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Case Study

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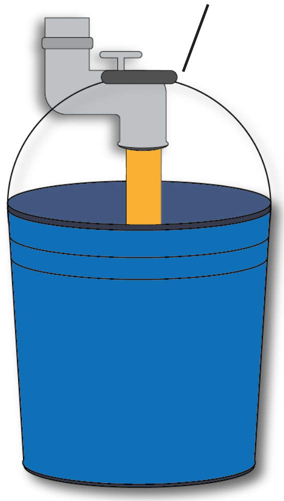
Drawing Toluene into an Ungrounded Bucket

Source: Pratt, T.H. and Center for Chemical Process Safety Staff (1997) Electrostatic Ignitions of fires and explosions. United States: American Institute of Chemical Engineers., Thomas H. Pratt 1997

Although static electricity can be regarded as a difficult subject to grasp, we hope that our series of case studies give you an insight into the reasons why static electricity provides an ignition source for serious fires and explosions that occur during everyday operations involving the handling and processing of flammable products.

This case study investigates the factors resulting in an electrostatic ignition incident involving toluene, a prolific charge generator filling a metal bucket via gravity fed 0.75" metal piping.

In this scenario, an operator opened a valve to draw toluene into a metal bucket with toluene from an overhead tank by gravity flow at approximately 5 gallons per minute. The operator hung a metal bucket with a wire bail and plastic handle over a globe valve. The plastic handle on the bail isolated the metal bucket from ground.



Metal bucket with wire bail hung over globe valve

On opening the valve, the operator backed away from the bucket allowing the toluene to flow as he had previously done several times. Within a few moments the toluene had ignited causing the operator to immediately leave the scene returning with a small fire extinguisher, which proved inadequate to put the fire out. The operator then left the scene returning with a larger fire extinguisher, however by the time he had returned the fire was out of control and he was unable to close the valve to prevent the flow of toluene to the bucket which was already over flowing.

The investigation into the incident outlined that the operator had opened the valve and backed away from the metal bucket. The operator stated

> ***"I was just standing there looking at it when it caught fire."***

As a result, discharge from the operator could be ruled out as a cause of the incident and the scenario of a streaming current was considered.

(I) $I_s = 2.5\text{x}10^{-5} \cdot v^2 \cdot d^2$

(II) $I_s = 2.5\text{x}10^{-5} \cdot 1.106^{92} \cdot 0.01905^2$

(III) $I_s = 0.01\mu A$

Where:

I_s = Streaming Current (A)
v = Velocity (m/s)
d = Pipe diameter (m)

The streaming current was found to be in the order of 0.01 μA were it not for the presence of the in-line filter. The residence time of the toluene between the in-line filter and the exit of the pipe was less than a second, much shorter than the recommended 30 seconds; therefore, a reasonable estimate of the streaming current at the exit of the pipe can be calculated around 0.1 μA. In any case, an estimate for the streaming current can be assumed to be between 0.1 μA and 0.01 μA.

Assuming that the toluene flow had continued for 30 seconds, there would have been a charge of 3 μC on the bucket provided that the bucket was completely isolated from earth.

The potential energy on the bucket can be found using the equation:

$$\text{Potential Energy (W)} = \frac{Q^2}{2C}$$

Where:

(I) Q = Charge on the bucket
(II) C = Capacitance of the bucket

Therefore the potential energy on the bucket:

$$\text{(I) } W = \frac{(3 \text{ x } 10^{-2})^6}{2(20 \text{ x } 10^{-12})} = 225 \; mJ$$

And the voltage on the bucket can be found using the Equation:

$$V = \frac{Q}{C} = \frac{3 \text{ X } 10^{-6}}{20 \text{ X } 10^{-12}} = 150{,}000 \; V = 150 \; kV$$

With the breakdown strength of air at 3 x 10^6 V/m a spark from the bucket could easily jump across a gap of 50 mm (1.96") meaning it was probable discharge from the wire of the bail to the body of the globe valve could occur.

Using a more conservative approach, the lower streaming current value of 0.01 μA used in the same calculation yields a potential energy of 2.25 mJ, a voltage of 15 kV, and a spark gap of 5 mm (or some 0.19").

With the MIE of toluene calculated to be 0.24 mJ a potential discharge with energy using the most conservative assumption of 2.25 mJ is still sufficiently high enough to ignite the flammable vapours produced by the toluene present in this process.

How could this have been prevented?

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 process operations that have suffered from the consequences of a fire or explosion caused by static electricity.

The first place to start is to determine why electrostatic charge was "permitted" to accumulate on the bucket. In this case electrostatic charge accumulated on the bucket because it was electrically isolated from the general mass of earth. Had the bucket been connected to a true earth ground charge would not have been accumulated on its surface. Instead excess electrostatic charges would simply have found their way to earth. So in accordance with industry guidelines like NFPA 77 and IEC TS 60079-32-1, the isolated bucket should have had a connection to a verified ground (in this case the process vessel) with a resistance of 10 ohms or less.

Both IEC TS 60079-32-1 (13.4.1) and NFPA 77 (7.4.1.6) & (7.4.1.4) state:

"Temporary connections can be made using bolts, pressure-type earth (ground) clamps, or other special clamps. Pressure-type clamps should have sufficient pressure to penetrate any protective coating, rust, or spilled material to ensure contact with the base metal with an interface resistance of less than 10 Ω."

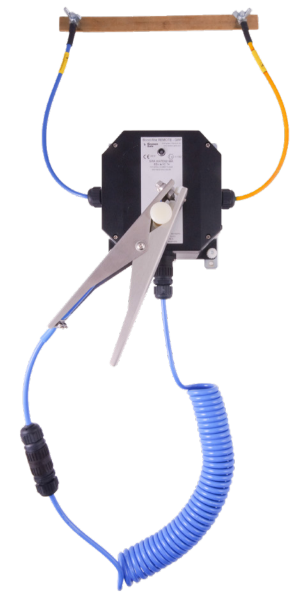
As can be seen from this case study, when highly flammable or combustible products are being handled it is essential to specify certified equipment which will protect the safety of your plant and employees.

Static grounding clamps and cables like the ones highlighted in the image below, are ATEX/FM certified to prevent any physical impedances such as paint coatings, product deposits and rust ensuring a good electrical connection has been made to the equipment's base metal.

ATEX/FM approved static grounding clamps with grounding station

For operations requiring continuous grounding, the next level of protection would be a self-testing earthing clamp with visual indication.

The Bond-Rite® REMOTE is a wall mounted static grounding device which encourages the operator to ground the equipment before the process starts. The ground loop monitoring system ensures a positive connection resistance of 10 ohms or less. Pulsing green LED indicators inform the operator with a simple GO/NO GO instruction that the process is ok to start.



Bond-Rite® REMOTE - Continuous Ground Loop Monitoring with visual indication

If you have any questions on this case study e-mail Newson Gale.

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.

United Kingdom
Newson Gale Ltd
Omega House
Private Road 8
Colwick, Nottingham
NG4 2JX, UK
+44 (0)115 940 7500
groundit@newson-gale.co.uk

United States
IEP Technologies LLC
417-1 South Street
Marlborough, MA 01752
USA

+1 732 961 7610
groundit@newson-gale.com

Deutschland
IEP Technologies GmbH
Kaiserswerther Str. 85C
40878 Ratingen
Germany

+49 (0)2102 58890
erdung@newson-gale.de

NG US CS03 Drawing Toluene BR 011021 R7