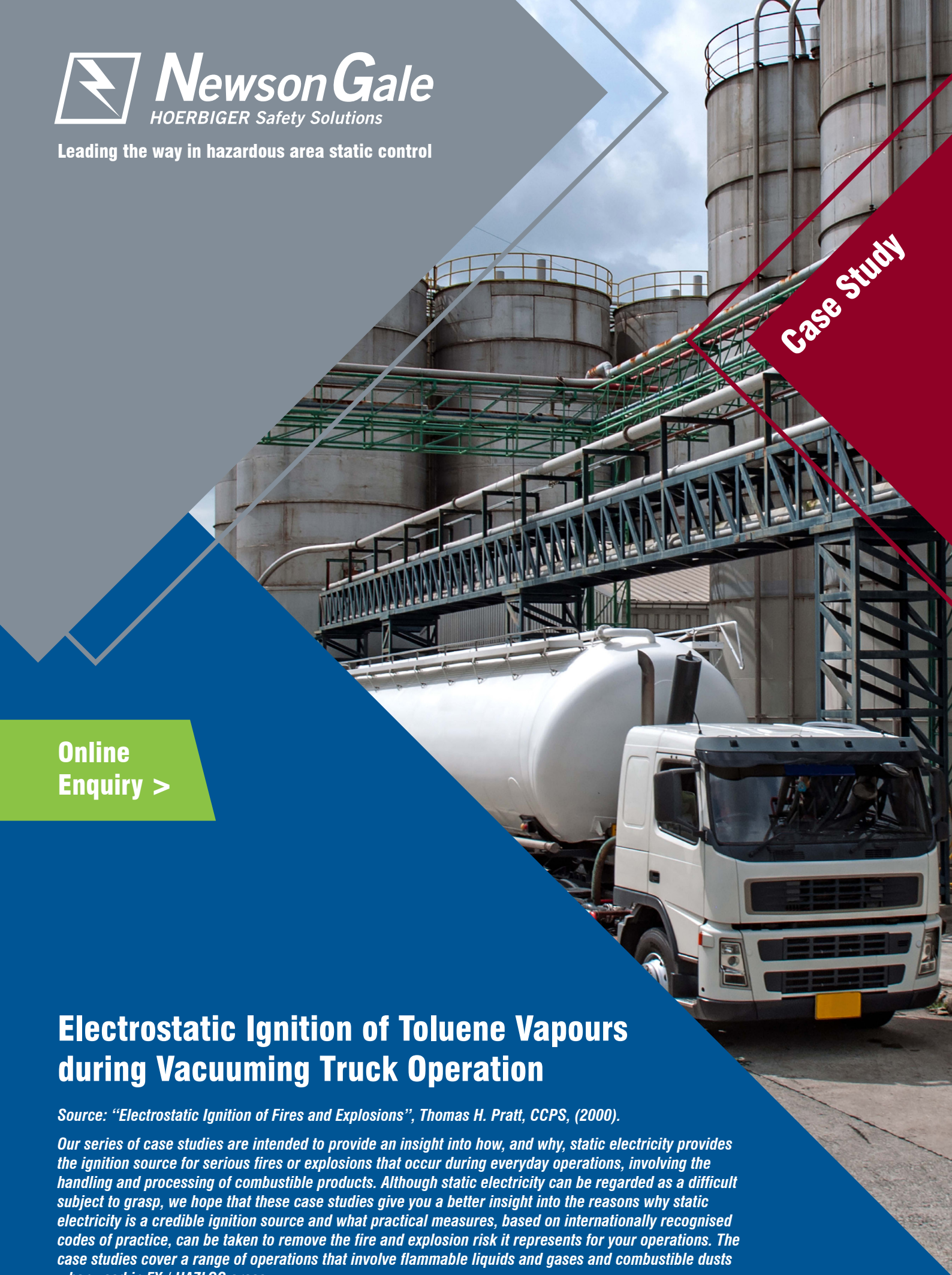
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Case Study



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Electrostatic Ignition of Toluene Vapours during Vacuuming Truck Operation

Source: "Electrostatic Ignition of Fires and Explosions", Thomas H. Pratt, CCPS, (2000).

Our series of case studies are intended to provide an insight into how, and why, static electricity provides the ignition source for serious fires or explosions that occur during everyday operations, involving the handling and processing of combustible products. Although static electricity can be regarded as a difficult subject to grasp, we hope that these case studies give you a better insight into the reasons why static electricity is a credible ignition source and what practical measures, based on internationally recognised codes of practice, can be taken to remove the fire and explosion risk it represents for your operations. The case studies cover a range of operations that involve flammable liquids and gases and combustible dusts when used in EX / HAZLOC areas.

Operation: vacuuming of off-spec toluene from a sump

This case study investigates the causes behind a fire that occurred during a vacuum truck operation. The vacuum truck was deployed to a below grade sump that contained mostly of "off-spec" toluene. As the vacuum truck operation was nearing completion of the removal of the toluene from the sump an ignition of the vapours occurred resulting in a fire. In the ensuing investigation of the incident it was determined that the vacuum truck had not been grounded by the operator. Although other ignition sources would have been considered, the fact that the truck was not grounded and the material being transferred was toluene, it was highly plausible that a static spark was the cause of the fire.

For a static spark to be discharged from the surface of a metal object there needs to be a voltage on the charged object that exceeds the "breakdown voltage" of the surrounding atmosphere. This voltage results from the presence of too many positive or negative charges on the object and simply means that the voltage of the charged object is strong enough to create a conductive channel through the air, to a secondary object. The conductive channel provides a path for the static charges to flow through.

In the split second that the channel is formed, the excess charges rapidly pass through the gap releasing energy in the process. The energy released results in a static spark and if a flammable atmosphere is present in the "spark gap" there is a high probability the energy of the spark will exceed the minimum ignition energy (MIE) of the vapour, gas or dust present in the spark gap.

To create a voltage there needs to be a constant supply of electrical charges to the object being electrified, which in this case is the vacuum truck. Effective grounding of the truck would have provided a means of sending the excess electrical charges to the general mass of the earth (grounding) removing the risk of the truck becoming electrified. In electrical terms this means there was a very high resistance from the chassis/tank of the truck to earth. A constant stream of electrical charge is a current so the more current flowing to the truck, the greater its voltage. But where does this electrical current come from? This is where the vacuuming operation combined with the suction of a material like toluene would have created a "streaming current".

Toluene has a very high resistivity with the effect that when it comes into rapid and repeated contact with other objects, especially conductive objects like metals, it strips electrons from the other material. This means the toluene carries more negative charge than positive charge. When the charged toluene makes contact with the truck it causes the outer surface of the truck to carry the same amount of negative charge.

In the case of this incident a neoprene hose with an embedded metal wire helix was used. As the metal helix would have been connected to the truck via the metal couplings of the hose, the full length of the hose would have been at the same voltage as the truck. To put some "hard numbers" on the case for static being the source of ignition we need to look at some of the physical characteristics of this operation.

A streaming current for a resistive liquid flowing through a pipe (including hoses) can be estimated from the equation:

$$\text{Streaming current, } I_S = (2.5\times10^{-5})(v^2)(d^2)$$

Where:

v = velocity of liquid (metres per second)

d = internal diameter of hose (metres)

It is known that the suction flow rate was 500 gallons per minute which is equivalent to 3.9 metres per second. The internal diameter of the hose was 4 inches which is equivalent to 0.102 metres. Hence the streaming current would have been somewhere in the region of 3 micro-amps (3×10^{-6} A). It was estimated that the resistance between the truck and ground was at least 1×10^{10} Ohms. Most of the resistance would have been provided by the truck's wheels and the asphalt on which the truck was positioned.

The voltage of the truck could be assumed to have reached a level of at least:

$$V = R \times I$$

Where V = the voltage of the truck-hose system

I = the streaming current provided by the charged toluene

R = the resistance to ground of the truck-hose system

$$V = (1\times10^{10}).(3\times10^{-6})$$

Minimum truck voltage = 30,000 volts

As the ignition of the vapours occurred in the sump, the discharge must have been from the hose to the metal rim of the sump. However, in order to prove this theory we must investigate the hose itself. As stated earlier the hose was made from neoprene with an embedded metal wire helix. This means that the metal spiral was not in direct physical contact with any external objects. In addition, neoprene is a high resistivity material with a dielectric strength that is several times greater than air with a typical value of 10,000 volts required per mm of spark gap. The neoprene layer was 2 mm (0.08 in.) in thickness. This would mean that for every millimetre of distance between the metal helix and the metal sump there must have been a high enough voltage to discharge a spark with enough energy to exceed the MIE of the toluene. In order to breakdown the neoprene, at least 20,000 volts must have been present to achieve this. Given that the minimum voltage on the truck-hose system is estimated to be at least 30,000 volts it means an extra 10,000 volts would have been present to discharge from the neoprene surface to the sump. So, at some point in the operation, a gap between the surface of the hose and the sump must have been created resulting in a complete spark being discharged across a gap that had toluene vapours present.

The final part of the jigsaw is the potential energy of the spark itself. We can estimate the amount of energy available for a discharge via the spark from the equation:

Potential energy of spark (Joules) = ½ x capacitance of charged object x square of the object's voltage.

$$E = \tfrac{1}{2} CV^2$$

If we estimate a low value of 1 nano-farad for the truck's capacitance value ($1x10^{-9}$ F) combined with a voltage of 30,000 volts on the truck-hose system at the time of ignition, we can assume a total potential energy of 450 milli-joules, which is far in excess of the MIE of toluene which is 0.24 milli-joules. A certain percentage of the energy would be given off in the form of sound and radial heat, but a significant percentage would have been released in the spark gap, igniting the toluene in the process.

Grounding: getting it right

It's pretty obvious that not grounding the truck was the single biggest contributor to this fire. However, grounding is not simply connecting the truck to something that looks like it's entering the ground. Careful consideration needs to be placed on the method of grounding and what parameters can be implemented so that a constant connection to ground is maintained for the duration of the operation. As stated earlier there are many guidance documents that can be followed in relation to providing effective grounding of equipment. In relation to vacuum trucks there are two guidance documents that should be adhered to.

These are:

- API 2219 "Safe Operation of Vacuum Trucks in Petroleum Service".
- IEC TS 60079-32-1 "Explosive atmospheres. Electrostatic hazards, guidance".

The code of practice outlined in API 2219 recommends the following:

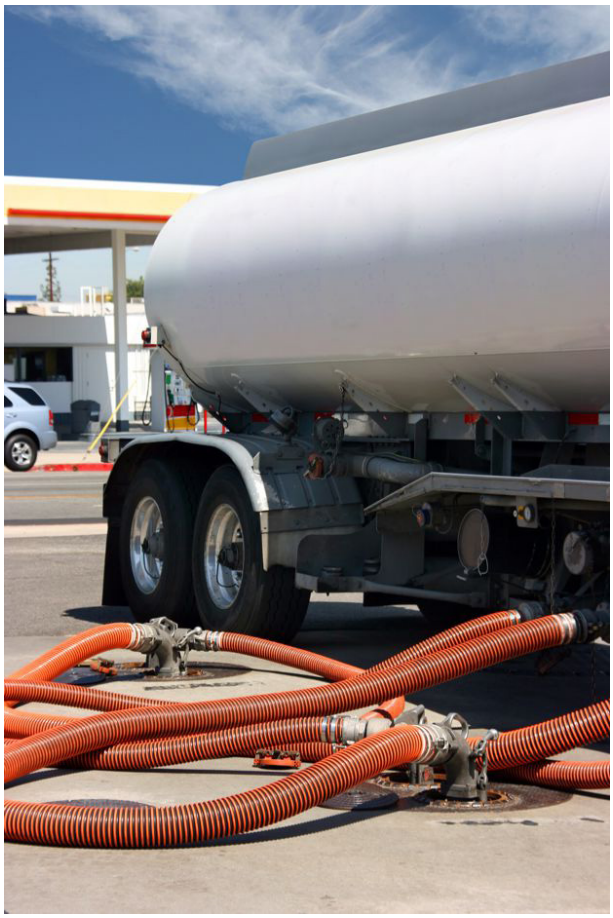
- "Before starting transfer operations, vacuum trucks should be grounded directly to earth or bonded to another object that is inherently grounded such as a large storage tank or underground piping."
- "A designated, proven ground source is preferred."
- "This system (grounding) should provide an electrical contact resistance of less than 10 Ohms between the truck and a grounded structure."
- "To assure proper bonding, the continuity should be verified with an ohmmeter following connection and prior to operation.

In a nutshell API 2219 recommends that the truck be connected to a "proven" ground source and that the connection to the ground source is not greater than 10 Ohms resistance. In order to ensure the connection resistance does not exceed 10 Ohms, this connection should be verified with an ohmmeter or some other device capable of indicating a 10 Ohm or less connection resistance.

The code of practice in IEC TS 60079-32-1 recommends the following:

- "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 MΩ for all other connections."
- "This requirement should be verified with a truck mounted earthing system or portable ohmmeter."

In summary IEC TS 60079-32-1 states that the truck should only be grounded via "designated" grounding points. "Designated" means that the point has been tested and verified as having a direct connection to earth.

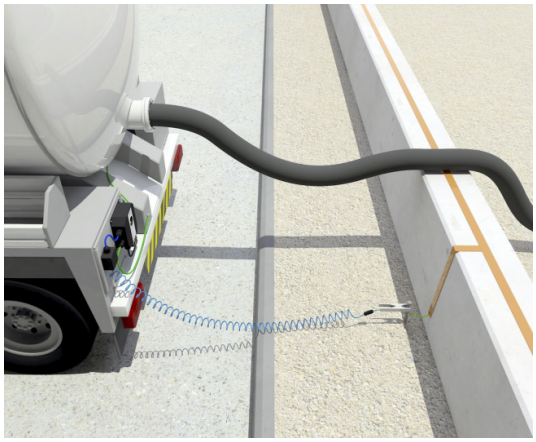


The primary function of designated grounding points is to provide grounding protection for electrical circuits, lightning strikes and static electricity. The resistance from the truck to the designated grounding point should not exceed 10 Ohms and should be verified with a truck mounted grounding system or ohmmeter. Metallic systems include electrical circuits inside grounding systems as the static charge should pass directly from the truck to the grounding clamp via copper tracking located on the grounding system's PCB.

Summary

If a truck mounted grounding system had been used by the contractor providing waste removal service at the site in this case study, this fire would have been avoided. There are several benefits of using a truck mounted grounding system. One such example is the Earth-Rite® MGV.

- The Earth-Rite MGV automatically verifies if the truck is connected to a ground source that is connected to the mass of the earth.
- It will monitor the resistance between the verified ground source and the truck so that if exceeds 10 Ohms the green LED indicators will switch form pulsing green to red.
- Internal dry contacts can be utilized to shut down the movement of liquid or powder if the Earth-Rite MGV detects that ground connection is not present.
- Site electricians do not need to perform a one-time check with a meter. The Earth-Rite MGV will not only perform this check automatically for the driver, it will continue to monitor the connection for the duration of the transfer operation.



If you have any questions on this case study e-mail Newson Gale.
If you would like to learn more about the Earth-Rite MGV follow this link to the product webpage.

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