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Static Spark from Explosive Vapours Ignites Road Tanker

Source: "Fire and Explosion of Highway Cargo Tanks, Stock Island, Key West, Florida". Hazardous Materials Accident Report. NTSB, (1998).

Although static electricity has been cited as an ignition source for a wide range of fires and explosions, it is one of the most misunderstood and underestimated hazards in the industrial workplace. Even on sites where static is thought to be under control, it is very often the case that through a lack of awareness, lack of understanding or through sheer disregard for its risk potential that ignitions can, and do, occur. This case study explores the repercussions and measures of control after an incident took place where static electricity was the ignition source.

Road tankers provide a number of services to the hazardous process industries, largely the transportation of dangerous materials from storage terminals to chemical processing refineries. The loading and unloading of road tankers with flammable and combustible products presents one of the most serious fire and explosion risks for site operations within industry. Carriage of such product is not without its risks and poses industries with one of the most complex problems in terms of assigning layers of protection that can control an electrostatic hazard in a safe and reliable way.

A study conducted by the American Petroleum Institute (API) in 1967 identified static discharges as being responsible for over 60 incidents in road tanker loading operations demonstrating just how long this potential threat has been acknowledged. The susceptibility of road tanker operations where electrostatic discharge is potentially present as an ignition source is increased due to a lack of, or unsuitable, grounding system, and the movement of product in a flammable and combustible environment. Without adequate static grounding protection mitigating a discharge, movement of product through the vehicle or connected plant equipment will cause the charge level to increase. When the accumulated charge is sufficient, a spark discharge is highly probable.

Tank truck operations can be conducted in remote locations where designated grounding points are not always available.



That said, due to the remote nature of the sites in question, should these designated grounding points be available they may not be tested on a regular basis and this means that their low resistance connection to true ground can be affected by environmental conditions and lifecycle effects.

Typical applications for specialised vehicles and mobile plant equipment include:

- Vacuum trucks
- Chemical spill and waste recovery service trucks
- Evacuating chemicals from reactors, storage tanks and containers
- Emergency response for hazardous/flammable tankers
- Mobile transfer pumps, blowers and mixing systems
- Refuelling aircraft and use of mobile bowzers

The natural presence of static electricity in product transfer operations, combined with its associated ignition hazards, ensures that regulators take static control precautions for road tankers very seriously. In order to mitigate the risk of fire and explosion on a tanker, it is necessary to prevent a source of ignition and a flammable atmosphere being present simultaneously. However, it is not always possible to exclude both these factors at the same time and precautions taken must be to control the risk accordingly.

In this incident a road tanker driver was on top of his vehicle checking the contents of its compartments and preparing to transfer material from a cargo tank when explosive vapours ignited within the vehicle he was standing on. The ignition caused an explosion that threw him from the top of the truck. The fire and series of explosions injured the driver and destroyed his tanker and nearby vehicles. The resulting damage was estimated at \$185,000, with the driver himself suffering from second and third-degree burns to his hands, arms, legs and a broken left knee which left him in hospital for three months.

	Incidents	Fatalities	Injuries	Damages
Loading and Unloading	6,381	7	290	\$9,917,723
En Route	1,698	44	279	\$69,408,595

(Reported hazardous materials incidents involving highway cargo tanks 1993 to 1997)

If it isn't already acknowledged, it should be known that static electricity is a very real and unseen threat. Any process involving relative movement will generate static electricity by contact and separation of the materials involved. The majority of plant equipment at risk of static charge accumulation is made of metal. If the metal body of a tanker is not grounded it quickly becomes an isolated metal conductor and consequently, the primary source of a static spark ignition hazard.



Incident

The company, an intrastate private motor carrier had a proven track record of hauling bulk liquid-petroleum products, primarily gasoline and diesel fuel in cargo tanks for local deliveries. The business had been keeping a temporary storage tank containing gasoline and diesel fuels. Fuel in the storage tank was to be transferred to road tankers as required for delivery to clients. Having transferred nearly 700 gallons of premium unleaded gasoline only a day earlier, the driver arrived on site with the intention of transferring a load of diesel fuel from the temporary storage tank to his cargo tank. At the time of arrival, the driver was carrying a plastic bucket of mixed fuels that he had retrieved from under the temporary storage tank. He indicated that he believed the bucket contained a mixture of gasoline and diesel fuel that had spilled during previous cargo transfers. When on top of the truck, the driver recalled that he had opened the lid of the front compartment and that he may have been pouring the contents of the bucket filled with gasoline and diesel fuel into the compartment when he saw flames rise out before he was thrown 75 ft from the top of the truck.

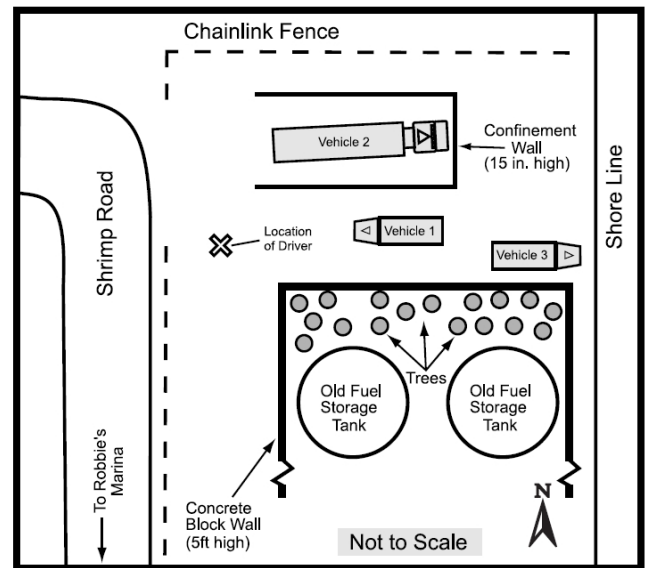


Fig. 1 - The resulting explosion started at vehicle 1 and propagated to damage all three vehicles

It was documented in the accident report that the explosion or pressure surge necessary to propel the driver such a distance from the truck would have had to come from an ignition and subsequent expansion of explosive vapours within one of the compartments. The investigation concluded that had the vapours ignited outside of a compartment, they would have been unconfined and thus unable to create enough of a pressure surge to throw the driver so far. Also, because no fragments or other evidence of catastrophic failure of the two front compartments of the tanker were discovered, it is likely that the pressure surge occurred through one of the compartment openings with the driver being thrown away from the centre of the explosion. Therefore, given the driver was found it is likely that he was, as he remembered, standing on top of the vehicle in front of the opening for the compartment when the ignition occurred.

Despite the pedigree and longevity of the organisation, the nature of road tanker loading and unloading operations is fraught with danger. It is highly plausible that this operation had been conducted multiple times without a visible incident occurring, with electrostatic sparking taking place in previous operations without a flammable atmosphere being present in the spark gap when discharges occurred. This is a common feature of operations that have suffered from the consequences of a fire or explosion caused by static electricity. Just because a charge hasn't discharged it doesn't mean any previous procedures haven't allowed it to accumulate to dangerous levels.

Ignition Source

Although there were a number of factors pertaining to the incident, this case study will focus largely on the ignition source, electrostatic discharge.

The investigation examined other potential ignition sources and concluded

1. There was no lightning in the area of the explosion.
2. The temperature of the nearby truck exhaust stack (65° to 94°C) was not sufficient to reach the auto ignition temperature of gasoline vapours (126°C).
3. While smoking as an ignition source cannot be totally discounted, and the driver himself being a smoker, there was no evidence to suggest he was smoking, and he confirmed this when the ignition occurred.



Fig. 2 – Top to bottom, Vehicle 1, 2 and 3. The NTSB concluded that the damage and fire on the other two vehicles resulted from exposure to heat from the fire on Vehicle 1. Combined all vehicles contained approximately 9,200 gallons of fuel that would have fuelled the blaze.



The full summary of events is available in the comprehensive accident report provided by the National Safety Transportation Board (NTSB) available on their website.

API: 2003 “Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents” describes the fundamentals of static electricity as

“ the accumulation of electrical charges on materials, the mechanisms by which charges are generated, and the processes of dissipating accumulated charges ”

The generation of electrostatic charge by itself does not produce discharges, a high electric potential and electric field is required for a discharge to occur. A spark resulting from high voltage does not mean that ignition of a flammable mixture will occur, this will only happen when the electrostatic charge that has been generated accumulates. Hazardous electrostatic charges can only accumulate on bodies that are insulated from each other and from the ground; otherwise the charges will naturally dissipate as fast as they are formed. For combustion to be initiated sufficient energy must be transferred from the spark to the surrounding flammable mixture. The energy that is stored and available from a capacitive discharge is related to voltage and capacitance.

For example, a typical road tanker when it is being filled with a liquid at recommended flow rates, but is without static earthing protection, could have its voltage raised to between 10,000 volts and 30,000 volts within 15 to 50 seconds. This voltage range is very capable of discharging a high energy electrostatic spark towards objects at a lower voltage potential, especially anything at earth potential. Examples of objects at earth potential could be operators working in the vicinity of the road tanker or the filling pipe situated in the hatch on top of the road tanker. It is possible to estimate the energy of such sparks by combining the capacitance of the road tanker with the voltage present on the road tanker. The capacitance is a measure of how much charge can accumulate on the outer surface of the road tanker. As road tankers have a very large surface area they can accumulate very large amounts of charge, which in turn, creates the presence of very high voltages on the surface of the road tanker.

The most hazardous electrostatic situation in petroleum operations is the building of charge on an isolated piece of conductive equipment. In this incident the vehicle was ungrounded (isolated); electrostatic sparks from isolated conductors are among the most incendiary sparks that can occur. When charge is stored on a conductive object almost all of the charge can be drained in a single spark. The energy contained in the spark is usually enough to ignite flammable mixtures. As well as the vehicle, it was also assumed that the driver himself was isolated from earth. Ungrounded personnel that acquire an electrostatic charge present a serious hazard in potentially flammable and combustible atmospheres. Over 30,000 volts can be carried by people who are completely unaware that they themselves are the potential source of electrostatic spark discharge that could ignite a flammable atmosphere. Research for this case study found that there was an absence of reports within the petroleum handling industry whereby static ignition had resulted from personnel electrification, indicating that the hazard had not been historically significant or at least documented anyway. The reason for the lack of incidents is that most operations occur outdoors or in semi-enclosed locations where the work environment is inherently conductive as a result of contamination or moisture and where the exposure of personnel to flammable atmospheres is limited.

Lastly, the bucket containing a mixture of fuels presented a serious threat; charge can accumulate regardless of the conductivity of the contents (fluid), if the container being filled is made of low-conductivity (non-conductive) material such as a plastic bucket, or if the container is conductive but inadequately grounded. The driver on top of the vehicle was holding a plastic bucket. As documented by the NTSB, from a static ignition concern alongside other safety considerations, small portable containers should never be filled while in or on a vehicle. According to the API, small portable containers, up to 45 litres (12 gallons) capacity, made of metal or approved plastic construction are allowed for the storage and transportation of liquid fuels by most local authorities.

Apart from the above factors and those further explored in the official investigation report, the company did not have records of the quantities and types of materials in each of the compartments on Vehicle 1; therefore the driver's naive decision to empty the contents of the bucket into a compartment with an unidentified fuel source was based purely on assumption that it was safe.

As part of tank truck operations, drivers regularly switched loaded materials in the compartments of their trucks to make deliveries. Switch loading is the process of loading diesel fuel into a tank compartment that had previously contained gasoline and still contained vapours. It became clear that both compartments held an underdetermined amount of residue of waste water and petroleum distillates. Both the NFPA and API note that this method can create dangerous conditions within a compartment. When compartments have previously contained diesel and then contaminated with an alternative such as gasoline, according to the NFPA

“ the atmosphere in contact with the rising oil surface is not enriched to bring gasoline vapours out of the flammable range. If circumstances are such that a spark should occur either across the oil surface or from the oil surface to some other object, the spark occurs in a mixture that can be within the flammable range, and an explosion can result ”

What actions could have been taken to prevent an incident?

With any incident the first place to start is to determine why electrostatic charge was “permitted” to accumulate. In this accident, charge had been allowed to accumulate and discharge because the tanker was isolated and ungrounded with no resistance to earth that would have enabled charge to safely dissipate. If charge is unable to safely dissipate to earth it will look to equalise its potential on the closest object. The generated charge only becomes a problem in hazardous areas when it is allowed to accumulate on objects that are not at ground (earth) potential. A build-up of electrostatic charge will eventually develop enough to discharge a spark onto an object held at a different potential in an attempt to equalise the charge. The common denominator for most incidents is that the rate of electrostatic charge generation on the body of plant/transport equipment was permitted to exceed the rate of charge dissipation resulting in the accumulation of static charges on some areas of the tanker.

Because road tankers have a very large surface area, they can accumulate very large amounts of charge, which in turn, creates the presence of very high voltages on the surface of the road tanker.

API RP 2219 states:

5.4.2 Grounding:

Before starting transfer operations, vacuum trucks should be grounded directly to earth or bonded to another object that is inherently grounded such as a large storage tank or underground piping.

5.4.2 Grounding and bonding:

This system (grounding) should provide an electrical contact resistance of less than 10 Ohms between the truck and a grounded structure.

IEC TS 60079-32-1, 8.8.4 "Vacuum trucks" states:

Vacuum trucks should be connected to a designated site earth before commencing any operations. In areas where site earths are not present, i.e. where portable earthing rods are required, or there is doubt regarding the quality of site earths, the resistance to earth should be verified prior to any operation. When the truck is connected to a verified earth, the connection resistance between the truck and verified earth should not exceed 10 Ω for pure metallic connections or 1 M Ω for all other connections.

The following precautions should have been taken:

1. The tank and all associated equipment, such as piping, pumps and filters should be grounded
2. Personnel entering or working near tank openings and compartments should be grounded
3. Limiting the flow rate
4. Splash filling should be avoided

The company did not have procedures for drivers to follow in handling buckets of mixed fuels under the storage tank and did not require drivers to ground and bond cargo tanks. This contradicted best practice as outlined in API RP 2219 and NFPA 77 Recommended Practice on Static Electricity. Static control measures need to be taken wherever ignitable mixtures might be present. A resistance to earth of less than 10 Ohms must be provided via a grounding cable from the loading system to the truck before any operation (connecting hoses, opening compartments) is carried out and must not be removed until all operations have been completed. Ideally, an interlock, such as those available within the Newson Gale Earth-Rite MGVS system should be installed to prevent the operation commencing when an earth cable is not connected.

Introducing a grounding system

Static charge build up, resulting sparks, and the ignition of flammable materials are an inevitable event if control methods are not appropriately used. The objective is twofold:

1. To mitigate the build-up of charge on product;
2. As well as surrounding objects within close proximity (such as equipment or plant personnel)

A vehicle installed (Earth-Rite MGVS) or gantry fitted (Earth-Rite RTR) grounding system empowers drivers, specifiers and operation managers to enforce safety protocols (SOPs) that should be followed to ensure static grounding is put into practice during product transfers. Using an Earth-Rite MGVS system enables the customer to demonstrate compliance with international recommended practices.

Principles of operation

The Earth-Rite MGVS system has a user-friendly operator interface which indicates when transfer operations are safe to begin. From the operator's perspective, this is identified visually (in the form of flashing green LED lights) and grounding the vehicle couldn't be simpler. The grounding system can be connected with a static grounding clamp to either buried structural metal work or to rods that are hammered into the ground. When the operator connects the clamp to a metal object buried in the ground the system will verify whether or not the resistance into the true ground via the metal object is low enough to dissipate static charges that could build up on the trucks transfer system. This function is referred to as **"Static Ground Verification"**.

Once this resistance to true ground has been confirmed then the Earth-Rite MGVS switches to continuously monitor the connection resistance of the truck to the verified grounding point for the duration of the transfer process; this is referred to as **"Continuous Ground Loop Monitoring"**. The connection resistance must be maintained at 10 Ohms or less for the duration of the product transfer process.

Both the Static Ground Verification and Continuous Ground Loop Monitoring checks need to be positive in order for the ground status indicators to change from red to green.

An additional layer of safety can be introduced by interlocking the pump with the grounding system relay contacts, so that if the truck loses its ground connection, the transfer process is shut down automatically.



Fig. 3 – When the Earth-Rite MGVS confirms the truck is fully grounded, three high intensity green LEDs pulse to indicate that the vehicle has established a static dissipative ground connection

Summary

Generally common causes of incidents include low understanding of the ignition source, lack of awareness of the importance of safeguarding against electrostatic discharges, poor implementation of control procedures such as elimination of ignition sources and badly managed transfer operations, such as the filling and emptying of equipment. The National Transportation Safety Board determined that the probable cause of the accident was the “company’s lack of adequate procedures and driver training, resulting in the driver’s pouring a mixture of gasoline and diesel fuel from a plastic bucket into a cargo-tank compartment that contained a mixture of explosive vapours”. The ignition and fire in the tank were probably caused by a static discharge in a compartment on Vehicle 1 that resulted from the driver’s pouring a mixture from a plastic bucket. Despite the driver having over a decade’s experience driving road tankers delivering gasoline and diesel fuel there will always be risks inherently associated with cargo tank loading and unloading. This was amplified by the organisation that had no written documentation to act as clear instructions for best practice standard operating procedures. Consequently, the driver considered it normal practice to pour contents of the plastic bucket, filled with a

mixture of fuel into an open compartment on top of his cargo tank. It was deemed that this is probably what he was doing when the fire ignited. The incident prompted the NTSB to make several safety recommendations to various associations, state marshals’ offices and transportation departments.

Of course, recognition of the hazard is only the first step. Regular static hazard awareness training combined with grounding equipment that displays compliance with industry codes will go a long way to eliminating fires or explosions caused by static electricity. A HAZOP risk assessment report will identify hazards, evaluate those associated risks and provide guidance on the subsequent control of the hazards.

To help control these risks, Newson Gale offers a wide range of static grounding and bonding equipment which is made to provide optimum safety in explosive atmospheres for a variety of process applications. The Newson Gale range mitigates static charge accumulation by using practical and innovative design, and ensures effective static control on three levels – grounding and bonding clamps, visual verification systems and interlockable control systems.

If you have any questions on this case study contact [Newson Gale](#).
If you would like to learn more about the **Earth-Rite® MG**V follow this link to the [product webpage](#).

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