

Static Electricity Hazards and Prevention



This document is intended for use as an awareness tool only and is not intended to cover all potential risks, hazards, and conditions. This document is not a substitute for compliance with applicable laws, regulations, or Chevron standards. Each contractor is ultimately responsible for the safety of its employees and its compliance with applicable laws, regulations, and Chevron standards. Changing conditions, such as weather, location, terrain, equipment, processes, etc., may not be addressed here, but must be addressed by each contractor with its employees before work begins.

Agenda



- What is static electricity?
- Why is static electricity a hazard?
- Conditions for static ignition
- Incident studies
- Preventing ignition hazards
- Precautions for specific jobs
- Bonding, grounding and testing
- Resources



Introduction: What is Static Electricity?

Static electricity is the electrical charge produced on two dissimilar materials through physical contact and separation caused by the imbalance of positive and negative charges between the two.

As an electrostatic charge accumulates, the electric fields and voltages increase. If the charge is unable to bleed off to ground when the electric field exceeds the insulating properties of the atmosphere, a static discharge can occur.

Lightning is a dramatic example of naturally occurring static discharge, but the same underlying principles are responsible for the shock you get when you touch a doorknob after walking across a carpeted room.





Introduction: **Why is Static Electricity a Hazard?**

In the petroleum industry, flammable vapors and dust may be present during normal operations and a discharge of static electricity has the potential of causing fires and explosions.

Additionally, the conductivity of refined petroleum liquids is very low, which allows static charges to accumulate. Charges of 20,000 to 40,000 volts can build up when pumping petroleum products.

Under certain conditions, high voltages can be generated from a relatively low flow, such as 8 gallons per minute from a gasoline dispenser. Even pouring liquid from one container into another creates static.

At the end of this training, you should have a better understanding of how to identify and mitigate the risks associated with static electricity.

Conditions for Static Ignition



This section describes the following conditions that must be present for a static ignition to occur:

1. A means of **generating** an electrostatic charge.
2. A means of **accumulating** an static charge capable of producing an incendiary spark.
3. A **discharge**.
4. An **flammable mixture**.

Conditions for Static Ignition: Static Generation

An electrostatic charge is normally **generated** by contact and separation between surfaces of dissimilar materials. Examples include:

- Fluid flowing through a pipe or hose.
- Fluid flowing through a filter.
- Splash filling.
- Bubbling or agitation.
- Steaming.
- Two-phase flow (liquid and gas or liquid and solid).
- Sand or grit blasting.
- Conveyor, roller or belt motion.

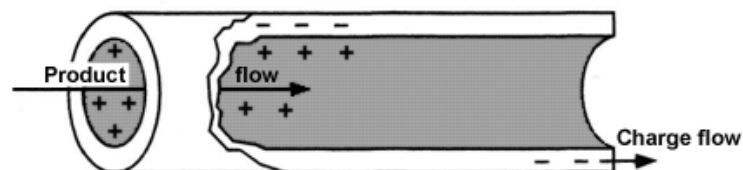


Figure A.2—Charge Separation in a Pipe

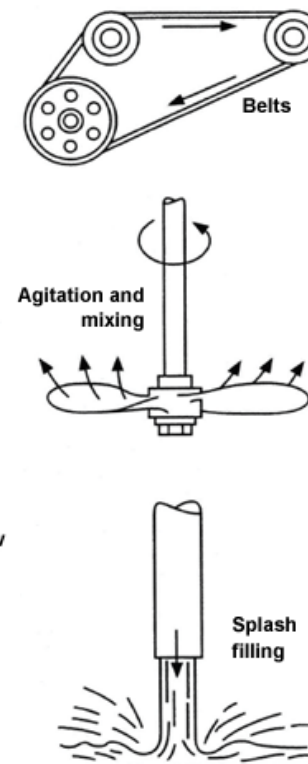


Figure A.1—Static Procedures

Images reprinted with permission from API RP 2003 (Seventh Edition, January 2008):
Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents, © 2008.



Conditions for Static Ignition: Static Accumulation

An electrostatic charge may **accumulate** when:

- The charge does not dissipate due to **low conductivity** of product.
- Inadequate time is given for charge to dissipate.
- The container is nonconductive or inadequately grounded.
- An ungrounded, conductive object accumulates the charge.

Highly refined petroleum products are poor conductors and, therefore, **good accumulators**.



Conditions for Static Ignition: **Static Accumulation** (continued)

Static In The Oil Industry

Product	Static Accumulation
Gasoline	High to low
Kerosene and diesel fuels	High
Jet fuels	High
Base oils	High to low
Heavy "black" fuel oils	Medium to low
Crude oils	Low

NOTE: Some products have a range, as cargos and seasonal and regional formulations can vary. Consult individual product specification data sheets for conductivity details. When in doubt, assume a material is a static accumulator.

Conditions for Static Ignition: Static Accumulation (continued)

In certain situations, very large static charges can be generated and accumulated in very short times. Static charges of several thousand volts are not uncommon.

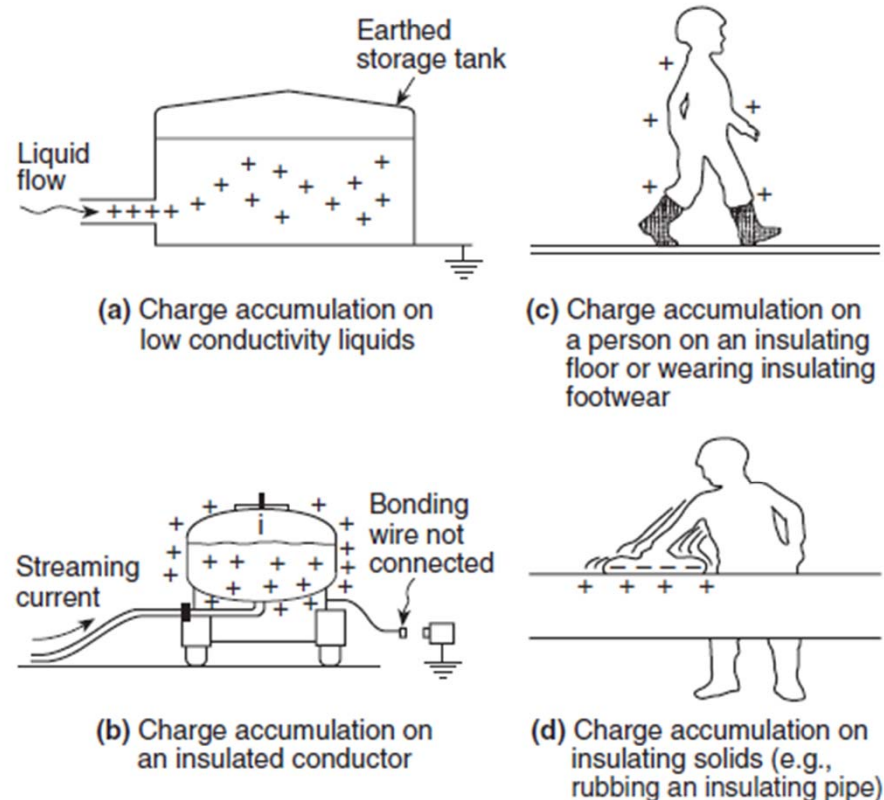


FIGURE 5.2.2 Examples of Charge Accumulation. (Source: H. L. Walmsley, *Avoidance of Electrostatic Hazards in the Petroleum Industry*, p. 37.)

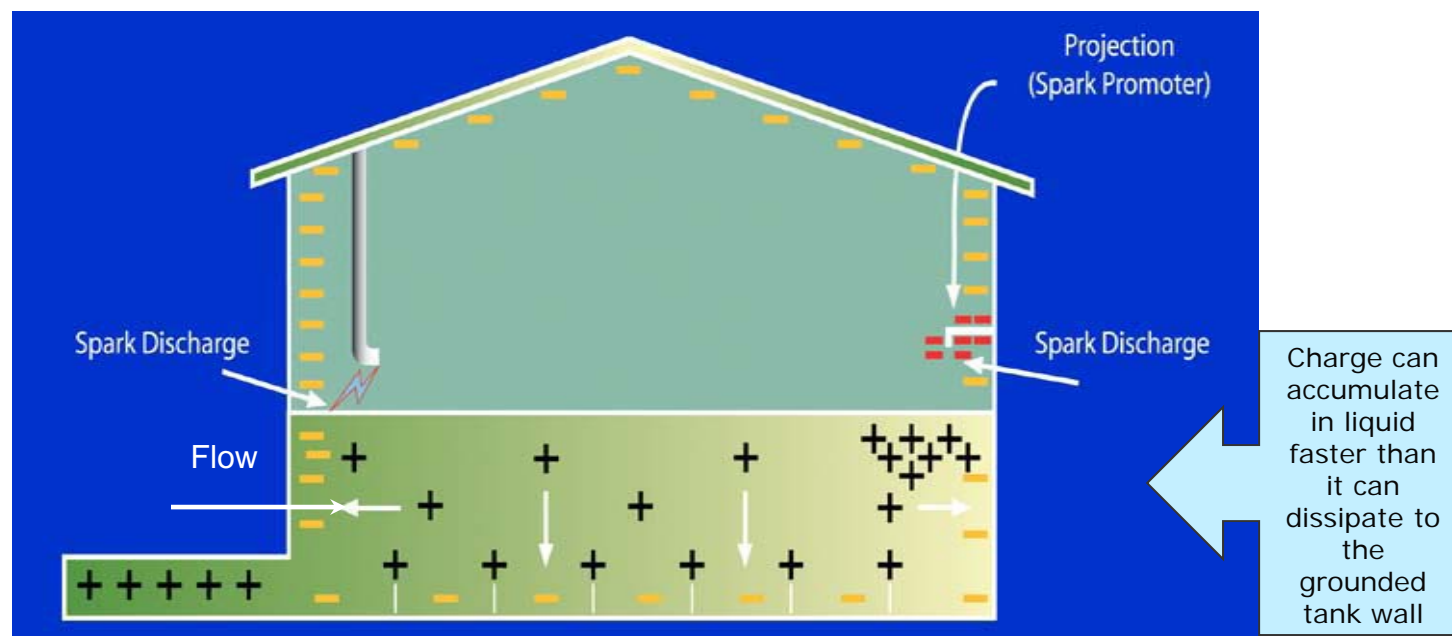
Reprinted with permission from NFPA 77-2007, *Recommended Practice on Static Electricity*, © 2006, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.



Conditions for Static Ignition: Static Discharge

A hazardous electrostatic **discharge** occurs when an accumulated static charge is released in the form of a spark with sufficient energy to cause ignition.

Spark discharge usually occurs between a grounded object and a surface that has accumulated a charge.





Conditions for Static Ignition: Flammable Mixtures

Flammable mixtures can occur in numerous situations. For example:

- Handling material at temperatures close to or above their flash point.
- Switch loading: loading low-vapor-pressure material (such as diesel) into a container having flammable vapors from a previous product (such as gasoline).
- Tank cleaning operations.
- Application of a protective coating inside a tank.
- Relief drums or other light stock pumped into heavy oil.



Conditions for Static Ignition: When Conditions Are Met – A Fiery Example

While watching this video clip captured on a service station security camera of an actual static ignition of gasoline vapor at a pump, see if you can identify the means by which the static charge was **generated**, **accumulated** and **discharged**.



Video courtesy of Petroleum Equipment Institute www.pei.org/static

Incident Studies

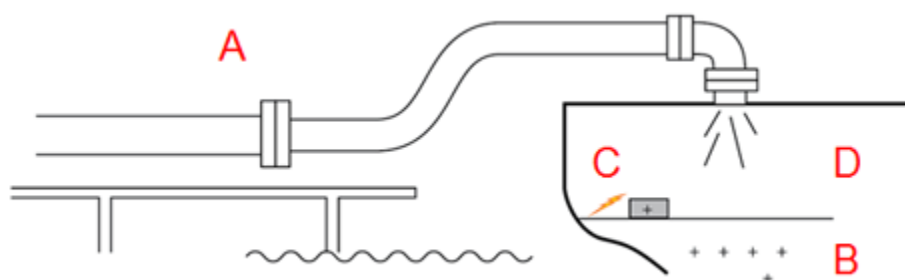


The purpose of this section is to reinforce the concepts you just learned regarding the conditions necessary for static ignition.

The following case studies should be used as appropriate for your operations:

- Barge and ship loading
- Truck and rail car loading
- Container and bucket filling
- Tank and vessel cleaning

Incident Studies: Incident 1 – Barge and Ship Loading

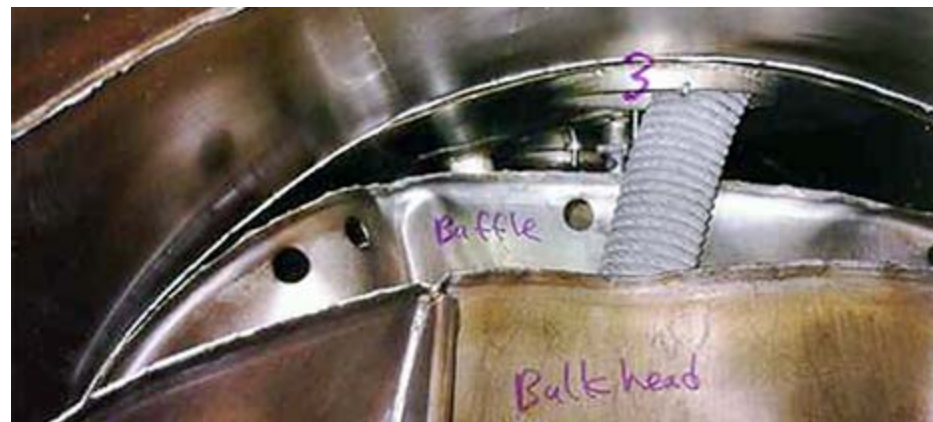


The result of a barge incident in 1998.

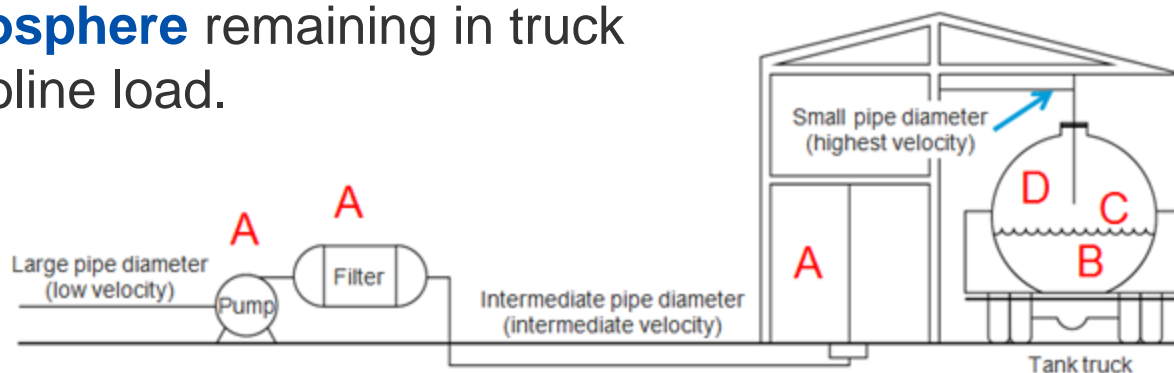
- A. Static charge **generated** in piping and hose at high flow rates.
- B. Charge **accumulated** in low-conductivity product being loaded.
- C. A **discharge** occurred between a floating object (e.g., sample bottle or piece of polypropylene rope) and wall of vessel.
- D. A **flammable atmosphere** in vessel.

Incident Studies: Incident 2 – Truck and Rail Car Loading

- A. Static charge **generated** in pump filter and piping.
- B. Electrostatic charge **accumulated** in low-conductivity lube oil being loaded.
- C. A **spark gap** between liquid surface and unextended downspout.
- D. A **flammable atmosphere** remaining in truck after previous gasoline load.

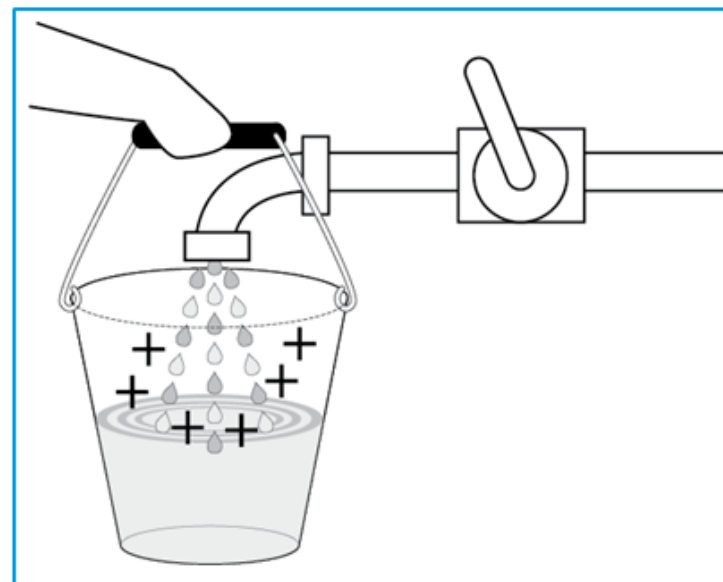
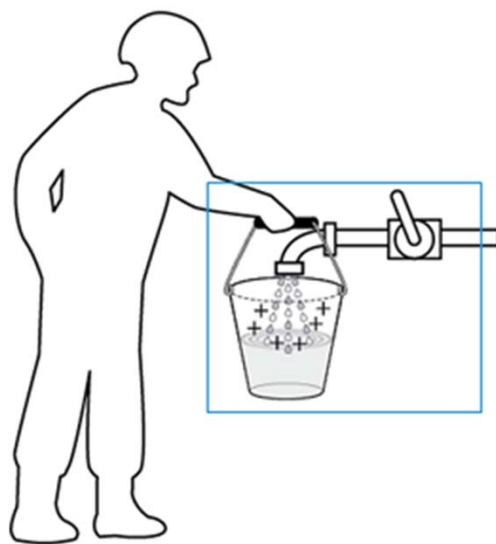


Damage inside a tank trailer resulting from an incident in 1998.



Incident Studies: Incident 3 – Container and Bucket Filling

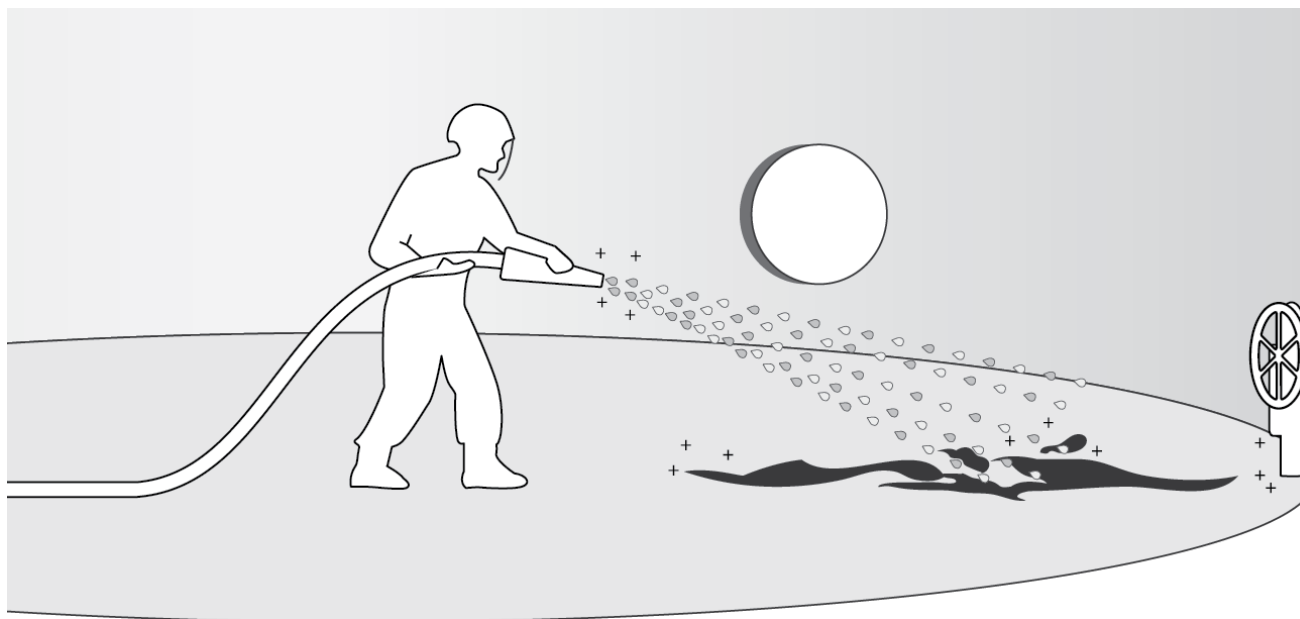
- A. Static charge **generated** by splashing into bucket.
- B. If using plastic bucket, the charge **accumulates** because the plastic bucket insulates the liquid from the ground. If using a metal bucket with a plastic handle, the charge **accumulates** because the handle insulates the bucket from the fill pipe.
- C. A **spark gap** between liquid surface and piping.
- D. A **flammable mixture** near surface of flammable liquid.





Incident Studies: Incident 4 – Tank and Vessel Cleaning

- A. Charge **generated** by spraying liquid.
- B. Charge **accumulates** on ungrounded nozzle.
- C. A **spark gap** between nozzle and manway or socket.
- D. A **flammable mixture** due to agitation of vessel sludge.





Preventing Ignition Hazards

A variety of preventive measures can be considered to reduce the risk of static discharge. This section provides examples of the following measures:

1. Limiting charge generation
2. Limiting charge accumulation
3. Eliminating spark gaps
4. Avoiding flammable mixtures

NOTE: Not all of these measures are applicable in every situation. It is important to follow your specific refinery procedures, standards and instructions.



Preventing Ignition Hazards: Limiting Static Generation

Static charges can be dissipated by:

- Controlling flow rates. Low or controlled filling rates will, in many cases, limit the amount of static being generated.
- Avoiding splash filling or misting operations.
- Avoiding pumping or flowing hydrocarbons with dispersed water or solids.
- Minimizing the need for jet and propeller blending.
- Avoiding free-falling or dropping of liquid through the surface of a stored liquid.
- Minimizing droplets of water or other particulate matter from settling through the body of a liquid.
- Avoiding the use of free-flowing steam to “inert” a potentially flammable vapor space, as wet steam has been described as a “horrendous separator of electrostatic charges”; carbon dioxide has similar properties when “snow” is formed at the nozzle.

NOTE: High voltages can still be generated at low speed or flow.



Preventing Ignition Hazards: Limiting Charge Accumulation

- Use bonding and grounding to prevent buildup of potential differences on isolated conductive parts of a system.
- Allow sufficient residence time downstream of filters and pumps.
- Allow sufficient relaxation time after filling containers, trucks, railcars and tanks.
- Add static dissipater additives to refined oils. This:
 - Increases the conductivity and permits the static charge to dissipate.
 - Is used in jet fuel and some diesel products.

NOTE: The charge that accumulates on the surface of liquids cannot be removed by bonding or grounding the container holding the liquid.



Preventing Ignition Hazards: Relaxation and Residence Time

Once a static charge is generated, it dissipates over time. Various materials have different insulating and conducting properties that determine the rate of dissipation of static.

Relaxation time is the time it takes for a charge to dissipate.

Example: A minimum of 30 minutes after flow has ceased before dipping or sampling bulk tanks and 1 minute for tank trucks.

Residence time is the amount 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.

Example: A residence time of at least 30 seconds should be provided downstream of filters for products with conductivities less than 50pS/m.

Example: A default residence time of 100 seconds should be used for products with conductivities less than 2 pS/m (or where the actual or possible minimum conductivity at field temperature conditions is unknown).



Preventing Ignition Hazards: Eliminating Spark Gaps

Static sparks generally occur between the surface of a liquid that accumulates a charge and a conductive surface or object that is grounded. Here are some basic guidelines to follow:

- Wait before gauging or testing a newly filled tank.
- Eliminate spark promoters projecting into a tank.
- Use bonding to provide a conductive path across possible spark gaps, for example:
 - At the top opening of a tank truck.
 - Between a hose nozzle and the wall of a tank being cleaned.
 - Between a metal container and a fill pipe or sample connection.



Preventing Ignition Hazards: Avoiding Flammable Mixtures

There are three methods to avoid flammable mixtures when handling materials below their flash points.

1. **Inerting** – adding inert gas to reduce the oxygen concentration below the limiting oxygen concentration (LOC).
 - At least 2 volume percent below LOC is target
2. **Dilution** – removing vapor to dilute the volume percent vapor in air below the lower flammable limit (LFL).
 - 25 percent of LFL is target
3. **Enriching** – adding combustible gas to increase the volume percent above the upper flammable limit (UFL).
 - 200 percent of UFL is target

NOTE: We typically only use the first two methods.



Precautions for Specific Jobs

This section examines specific precautions that should be taken when performing job functions including:

- Loading tank trucks
- Loading ships and barges
- Using vacuum trucks
- Working with tanks
- Tank cleaning
- Filling drums and portable containers



Precautions for Specific Jobs: Loading Tank Trucks

- Avoid splash filling. Initial inlet velocities less than 3ft/sec (1m/sec) until inlet nozzle is submerged.
- Limit maximum fill velocity to minimize charge generation.
- Residence time greater than 30 seconds downstream from filters.
- Effective bonding and grounding.
- No spark promoters inside compartments.
- Allow at least 1 minute before gauging or sampling.





Precautions for Specific Jobs: Loading Ships and Barges

Follow the guidelines in the **International Safety Guide for Oil Tankers and Terminals** (ISGOTT) :

- Avoid flammable vapors spaces (inerting).
- Avoid splash filling. Initial inlet velocities (into all compartments) less than 3ft/sec (1m/sec) until inlet nozzle is submerged.
- No spark promoters or ungrounded objects inside tank.
- 30-minute relaxation time before sampling and gauging if there is no gauge well and the tank is not inerted.
- Use proper gauging techniques.





Precautions for Specific Jobs: Using Vacuum Trucks

- Use conductive hose and nozzle.
- Do not use ungrounded metal nozzles or connectors.
- Test all hoses, including spiral-wound hoses, for continuity prior to use.
- Bond nozzle to container.
- Avoid vacuuming out of plastic containers (e.g., plastic half barrels).
- Ground/earth truck.



For detailed guidance, refer to American Petroleum Institute Publication 2219: “Safe Operation of Vacuum Trucks in Petroleum Service.”



Precautions for Specific Jobs: Working with Tanks

- Avoid flammable vapor spaces if possible.
- Avoid splash filling – inlet velocities less than 3 ft/sec until inlet nozzle is submerged.
- Adequate bonding and grounding.
- No spark promoters or ungrounded objects inside tank.
- Use gauge wells for gauging/sampling.
- 30-minute relaxation time before sampling/gauging if there is no gauge well.
- Use proper gauging techniques.





Precautions for Specific Jobs: Tank Cleaning

- Do continuous monitoring for flammable atmosphere if tank entry is required.
- Provide a gas-free vapor space.
- Bond spray nozzles to tank.
- Only use conductive hoses/nozzles; check continuity of system daily.
- Avoid misting-type operations.
- Avoid ungrounded conductors in the tank.





Precautions for Specific Jobs: Filling Drums and Portable Containers

Metal

- Set container on ground or grounded structure.
- Keep nozzle in contact with container.
- Preferable to bond nozzle to drum.



Plastic

- Avoid use of plastic containers in flammable service if possible.
- Insert fill pipe to bottom of container before filling.
- Fill at low rates (less than 3 ft/sec or 1m/sec).
- Avoid ungrounded metal objects on the container.



Precautions for Specific Jobs: Clothing and the Human Body

It is possible for the human body to accumulate sufficient charge for an incendiary spark.

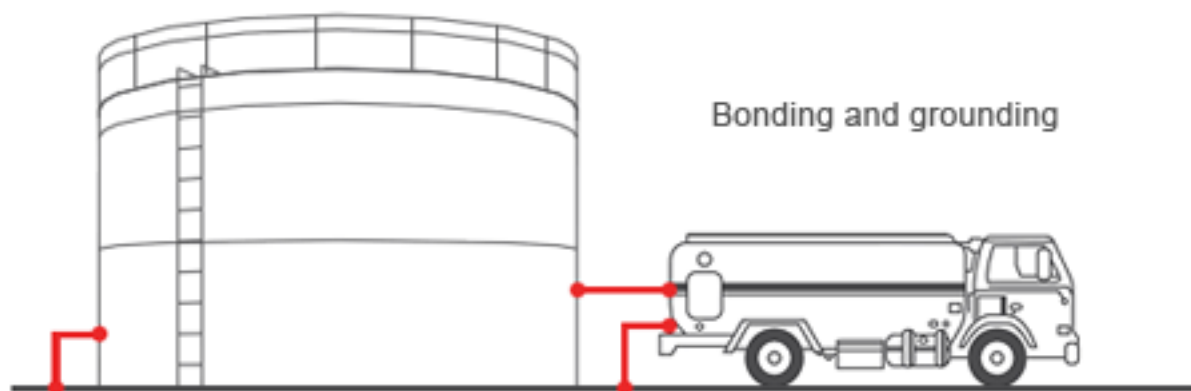
“Under favorable conditions, many fabrics can generate static electricity. Static discharges directly from clothing are highly unlikely to ignite ordinary hydrocarbon gases in the air. However, clothing can be a significant contributor to body charging as a result of its removal or movement relative to other clothing (e.g., wearing very loose coveralls).”



“This possibility should be recognized and prudence exercised on any occasion when flammable vapors/gases are present. As a minimum precaution, clothing must not be removed in a potentially flammable atmosphere, loose clothing should be avoided, and hydrocarbon-saturated clothing should not be removed until personnel involved are adequately grounded.”

Source: American Petroleum Institute, 2003.

Bonding and Grounding

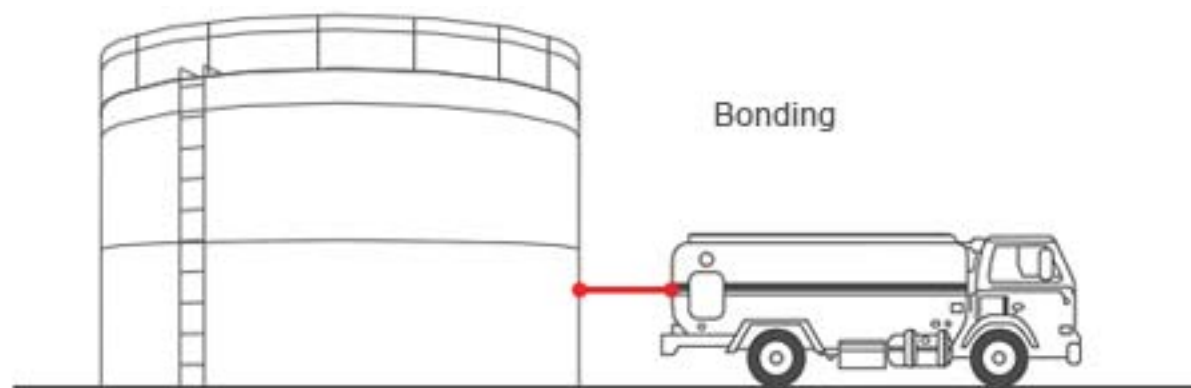


Bonding and grounding is a very effective technique for minimizing the likelihood of an ignition from static electricity.

There is a difference between bonding and grounding, and best practice is to **bond AND ground**.



Bonding and Grounding: Bonding

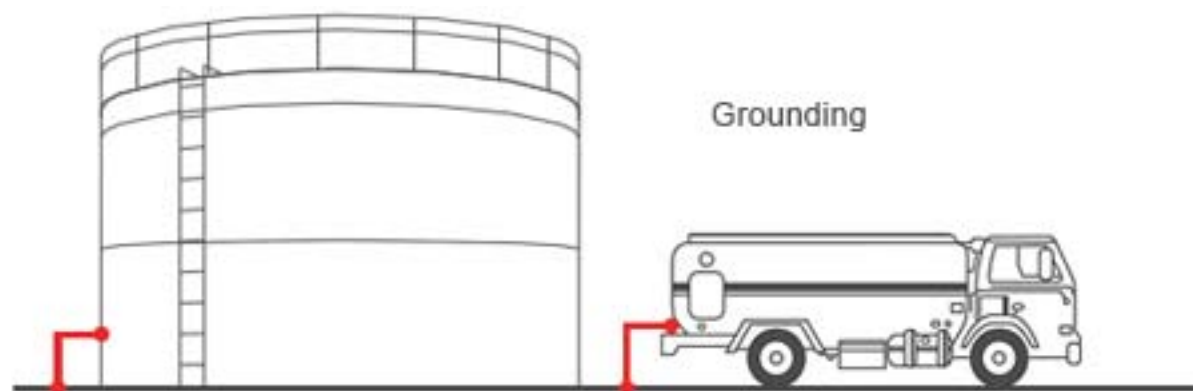


Bonding means physically connecting various pieces of conductive equipment together with a suitably strong conductor (wire) to eliminate a difference in static charge potential between them.

Bonding will not eliminate a difference in potential between objects and ground/earth, and there can be scenarios where there could be a spark between the objects and ground unless one of the objects is also connected to the earth with a ground wire.



Bonding and Grounding: Grounding



Grounding refers to a true “ground/earth” connection applied to one or more of the bonded objects (also known as earthing).

Grounding equalizes the potential difference between the objects and the earth; that is, any object connected to it will be at zero potential or voltage.



Bonding and Grounding: Temporary Field Applications

Clamps

Bonding and grounding clamps must be:

- Approved for the intended purpose.
- Have strong spring compression.

Wires/Cables

Bonding and grounding cables must be:

- Durable and of low resistance.
- Sized for physical or mechanical strength.
 - 1/4" Bronze or 1/8" stainless steel, aviation type flexible cable is recommended (copper is soft and prone to damage).
- Uninsulated so that they can be checked visually, or covered with a special coating such as Hytrel ®.



NOTE: Bonding and grounding systems must not be tied to any part of the electrical current carrying system.

Image courtesy of Megger Limited www.megger.com/us.
Hytrel is a federally registered trademark of E.I. du Pont de Nemours and Company.



Bonding and Grounding: Use Certified Clamps Only

Not Approved

Alligator clamps, automotive “jump-start” cable clamps and welding earth clamps.



Approved

FM- and ATEX-certified clamps with strong spring compression able to “bite” through rust, paint and deposits.



Images of approved clamps (on right) courtesy of Newson Gale www.newson-gale.com.



Bonding and Grounding: What's Wrong With This Picture?

In this photo of a bond-and-ground system on an underground tank cleaning and removal, several things are wrong.

To begin with, the “jumper cable” type clamp is not designed for static applications. It is in poor condition and has a very weak spring. In addition, the clamp has red plastic and black tape on the handle, which act as an insulator. And if you look closely, you'll see that the short wire to the clamp is loosely wrapped around the main cable.





Bonding and Grounding: Testing Continuity

To test the continuity of hoses and bonding wires – including clamps and connectors – an ohmmeter is typically used.

When performing such tests in a hazardous atmosphere, an intrinsically safe certified multimeter is required.

NOTE: These devices provide one-off tests only, not continuous monitoring.

Image of intrinsically safe certified multimeter (bottom) courtesy of Newson Gale www.newson-gale.com.



Bonding and Grounding: Testing Ground Resistance

To test the actual resistance of a ground rod or grounding network to earth, an earth/ground resistance tester is needed.

The test is called the fall-of-potential test. This technique is the most generalized approach that will work in almost all situations to determine the ground resistance or impedance of a grounding electrode.



Images courtesy of Megger Limited www.megger.com/us.

Summary



- Static occurs in all daily operations.
- Static accumulation can cause substantial buildup of energy.
- The main hazards of static are fire and explosion from sparks with enough energy to ignite flammable vapors.
- Effective bonding, grounding, relaxation times and, where possible, minimizing the generation of static by controlling flow rates are ways to prevent static electricity from causing a spark.
- Low-conductivity fuels accumulate static more than high-conductivity fuels.
- Static buildup does not require high flow rates.
- Static can be controlled by allowing the charge to dissipate safely.
- When in doubt, assume a material is a static accumulator.

Conclusion



This material is generic in nature and specific applications may require additional precautions.

Always involve the right people.

Always use the right equipment.

Always follow procedures and use Stop Work Authority if unsure.



A variety of technical references are available, including the following:

- NFPA 77: Recommended Practice on Static Electricity.
- Cenelec CLC/TR 50404: Code of Practice for the Avoidance of Hazards due to Static Electricity.
- API RP 2003: Protection Against Ignitions Arising out of Static, Lightning and Stray Currents.
- API RP 2219: Safe Operation of Vacuum Trucks in Petroleum Service.
- API 500, Classification of Locations for Electrical Installations.
- API 2015, Safe Entry and Cleaning of Petroleum Storage Tanks.
- NFPA 30, Flammable and Combustible Liquids Code.
- IEEE Standard 81-1983: IEEE Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground System.
- International Safety Guide for Tankers and Terminals (ISGOTT).
- Chevron Fire Protection Manual, Section 200.