64 \text{ in-} \text{ft}/\text{sec}) \]

where: \( v \) = velocity in meters per second [feet per second],
\( d \) = inside diameter of the downspout in meters [inches].

SPLASH LOADING
The third charge generation mechanism important in tank truck loading is splash loading. In this instance, the electrostatic charge is generated in the liquid by turbulence and by the generation of a charged mist. Splash filling should be avoided to minimize turbulence and mist generation.

MULTI-PHASE FLOW
Multi-phase flow generates electrostatic charge as a result of both flow-through piping (where the presence of multiple phases enhances several-fold the charge generation potential of pipe flow) and also when the different phases settle in the tank compartment. Therefore, whenever the fluid is a static accumulator and contains a dispersed phase, such as entrained water droplets, the inlet flow velocity should be restricted to 1 meter per second (3 feet per second) throughout the filling operation. In addition, a suitable waiting period should be employed to allow for product charge relaxation before any object such as temperature gauge or sample container is lowered into the tank compartment.

Relaxation time constant: The time for a charge to dissipate to e-1 (approximately 37%) of the original value. In general, for hydrocarbon liquids, relaxation time constant is approximated by the relationship:

\[ \tau = \frac{18}{\sigma} \]

where: \( \tau \) = relaxation time in seconds,
\( \sigma \) = electrical conductivity of the liquid in pS/m.

As an example, a liquid with a conductivity of 6 pS/m would have a relaxation time constant of 3 seconds. As a rule of thumb a charge can be considered “practically dissipated” after three time constants and “completely dissipated” after five time constants.
**Residence Time:** The length of time that a product remains in a grounded conductive delivery system from the point at which a charge is generated before it reaches the point of delivery, e.g., from the outlet of an inline filter or a micro filter to the inlet of a tank truck or a tank. Residence Time is determined by system configuration and operation.

**Waiting Period:** The elapsed time after the completion of product dispensing into storage or transportation containers (i.e., storage tanks, tank trucks, and tank cars) before sampling or gauging activities.

### Electrostatic Charge Generation During Tank Truck Loading

### Bonding and Grounding Definitions

**FROM NFPA 70:**

**Grounded:** Connected to earth or to some conducting body that serves in place of the earth [NFPA 70 Article 100].

**Bonding (Bonded):** The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed [NFPA 70 Article 100].
FROM NFPA 77:

**Grounding:** The process of bonding one or more conductive objects to the ground, so that all objects are at zero (0) electrical potential; also referred to as “earthing” [NFPA 77 – 3.1.10]. Keep in mind that the term earthing is not currently a defined term.

**Bonding:** The process of connecting two or more conductive objects together by means of a conductor so that they are at the same electrical potential, but not necessarily at the same potential as the earth [NFPA 77 – 3.1.2].

Sparking between two conducting bodies can be prevented by means of an electrical bond attached to both bodies. Bonding prevents the accumulation of a difference in potential across the gap, thus no charge can accumulate and no spark can occur. Using the earth as part of the bonding system is known as grounding and is used when a potentially electrically charged body is insulated from the ground such as a tank truck or rail car. Thus, the ground connection bypasses this insulation.

Since most terminal loading is still top loading in developing countries it should be noted that Top-loaded tank trucks, in which flammable vapors are likely to be present, should be electrically bonded to the downspout, piping, or steel loading rack. If bonding is to the rack, the piping, rack, and downspout must be electrically interconnected. Ideally top loading should be done with downspouts in contact with the tank bottom to avoid turbulence and the initial velocity limited until the flow is submerged for both top and bottom loading.

The bond connection should be made before the dome cover is opened, and it should remain connected until the dome cover has been securely closed after loading is complete. The bond prevents a build-up of a high electrostatic potential between the fill stem and the tank truck, and it eliminates the likelihood of sparks in the vicinity of the dome opening where a flammable mixture may exist.

Bonding and grounding are essential where high and intermediate vapor pressure products are loaded through open top domes. Bonding should also be employed when loading a low vapor pressure product that is contaminated with a high or intermediate vapor pressure product and when loading low vapor pressure products that are heated above their flash points. Bonding is particularly important when low vapor pressure stocks are loaded into cargo tanks that previously contained high vapor pressure products (switch loading).

In addition to bonding and grounding, when vehicles are loaded or unloaded through closed connections, irrespective of whether the hose or pipe used is conductive or nonconductive the potential for sparking is greatly reduced. A closed connection is one in which contact is made before flow starts and is broken after flow is completed (e.g., bottom loading of tank trucks).

It should be noted that since the dissipation of the static charge is a function of the liquid’s conductivity the dissipation time will vary. The “Relaxation Time” and general “Wait Period” times are specified in the following for different products, size of tanks (amount of product), pressures and temperatures.


**API 2003** API Recommended Practice 2003, “Protection Against Ignitions Arising out of Static, Lightning and Stray Currents”.

**API 2015** API Publication 2015, “Safe Entry and Cleaning of Petroleum Tanks”.

**NFPA 77** “Static Electricity”.

It should also be noted that many of the major oil companies also have their own static and safety codes that specify “Relaxation time” and “Waiting period”.
Grounding and the Resistance in the Path to Ground
To prevent accumulation of static electricity in conductive equipment, the total resistance of the path to earth (grounding path) should be minimal to dissipate charges that are otherwise likely to be present. The basic goal here is to create a path of dissipation that will not be subject to the negative effects of pressure piling of electrons. A resistance of 1 mega ohm or less is generally considered adequate. Where the bonding/grounding system is all metal, resistance in continuous ground paths will typically be less than 10 ohms. Such systems generally include multiple component systems. Greater resistance usually indicates the metal path is not continuous, usually because of loose connections or the effects of corrosion or painted surfaces. A number of standards specify the 10 ohm maximum resistance for metal circuits, they include: NFPA 77, CLC/TR: 50404, API 2003 & 2219 and BS 5958.

The NEC provides rules for sizing grounding and bonding conductors. Sizing grounding and bonding conductors for static protection differs because their primary purpose is different. Where electrical conductors of the wire-type are used for static protection, the minimum size of the bonding or grounding wire is dictated by mechanical strength, not by its current-carrying capacity. Stranded or braided wires should be used for bonding wires that will be connected and disconnected frequently (NFPA 77).

References:
Following is a list of relevant published references for those wishing to explore the subject of static electricity further:

1. Precautions Against Electrostatic Ignition During Loading of Tank Truck Motor Vehicles, API Publication 1003
2. Safe Entry and Cleaning of Petroleum Tanks, API Publication 2015
3. Cleaning of Mobile Tanks in Flammable or Combustible Liquid Service, API Publication 2013
4. Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter, ASTM D 4308
5. Static Electricity, National Fire Protection Association, (NFPA) NFPA RP 77
6. International Safety Guide for Oil Tankers and Terminals, OCIMF