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Case Study

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Risk of Electrostatic Ignition during Storage Tank Cleaning Operations

Source: "Safety Alert: Explosion in tank during HP activities, SIR, (2018)".

Uncontrolled static electricity is a major risk in industrial processing operations. Whilst the generation of an electrostatic discharge is commonly associated with the movement of product in a flammable or combustible environment, this case study explores how static electricity is an insidious ignition source in everyday operations such as routine storage tank cleaning.

Storage tanks in oil refineries and chemical plants contain large volumes of static accumulating flammable liquids. Usually fixed or mobile and made of large metal containers, storage tanks vary in size, construction and design, from vertical and horizontal to open top and closed top, to name but a few. One thing that is certain, the risk of an electrostatic discharge remains an ever present and un-seen threat in industrial petroleum hazardous area environments.

The majority of process plant equipment at risk of static charge accumulation is made of metal. Metals are excellent conductors and the natural conductive properties of metals, ranging from copper through to steel, meaning that electrical resistance to the transfer of charges from the body is low, provided that the body has good contact with the ground. However, this positive characteristic can quickly become a negative if the metal body is not grounded, as isolated metal conductors are the primary source of static spark ignition hazards. When dealing with metal objects such as storage tanks, because they are predominantly made of steel it will give the majority of their discharge energy in a single incendive spark capable of releasing enough energy to ignite flammable vapors.

Typically oil refineries have a product storage area or 'tank farm' which provides storage capacity to ensure uninterrupted refinery operations. Although found within the boundary and then subsequently the fire and bund wall, the layout of storage tanks self-contained inside the perimeter are often in close proximity, to within a few meters apart. Their location should adhere to the minimum recommended separation distances, and although dependent on various factors, it is primarily determined by the capacity of the tank.

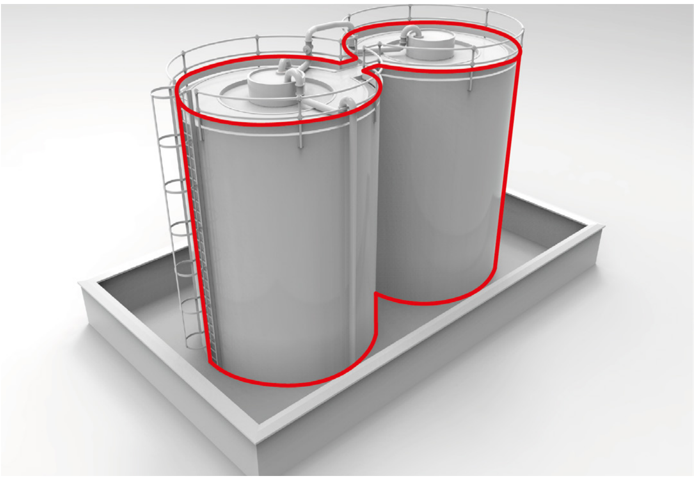


Fig. 1 – Storage tanks within close proximity of each other, means fires can viciously propagate through a tank farm if an incident is to occur.

As outlined by the Health and Safety Executive (HSE), these distances are unlikely to give complete protection in the event of a fire or explosion involving a tank, but "should allow sufficient time for people to be evacuated, providing there are adequate means of escape". Although no incident can ever be considered innocuous, what may begin as a single storage tank fire can quickly escalate and propagate a chain reaction throughout a facility that can lead to severe financial losses, not to mention the interruption in production and potential loss of life. Therefore a twofold approach should be considered; firstly to understand the potential sources of ignition within the hazardous areas and secondly, to then put measures and standard operating procedures in place to mitigate such an incident occurring.

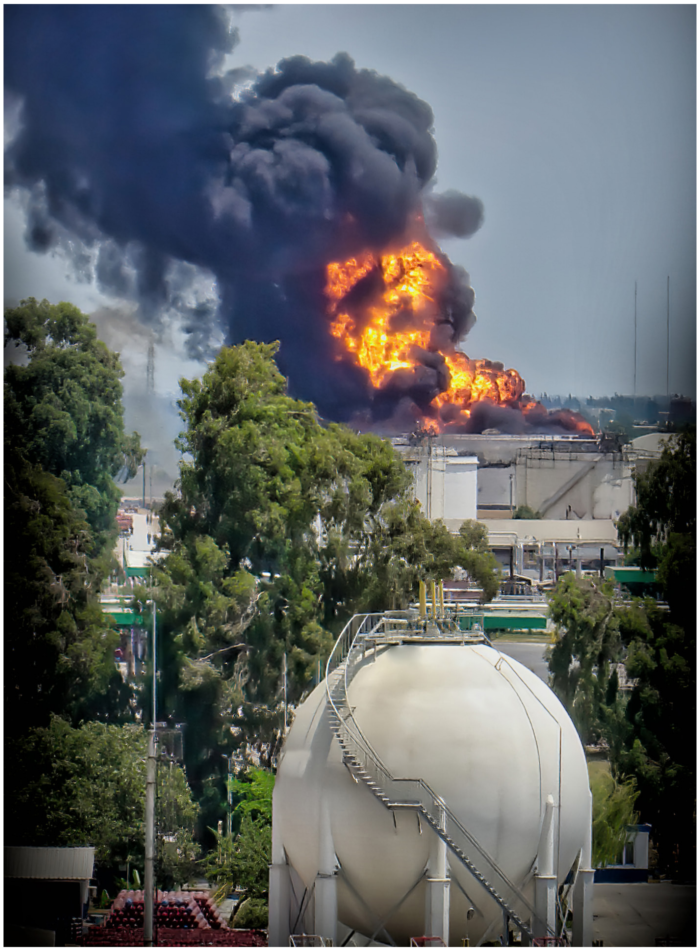
The generation of static electricity during cleaning of petroleum storage tanks can be mitigated by taking precautions through certain procedures.

Tank vessel explosions have occurred where no probable cause has been established, but where static electricity was identified as a potential source of ignition. In some cases, poor adherence to safe procedures was indicated, but not proven as causative. The continued occurrence of these accidents suggests a larger pattern of operational safety deficiencies. Electrostatic discharge has long been known as a hazard associated with petroleum products and this incident highlights the severity of static as an ignition source and the impact it can have on what can be considered a routine task, such as tank cleaning.

Tank Cleaning Incident

In this incident a site employee was cleaning a storage tank that was partly filled with sludge (production process water, petroleum residues and sand) before an ignition occurred that resulted in an explosion. The hose operator who was directly next to the tank opening saw a flash and ducked down immediately. Despite his best efforts to take cover and avoid the combustion that had taken place, he suffered minor burns to the face.

Given the high rate of charge generation and the flaws that had been exposed in the cleaning activity, not to mention the injuries sustained by the hose operator; a thorough review of the operation was carried out. The investigation scrutinised the operating procedure during industrial cleaning operations, including the lack of accurate information on the flammable products stored within the vessel, as well as the grounding and bonding integrity of the storage tank. Brought about by the subsequent inspection, a number of lessons were learned and recommendations made, promoting on-site changes to be implemented.



Conclusion

There are multiple potential physical mechanisms that could cause mist to ignite. It is outside the scope of this case study to explore all of the ignition sources and basic activities applicable to every tank that has to be cleaned. However, API Recommended Practice 2016, “Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks” is intended to assist employers and operators in conducting safe tank cleaning operations in accordance with the requirements of this standard.

Cause of tank accidents

Year	1960-1969	1970-1979	1980-1989	1990-1999	2000-2003	Total
Lightning	4	10	19	37	10	80
Maintenance / hot work	1	5	9	12	5	32
Operational error	1	5	6	8	9	29
Equipment failure	3	1	5	7	3	19
Sabotage	2	5	2	6	3	18
Crack / rupture	0	3	3	3	8	17
Leaks and line rupture	0	3	2	5	5	15
Static electricity	2	1	2	2	5	12
Open flame	1	0	4	2	1	8
Nature disaster	1	2	1	1	2	7
Runaway reaction	2	1	0	2	0	5
Total	**17**	**36**	**53**	**85**	**51**	**242**

Fig. 2 – A Study of Storage Tank Accidents. Based on 242 storage tank accidents in industrial facilities over the last 40 years. Source: "Journal of Loss Prevention in the Process Industries", James I. Chang, Cheng-Chung Lin, (2005).

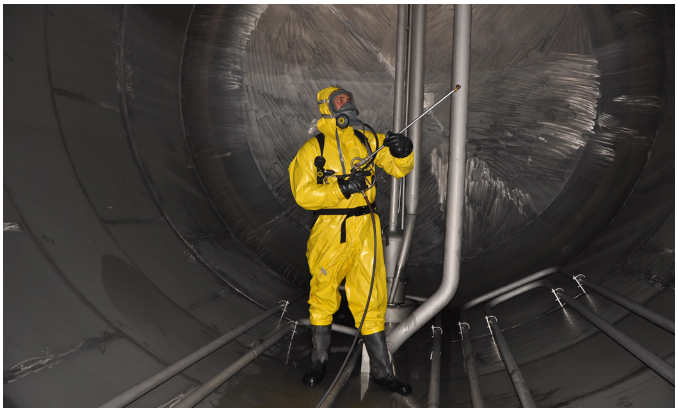
The nature of tank cleaning operations means that the generation of static electricity accumulates due to splashing against the tank surface. The accumulated charge associated with water washing should always be considered – and expected to be much higher when cleaning chemicals are used. Stopping the accumulation of static is critical during all tank washing operations because of the vigorous agitation of liquids involved. In this incident the impact of a high pressure water jet used to clean and remove deposits from the surface inadvertently created a fine electrostatically charged mist in the tank space that was ignited by a static discharge.

Mist: The term "mist" is used generically here to describe a collection of droplets of liquid suspended in a gas medium. It is usually distinguished from sprays in having lower momentum and behaving more as a quiescent cloud. In the context of fire suppression, water mists are generally assumed to be composed of smaller droplets than water sprays. Source: "Generation of flammable mists from high flashpoint fluids: Literature review", Health and Safety Executive, (2013).

Mists that are formed during water washing (or potentially from the introduction of steam) can become electrostatically charged. In this incident charging arose, and the charge on water mist formed by tank washing produced an electrostatic field throughout the tank. When a spark is generated between two conductors submerged in a mist of fine droplets, the temperature rapidly increases within a small, roughly spherical, volume of gas and droplets, known as the spark kernel.

Within this volume, any fuel droplets rapidly vaporise and the fuel vapor rapidly mixes with the surrounding air. Since the temperature is high, reaction rates tend to be extremely fast and the fuel vapor is almost transformed into the combustion products, releasing heat in the process.

The minimum ignition energy (MIE) necessary to produce a self-propagating flame in a mist is affected by a number of factors – most significant of these is the droplet size, but fuel concentration, volatility, air velocity and the presence of any fuel vapor is also important. Sprays produced by a release of pressurised liquid through a nozzle are usually composed of larger droplets. The pressure of any vapor reduces the MIE of a mist. As the fuel volatility is increased, the amount of energy required to vaporise the droplets is reduced and therefore the ignition requires less energy.



Vapor was generated by the hose held by the operator used to clean the surface of the tank where petroleum residue acted as fuel. If an ungrounded conductor (such as a hose) is lowered into the charged mist, it becomes charged to a voltage which may be high enough for an incendive spark to jump to some part of the tank structure. If a hose with the wrong electrical resistance is selected there is potential for static sparks that could interact with the mist. Charged mist is often present for the duration of the cleaning process and can take several hours to fully relax. The properties of the material itself are fundamental to understanding both charge generation and relaxation. The lower the conductivity, the greater the relaxation time.

The investigation into the incident showed that the risk had incorrectly assessed 'sludge', and was classified by the parties involved as non-hazardous. As a result, the activities that made up tank cleaning had not been planned in as high-risk. It was also noted that on the day of the incident it was particularly hot, which may have led to nebulisation (conversion of a liquid to a fine spray/mist) occurring at a rapid rate that would not have otherwise occurred under normal environmental conditions. As no grounding was in place charge was permitted to accumulate freely, meaning that the tank was not only an isolated component but it was holding large amounts of static electricity. 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.

Consequently, this meant that the incident had all the elements for an ignition to occur:

a. Fuel – 'sludge' (petroleum residue)

b. Atmospheric conditions (hot flammable/combustible atmosphere)

c. Ungrounded storage tank (isolated from earth)

d. Ignition source (static electricity)

e. Ungrounded conductor (hose and operator)

IEC TS 60079-32-1, 13.3.1.4

"Movable metal items" states:

Where such situations are expected, the object should be earthed by an alternative means (e.g. earthing cable). A connection resistance of 10 Ohm between the cable and the item to be earthed is recommended. Earthing and bonding need to be continuous during the period that charge build-up could occur and cause electrostatic hazards.

* Always check for and read the latest version of the International Standards, Guidance and/or Recommended Practices.

What actions could have been taken to prevent this incident?

A proactive approach of installing a suitable grounding and bonding solution is always highly recommended. It is entirely possible that this incident highlighted ongoing pitfalls with tank cleaning operations and similarly previous operations may have occurred without a visible electrostatic ignition occurring.

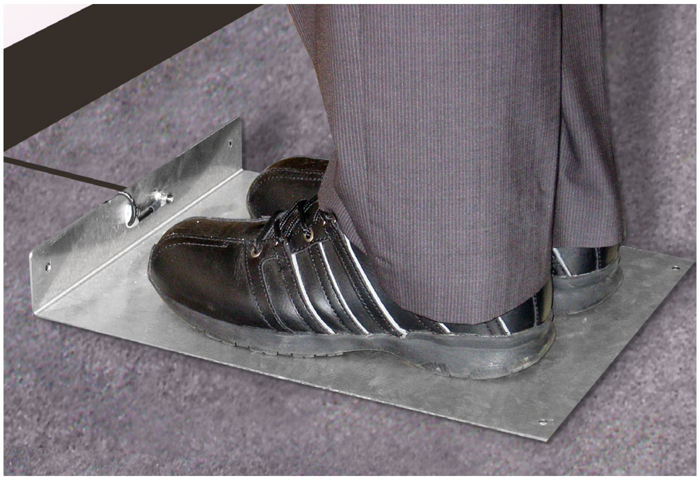
The rate of charge generation is notoriously difficult to predict, and the only way to control it is to put static control measures in place to mitigate the potential risk of an electrostatic ignition. The generated charge only becomes a problem in hazardous areas when it is allowed to accumulate on objects that are not at ground (earth) potential. The most important action an operator can take to control static electricity is to ensure any conductive objects are connected to a verified earth. Those who ignore the dangers of electrostatic discharge in hazardous environments jeopardise people and the plant alike.

A literature survey of reported accidents (Santon, 2009), found that the consequences of mist explosions can be potentially very severe. The study identified 37 incidents including 20 explosions, of which 9 were collectively responsible for a total of 29 fatalities. Source: "Generation of flammable mists from high flashpoint fluids: Literature review", Health and Safety Executive, (2013).

The optimum solution is to provide operators with a visual means of verifying a connection to equipment at risk of static charge accumulation with a resistance of 10 Ohms or less, as stated by the IEC TS 60079-32-1 "metallic items in good contact with earth should have a resistance to it of less than 10 Ohms".

Testing Plant Personnel's Footwear

Closer examination of the equipment has to be considered, as well as the operator's path to earth. Through their own movement people can generate large amounts of static charge if they are not grounded. Over 30,000 volts can be carried by people who are completely unaware that they themselves are the potential source of an electrostatic spark discharge that could ignite a flammable atmosphere. The hose operator could have already been carrying enough charge as he entered the vicinity of the tank, however conclusive measures should be implemented to ensure that the condition and resistance of footwear to demonstrate static is capable of dissipating through shoes to ground is ensured. Static dissipative footwear is designed to reduce hazards that may occur due to personnel having excessively high resistance to ground. Regular testing of static dissipative footwear is strongly recommended to ensure the static dissipative properties of the shoes do not change during the duration of their use. The provision of footwear to plant personnel only reduces the risk if properly maintained, and this cannot be detected by visual inspection of the shoes alone. It should therefore be a fundamental requirement of organisations that have employees operating in flammable and combustible hazardous environments to ensure that the product (footwear) is capable of fulfilling its designed function of dissipating electrostatic charges.

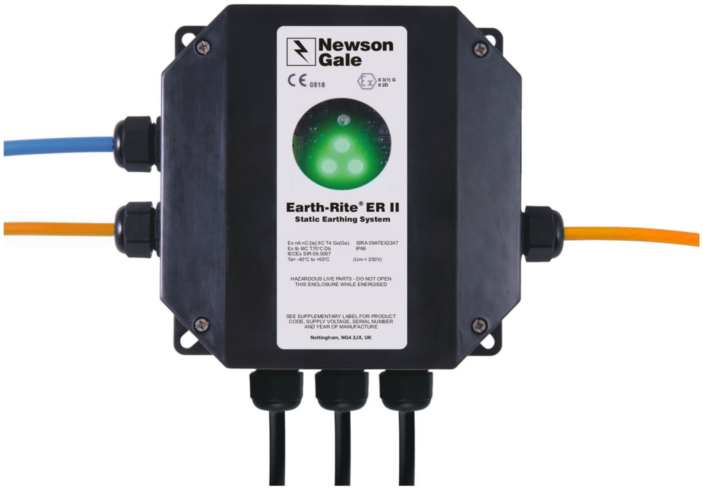


Stopping charge accumulation on plant personnel is trouble-free and dependent on both wearing the correct footwear and ability to test the properties of the footwear before entering a hazardous area. Prior to commencing with the tank cleaning operation an electrical resistance test would have been recommended.

The Sole-Mate™ II tester from Newson Gale provides a time efficient and cost effective method of ensuring personnel operating in hazardous areas are wearing static dissipative shoes that are capable of limiting electrostatic charge accumulation on their bodies. The system tests the condition and measures the resistance of footwear to ensure static is capable of dissipating from personnel through their shoes to ground.

Grounding Storage Tanks / Ancillary Equipment and Interlocking with the Process

The Earth-Rite® PLUS™ grounding system from Newson Gale combines a simple visual GO/NO GO via a traffic light model (red/green) of indication with interlock control capability. Interlocking with the process is the most effective means of controlling the risks of ignition caused by static electricity during operations. Conductive objects like storage tanks, skids, IBCs and rail cars can accumulate hazardous levels of electrostatic charge that could discharge static sparks with energies far in excess of a vast range of combustible gases, liquids or vapors. The ignition of combustible atmospheres by static electricity can be mitigated by ensuring that such objects are grounded, and the Earth-Rite PLUS system continuously monitors the connection to ground ensuring static is dissipated safely throughout the operation. If the connection to ground is broken during the operation then the red negativity ground connection LED will show and the interlock contacts will open. The Earth-Rite PLUS system demonstrates the full range of ATEX and IECEx certification for all gas and liquid groups. It also ensures there is a 10 Ohms or less connection between the tank and the product transfer system.



Lessons Learned**

- During the joint risk assessment, it must always be ensured that the correct information about the product is supplied by the client and that the cleaning technique to be used by the cleaning company is appropriate for it.
- Industrial cleaning of sludge can create an explosive atmosphere because the hydrocarbons in the sludge can form a mist when it is stirred up.
- In industrial cleaning activities, all potential sources of ignition (e.g. static electricity, short circuits in instrumentation, use of non-EX equipment and the flammability/explosiveness of the medium) must be eliminated/controlled as fully as possible.
- Because complete control of all potential sources of ignition is not always possible, explosive atmospheres in the tank must not be allowed to build up and measurements must be taken continuously.
- The procedure for rendering it safe must focus on creating a safe place to work throughout the activity, not just the start.

Summary

Ignition risks can arise in a variety of ways and static electricity in tank cleaning operations is just one example. It is important to appreciate the ways risks can arise and the precaution needed to ensure a safe working environment. Despite the ever-present dangers, by mitigating the charge and the potential for an uncontrolled electrostatic discharge, the resulting ignition is eradicated. The primary mind set should be to source a grounding solution that provides the best level of protection and is capable of being incorporated alongside current operations. The more layers of protection deployed to protect against an ignition source, the more likely static will be controlled in a safe, repeatable and reliable way, day in and day out.

** *As outlined by the SIR accident report, March 2018.*

If you have any questions on this case study contact Newson Gale.
If you would like to learn more about the Earth-Rite® PLUS™ follow this link to the product webpage.

Please note this case study is referenced from a third party source and is not in any way linked to the operations of Newson Gale customers.

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