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Learning lessons from five electrostatic incidents

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ABSTRACT

It is well known that electrostatic discharges can ignite mixtures of flammable gases with air and suspensions of combustible dust in air. For this reason, the prevention of electrostatic discharges is an essential part of measures to prevent explosions and fires. Incendive electrostatic discharges occurred in five cases in various chemical plants.

The incidents involved were:

1. Spark type electrostatic discharges from a leaking steam pipe.
2. Spark type electrostatic discharges inside a charging chute for a solid.
3. A spark type electrostatic discharge whilst transferring a solid powder from a bin, which led to ignition of the powder.
4. A propagating brush discharge during pneumatic transfer of solid, which caused a severe electric shock to a process operator.
5. A brush discharge inside an electrostatic precipitator which caused ignition of an aerosol of hydrocarbon.

To avoid explosions and fires it is important to prevent incendive electrostatic discharges from occurring in industrial facilities. To help managers of chemical plants to do this, the incidents above are presented in the form of learning lessons including:

- the mechanism of the generation and separation of electrical charges,
- the mechanism of the electrostatic discharge,
- the root causes of the incident,
- the safety measures which are necessary to avoid a repetition.

1. Spark type electrostatic discharges from a leaking steam pipe

1.1. Description of the incident

During engineering work near an insulated steam pipe, repeated electrostatic discharges were seen between the metallic insulation covers and the steam pipe itself, close to a flange joint. The pipework was situated in an area classified zone 2 (i.e. a place in which explosive mixture of a flammable gas/vapor/mist with air or another oxidant gas is not likely to occur in normal operation but, if it does occur, will persist for a short period only).

1.2. The facts

There was a steam pipe inside a classified hazardous area of a chemical manufacturing plant. The steam pipe had rock-wool type insulation with galvanised steel covers. Work was carried out to install a cable tray near to the steam pipe. The tray was made of steel, covered with epoxy paint and destined to carry electrical instrumentation cables. The sparks were seen after completion of this work. Steam was leaking about 1 m away from the place where the discharges were seen. When a field meter was held about 1 m from the leak, an electrical field was detected. It was noticed that

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the insulation covers of the steam pipe had been dented. The electrical resistance between the insulation covers and ground was high (over 10^6 Ω). The discharges disappeared as soon as the insulation covers were bonded to the pipe.

1.3. The explanation

Aerosols are known to generate electrostatic charges, whatever the electrical resistivity of the fluid. When there is a leak of steam, water droplets are formed by condensation etc. The droplets become charged by a process of contact-separation with the pipe as well as by division of the cloud into droplets with opposite charges. So a permanent electrical field is formed near a steam leak.

The insulation cover situated near the leak was electrically isolated (this probably happened when the cable tray was put in place), which is confirmed by the fact that the phenomenon stopped when the cover was bonded to the pipe.

The isolated conductor, which was situated near to a continuous generator of electrostatic charges, picked up those charges from the droplets of water. Its electrical potential rose and so did the associated electrical field. It reached the rupture threshold of air, 3 MV m^{-1}, in some places leading to a spark type of electrical electrostatic discharge. See Fig. 1.

Normally air is an insulator. But when there is a very strong electrical field, molecules of air are ionised. Equal numbers of positive and negative ions are formed and they move in opposite directions in the electrical field. A plasma, consisting of ionised air at high temperature, is formed and an electric current flows. In the case of a short circuit, the current is continuous: an arc. In the present case, only a limited quantity of charge could be stored on the insulation cover. So, when sufficient charge had built up, there was a spark, using up the stored charge and neutralising the electrical field. Then the charge and the electrical field built up again, until the rupture threshold was reached, leading to a further spark. In this way a discontinuous current, or series of sparks, was generated.

1.4. Lessons

Inside ATEX zones for gases and for dusts, all metallic equipment must be securely grounded or bonded to equipment which is itself grounded. The resistance between metallic objects and ground should be checked on a regular basis. If it is not practical to test every item then a sample of representative items should be tested. If any faults are found in the sample then all metallic items in the zone should be checked. The resistance between a metal object and ground should be less than 10 Ω. If the resistance is greater than 10 Ω, it is not dangerous as such but it indicates that there is a problem. The danger level is much higher: 10^6 Ω for metallic objects and 10^8 Ω for dissipative objects and personnel.

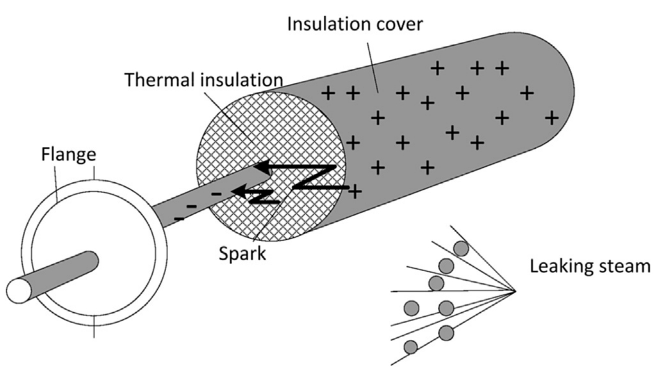

Fig. 1. Electrostatic discharges from a leaking steam pipe.

2. Spark type electrostatic discharges inside a solid charging chute

2.1. Description of the incident

A customer complained that our adipic acid was giving visible sparks when unloaded from super sacks to the solids charging hopper in his installation. He thought that the super-sacks were unsuitable because they were not grounded. We supply adipic acid in type B super sacks. They are insulating and indeed cannot be grounded, but they have a breakdown voltage under 6 kV, in order to avoid propagating brush discharges. Our competitors use the same type of super sack for their adipic acid.

2.2. The facts

We visited the customer's installation, which is shown below (see Fig. 2). Adipic acid was unloaded to a solids charging hopper and passed via a rotary valve to a mixing vessel underneath. There was a loose fitting steel cross piece in the charging chute. In fact sparks were observed when several different organic solids were unloaded from super sacks to the hopper. These materials gave sparks whether the super sacks were type A (insulating), type B (breakdown voltage below 6 kV) or type C (conducting).

2.3. The explanation

Whenever solids move, for example, when an insulating solid is emptied from a super-sack, opposing charges are generated. The particles of solid which are transferred to the hopper have one sign (say negative in order to simplify the discussion) and opposing (positive) charges are left on the inside of the super sack. The latter charges are located on particles of solid which remain behind (the insulating plastic can acquire comparatively little charge).

There was a cross-piece in the charging chute, as is very common in this type of installation. Its role was to stop the liners present in some super sacks from falling into the hopper. The cross-piece had no grounding line. Presumably, on the first batch of a campaign with a given raw material, the charging chute was perfectly clean and the cross-piece was grounded by contact with it. Then, as the installation was used repeatedly, solid built up. Now organic solids, such as adipic acid, are nearly all insulating. At some point the cross-piece was no longer effectively grounded. But it was in contact with moving particles of solid which were flowing into the hopper. The movement of solid against the cross-piece created opposing charges. Charges of one sign stayed on the particles. Opposing charges were retained on the cross piece which became charged itself, creating an electrical field between itself and the charging chute. This charging mechanism is known as “contact-separation” or “tribocharging”. The charging chute was metallic and bolted to other large metallic equipment items, so it was effectively grounded.

Between two parallel plates at different potentials a uniform electrical field is formed. The electrical field strength, E, in Volts per meter, is given by:

$$E = \frac{U}{d} \quad (1)$$

where:

U is the difference in potential in Volts
d is the distance in meters.

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