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ELECTROSTATIC HAZARDS IN THE CHEMICAL PROCESS INDUSTRY

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Introduction

In the chemical process industries, electrostatic ignition risks often go unrecognised. They can be lurking during the handling of liquids and powders, for example. Both substances readily produce electrostatic charges that pose a very real hazard of ignition. To minimise these risks is an essential part of process safety management.

This article describes the electrostatic charging processes and hazards during liquid and powder processing operations. It covers the general principles and procedures that minimise the electrostatic risks. It illustrates electrostatic hazards with a case study associated with manual transfer of materials into a chemical reaction vessel. The issue is: Hazards are real but can be controlled.

Electrostatic charging

The process of charge generation and retention on insulating materials, both liquids and solids is well understood. Electrons are transferred across the interface between different materials in contact, producing a positive charge on the donor and an equal negative charge on the recipient. If either of the materials is a poor electrical conductor, the charges will remain on both contacting surfaces. Electrical conductors (e.g. metal) on one side of a surface will retain the electrostatic charge only if isolated from ground. Even if the metal is grounded, charge is still produced [1, 2, 3, 4].

Surface properties of the materials influence the magnitude and polarity of the charge. Environmental conditions, particularly humidity, have an effect. For instance adsorbed water affects the charging process and radically alters the charge migration properties of insulators. A thin film of moisture is formed on the material surface. That provides a conduction path for the charge to dissipate to ground.

The magnitude of the retained charge relates to the contact area and to the speed of contact and separation. In practice, due to surface roughness only a fraction of the geometric area is available for intimate contact. The contact area increases with an increase in the impact speed which could, in turn, results in a higher charge separation. This is especially true if one of the contacting components exhibits some charge dissipation characteristics. All these mechanisms apply to both solids and liquids, although liquids can also become charged by breaking up into droplets by splashing or spraying.

The electrostatic ignition hazard arises when the local electric fields adjacent to charged surfaces exceed the dielectric strength of the surrounding atmosphere - usually air. An electrical discharge can then be produced. If that discharge is in the presence of a flammable vapour and air, or dust and air mixture, it can cause ignition. A minimum amount of energy is required to cause ignition depending on material. Typical values for some common solvents and sensitive dusts are listed in Table 1.

The Minimum Ignition Energy (MIE) relates to the optimum flammable mixture. It is clear from the table that it generally requires more energy to ignite flammable dust clouds than vapor atmospheres. The sensitivity or Minimum Ignition Energy (MIE) of chemical powders (intermediate) often isn't known. It is best to determine this as part of any hazard assessment.

Predicting the energy of discharges from charged surfaces is possible if the material is a conductor and data are available for capacitance of the surface. The discharge energy provided by charged insulators is unpredictable. Energies of several millijoules can be produced. Such discharge can clearly ignite flammable solvent vapours; but only the more sensitive dust clouds.

TABLE 1

MINIMUM IGNITION ENERGIES (MIE) FOR SOME MATERIALS (5)	
Material	MIE (mJ)
Alkanes	0.28
Aromatics	0.2
Hydrocarbons	0.3
Alcohols	0.14
Acetone	1.15
Aluminium	10
Coal (37% volatiles)	60
Magnesium	20
Polystyrene	15

Chemical reaction vessels

Below is a review of a typical chemical process, transfer of powder into a reactor, and an assessment of the possible ignition hazards. It is followed by a case study that highlights the systematic approach to identify the potential electrostatic hazards. Lastly, there will be suggestions for eliminating the risk of an ignition by such discharges. It is a common practice to partially fill a reaction vessel with solvents and then add reactant powders from plastic lined drums manually through an open manhole. Two problems can arise. The solvent itself can become charged if splashing, agitation, or recirculation occurs. Also, glass-lined vessels particularly retain this charge.

Also, expect the powder to pick up a charge as it leaves the drum. This produces a counter-charge on the drum liner and on the operator, unless he or she is electrically grounded. At the same time a flammable solvent-air or dust-air mixture can be produced at the manhole and inside the reactor within a few moments of opening the reactor. The mixture can get ignited by discharges from the liner and even from the operator who becomes an isolated electrical conductor.

Incident Description

The following case study describes an incident that occurred during manual additions of materials into a reactor vessel and discusses a systematic approach for quantifying and eliminating the electrostatic hazard.

A 1,000-gallon glass-lined reactor was washed with acetone and left to drain for 24 hours. The task for two process operators was to charge the vessel with 1,000 kg of a fine chemical intermediate. The powder supply comes in polyethylene-lined fiber-board drums, each containing about 50 kg of powder. The procedure is for the operators to work together and tip the drum contents into the vessel. The drum liner is not to fall into the reactor. During the unloading of the sixth drum, something exploded. There was a flame front and pressure wave from the charge hatch. The operators were badly burnt.

Measurement and Results

To begin an investigation of the incident follow these three steps:

1. Measure ignition sensitivity and electrostatic properties of the powder
2. Measure electrostatic properties of the equipment
3. Conduct trials under realistic plant conditions

(a) Properties of Reactants:

Electrical volume resistivity (per British Standards 5958) $\approx 10^{15}$ ohm.m

Charge decay time ≈ 3 h

Powder minimum ignition energy (per British Standard 5958) ≈ 1 to 5 mJ

Acetone minimum ignition energy (see table) ≈ 1.15 mJ

In electrostatic terms, these data indicate that the powder is highly resistive. Charged powder in contact with ground would take about 3 hours to lose its charge.

The powder was stored in a polyethylene-lined drum under low humidity conditions with no opportunity for loss of charge by conduction. The powder can be ignited with an electrostatic spark of very low energy (1 to 5 mJ).

(b) Properties of Equipment:

Resistance of drum to ground $\approx 10^{12}$ - 10^{13} ohm (resistance is due to footwear of the operator holding the drum)

Resistance of floor to ground (metal floor) < 10 ohm

Surface resistance of liner $> 10^{15}$ ohm

End-to-end resistance of fibreboard drum $\approx 10^6$ ohm

(c) Simulation Results:

The lab technicians suspended a filled fibreboard drum from a hoist with nylon ropes to electrically isolate it from ground. The isolated drum had a capacitance of 250 pico-Farads (pF). This is the baseline before opening.

The test consisted of emptying the drum contents and measuring the build-up of voltage on the drum using an electrostatic voltmeter. The voltages found exceeded 12,000 volts, reflecting a stored energy of 18 mJ. When a grounded probe was brought close to the charged drum there was a spark from the drum to the probe.

Analysis of incident

The most likely explanation is that a discharge of static electricity from the drum to the grounded plant ignited a flammable atmosphere. The flammable atmosphere was probably a mixture of acetone vapour plus powder fines from reactor loading.

Another test was run. It showed that even 24 hours after washing with acetone, the lab could detect 30% or more of the lower flammable concentration limit. Also, the fine dust was very easy to ignite (MIE of 1 to 5 mJ). A static spark from the drum can ignite either an acetone-vapour atmosphere or this dust or combination of both.

The 18 mJ of stored energy measured in the tests was greater than the minimum ignition energy of both powder and acetone vapour. If the drum and operator are both isolated from ground, a higher spark energy than 18 mJ could have resulted when the operator was holding the drum.

Safety Suggestions

A number of changes are possible to improve reactor charging safety:

1. If possible, avoid charging powders to reactors containing flammable solvents.
2. Use antistatic plastic liner, together with a drum grounding clip. Make sure they are connected to ground.
3. Pre-purge the reactor with nitrogen. Then charge the reactor through an open air-lock systems so that nitrogen can be retained in the receiving vessel.
4. Make personnel wear antistatic footwear and gloves to ensure good grounding. The local floor should be conductivity treated to give an operator resistance to ground of less than 10^8 ohm.

The Generalised Approach

Electrostatic ignition hazards exist in the chemical process industry. Every process can present a particular hazard. Combat hazards by identifying all potential electrostatic ignition sources and then take appropriate steps to:

- 1) Reduce electrostatic charge generation
- 2) Eliminate static charge accumulation
- 3) Prevent the formation of flammable atmospheres
- 4) Train personnel to recognise hazards and to adopt the correct safety procedures.

References

1. Harper, W.R., "Contact and Frictional Electrification", Oxford Press, Oxford, England, 1967
2. Blythe, A.R., and Reddish, W., "Electrostatics 1979", Inst. Phys. Conf. Ser. No. 48, pp. 107-114, 1979
3. Bauser, H., Klopfer, W., and Robenhorst, H., "Advanced in Static Electricity", 1, p.2, Auxilia, Brussels, 1970
4. Krupp, H., Proc. Third Conf. Static Electrification, Inst. Phys. Conf. Ser. No. 11, p.1, 1970

5. Shell Safety Committee, June 1988

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