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Electrostatic Hazards Associated with Liquid and Powder Processing

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Introduction

Often, an electrostatic ignition hazard arises when the electrostatic charge generated in a process is allowed to accumulate to levels sufficient to give rise to electrostatic discharges. Thus, the first step in an electrostatic hazard assessment is identifying where in the process electrostatic charge can be generated and accumulated. Next, if the generation and accumulation of charge cannot be controlled, the types of electrostatic discharges that can arise must be identified. Lastly, in order to verify that a hazard exists, the effective energy of these discharges must be determined and compared to the minimum ignition energy (MIE) of the prevailing flammable atmosphere or the dielectric strength of lining (the natural limitation of charge accumulation) in vessels, containers and piping.

A systematic approach for identifying electrostatic hazards is outlined in the National Fire Protection Association (NFPA) Recommended Practice # 77. This document states that an assessment of each process should be conducted to identify electrostatic hazards, including ungrounded conductors, such as metal devices and equipment, personnel, as well as items made from electrically insulating materials. The assessment should:

1. Be conducted under actual operating conditions, to the extent practicable;
2. Be based on actual measurements of resistance-to-ground, electrical continuity, electric field strength, streaming current, and accumulated charge; and
3. Consider prevailing environmental conditions that may affect charge generation and accumulation.

This paper discusses some of the measures that could be considered for controlling potential electrostatic hazards during liquid and powder handling operations

Liquid Handling/Processing

Electrostatic charge is most commonly generated on liquids when they flow through pipes, hoses, and filters and when they are stirred. Liquids can also become charged if they are transferred into a container that is either already charged (e.g., an electrostatically charged plastic container) or becomes charged while containing the liquid (e.g., when the outside surface of a plastic container containing a liquid is rubbed). Charge can accumulate within the liquid if it is insulating in electrostatic terms or electrostatically isolated from ground. The accumulation of electrostatic charge on the liquid's surface can give rise to electrostatic discharges from the surface. These discharges can be sufficiently energetic to ignite flammable vapor, such as that which may be evolved in the vessel headspace from a flammable liquid, or a liquid processed above its flash point.

The flow and agitation of liquids can also cause insulating (plastic or rubber) and ungrounded conductive (metal) vessels, piping, and fittings to become electrostatically charged. Charge accumulated on insulating (plastic or rubber) and ungrounded metal devices and equipment can give rise to electrostatic discharges sufficiently energetic to ignite flammable atmospheres. Electrostatic charge accumulation on the insulating linings (glass or plastic) of vessels and pipes could also result in the creation of pinholes in the lining, causing leaks, corrosion of the piping or vessel, and contamination of the liquid. It should be noted that pinholes could even occur under inert atmospheres. Consequently, it is essential to identify and eliminate or control electrostatic charge generation, accumulation, and/or discharges. Approaches for controlling electrostatic hazards associated with liquid processing include:

<u>Raising the Liquid's Conductivity</u>

The potential electrostatic hazard posed by a liquid can be reduced by increasing its electrical conductivity. Specifically, it is desirable to increase the conductivity of single-phase liquids above 100pS/m (picosiemens per meter), and liquids containing solids and immiscibles above 1,000pS/m. This can be accomplished through the addition of conductive liquids or antistatic additives.

<u>Grounding of the Liquid</u>

Efforts should be made to keep liquids in continuous contact with electrical ground, even in insulating vessels and plastic-lined piping, in order to minimize the accumulation of electrostatic charge on the liquid. In insulating vessels, a suitable pathway may be provided by a grounded, metal-bottom runoff valve, a grounded tantalum patch below the liquid surface, or a grounded metal dip pipe. The incidence of pinholing can be eliminated by using an antistatic or conductive lining.

<u>Limiting the Liquid Velocity</u>

Limiting the liquid velocity during filling operations helps to reduce electrostatic charge generation during pipeline flow, as well as minimizing splashing and spraying in the receiving vessel or container. If flow velocity limitations cannot be observed or if a grounded metal dip pipe cannot be used, it may not be possible to dissipate electrostatic charge from the liquid at a rate sufficient to reduce the probability of ignition from an electrostatic discharge from the liquid to a suitably low level. Therefore, in such cases, *inerting* of the vessel or container before and during filling should be considered in order to minimize the fire and explosion risk.

Managing Electrostatic Hazards During Filtration

Liquids are often passed through a filter before they are introduced to a receiving vessel or container. The flow of liquids through filters is often characterized by the generation of relatively high levels of electrostatic charge due to the relatively large amount of surface area available for contact. It is desirable to dissipate the electrostatic charge from a flammable liquid before it enters a receiving vessel in order to reduce the potential electrostatic ignition hazard. This is typically accomplished by locating filters as far upstream of receiving vessels as possible, so that charge can be dissipated from the liquid in the grounded metal piping downstream of the filter before the liquid is introduced to the vessel.

Managing Electrostatic Hazards During Agitation

Because electrostatic discharges from the liquid surface are inherent to the operation, it is generally recommended that agitation of electrically insulating liquids be conducted under an inert atmosphere.

Powder Handling/Processing

In this section, it is assumed that the powder *does not* contain any flammable solvent, and it is handled and processed in an atmosphere free from flammable gases and vapors.

Charge Generation

Although the magnitude and polarity of charge is usually difficult to predict, charge generation should almost always be expected whenever powder particles come into contact with another surface, or each other. It occurs, for example, during mixing, grinding, sieving, pouring, and pneumatic transfer. The chemical composition and the condition of the contacting surfaces can often influence the charging characteristics.

Charge Accumulation

Generally, powders are divided into three groups, depending on their ability to retain static charge, even if the powder is in contact with an electrically grounded conductive object. This ability is known as volume resistivity:

1. Powders with volume resistivity up to about $10^6 \Omega.m$ are considered conductive;
2. Powders with volume resistivity in the range $10^6 \Omega.m$ to $10^9 \Omega.m$, are medium resistivity powders; and
3. Powders with volume resistivity above $10^9 \Omega.m$ are high resistivity powders.

Charge will accumulate on a powder if the charge generation rate exceeds the rate at which the charge dissipates to containment or the atmosphere.

Electrostatic Discharges

The accumulation and retention of charge on powder or equipment creates a dust explosion hazard only if the charge is suddenly released in the form of a discharge with sufficient energy to ignite the dust cloud. Potentially incendive discharges resulting from charged powder and equipment include: spark discharges, brush discharges, propagating brush discharges, and cone (bulking) discharges

General Precautions for Powder Handling/Processing

Bonding and Grounding
Spark discharges may be avoided by electrically grounding conductive items, such as metal devices and equipment, fiberboard drums, low resistivity powders and people.

Use of Insulating Materials
Where there could be high surface charging processes, non-conductive materials should not be used, unless the breakdown voltage across the material is less than 4kV. Examples of non-conductive objects include flexible connectors, hoses, plastic pipes, containers, bags, coatings, liners, and filter elements.

Charge Reduction by Humidification
High relative humidity can reduce the resistivity of some powders and increase the rate of charge decay from bulked powder in grounded metal containers. However, in most cases, this will only be effective if a relative humidity in excess of 65% is maintained. This is often impracticable due to agglomeration issues. See the section on “Static Electricity and Relative Humidity” (below) for more information.

Charge Reduction by Ionization
Localized ionization (corona discharges) from sharp, grounded, conducting probes or wires can, on occasion, be used to reduce the level of electrostatic charge from powder particles entering a vessel. Electrostatic ionization devices are not, however, without problems, and should only be used after consulting expert advice. See the section on “Electrostatic Charge Neutralization” (below) for more information.

Explosion Protection
In some powder handling processes, it is not possible to avoid having both an explosible dust cloud and hazardous build up of charge. In those situations, additional measures should be taken to prevent or protect against the consequences of dust explosions. These include inerting, use of explosion resistant equipment, explosion venting or explosion suppression.

NOTE: The above precautions are not intended to be exhaustive or all-inclusive. Rather, they are the precautions most commonly employed, and address some of the more common liquid and solid processing operations. These precautions are necessarily general in nature and therefore may not be appropriate for all applications. Additional or different precautions may be required depending upon the specific application or conditions that could not have been reasonably foreseen. Additional precautions concerning the operations covered in this document and other operations should be reviewed. Expert advice should be sought as necessary.

Additional Information on Electrostatic Hazards

Electrostatic Charge Neutralization
Electrostatic charge on materials often leads to problems with their handling and control. Charged powders may stick where they are not wanted and be difficult to move to where they are wanted. The solution is usually to encourage the charge to dissipate naturally by conduction through the material; however, there are occasions when this will not work and the only answer is electrostatic charge neutralization.

Charge neutralization (otherwise known as static elimination) involves generating ions in air and directing the opposite sign of ion towards the charged material. For example, a negatively charged item would have a stream of positive ions directed at it so that, with the appropriate controls in place, the material is just taken to electrical neutrality, at which point the problems cease.

Four main types of static eliminator are in use today: passive, active AC, active DC, and radioactive. In addition, various manufacturers have their own preferred enhancements for most of these. However, given the four main types of static eliminator, the various sub-types, and the fact that some are suitable for use in the presence of flammable atmospheres, it can often appear that there are a very large number of possible devices available. In reality, though, only one or two may be best suited for a particular application. Furthermore, the location of installation can often be crucial, making all the difference between a system working, failing to work, or even making things worse. In a few situations, it is even possible that an inappropriately installed static eliminator could introduce a hazard where previously there was none.

Static Electricity and Relative Humidity

We all encounter static electricity in our everyday lives. However, few people receive training in the field, including professional engineers. This leads to the common misconceptions that static is unpredictable, and that dealing with it is some kind of "black art." One important factor leading to this impression is the effect of relative humidity.

<u>Relative Humidity</u>
Relative Humidity is the amount of water vapor in the air, expressed as a percentage of the maximum possible. As the maximum varies with temperature, relative humidity is not an absolute measure of the concentration of water in air, but it can be thought of as an indicator of its availability.

<u>Relative Humidity and Solid Surfaces</u>
For solids that have an affinity with water, relative humidity (availability of water in the air) determines the amount they can attract to their surfaces. This surface adsorption of water can seriously affect the electrostatic properties of any solid, including sheet, films, granules, and powders. The amount of water required to affect electrostatic properties may be less than a molecular monolayer, often too little to be detected using normal moisture content measurements.

<u>Relative Humidity and Static Electricity</u>
Any material will exchange charge with another that it contacts. This is most commonly seen when one material is rubbed against another. One acquires negative charge, leaving behind a positive charge on the other. Whether either or both of these charges will be problematic, or even apparent, depends on the rates of charge gain and charge loss, both of which occur simultaneously, and both of which may be affected by relative humidity:

- **Surface Resistivity** is measured in Ohms (Ω) per square and represents a material's ability to lose charge across its surface. Normal variations in relative humidity can alter the value of surface resistivity by several orders of magnitude, enormously affecting a material's ability to dissipate charge. A value to remember is:
  - More than 10^{10} Ω per square and the material is considered insulating.
- **Powder Volume Resistivity** is measured in Ohm-metres (Ω.m) and represents a powder's ability to lose charge through its bulk. Since many powders conduct electricity across the particle surfaces, powder volume resistivity may also change enormously with varying relative humidity. Values to remember here are:
  - Less than 10^6Ω.m indicates that the powder is conductive where static electricity is concerned.
  - Over 10^9Ω.m, a powder is considered insulating.

- **Charge relaxation time,** measured in seconds (s), is a very practical way of showing how quickly a material loses charge, through the bulk or across the surface. It is complimentary to, but not the same as, resistivity. Relative humidity changes can alter charge relaxation time enormously, too. Values to remember are:
  - Less than 0.1 s is considered a fast charge relaxation time in most situations.
  - More than 100 s is considered slow.
- **Chargeability** is a measure of the likely worst-case charge level for the material. Since charge is generated at the surface, chargeability, too, may be affected by relative humidity. For powders, chargeability is measured in Coulombs per kilogram ($C.kg^{-1}$), and values to remember are:
  - Less than 10^{-9} $C.kg^{-1}$ is a low chargeability powder.
  - More than 10^{-6} $C.kg^{-1}$ is a high chargeability powder.

All these properties are individually important, but also act together to determine the charge level seen in a process. Relative humidity can dramatically affect each property, and a proper understanding of how is essential to predict the overall effects in terms of likely static problems and hazards.

Some Practical Effects of Relative Humidity

During the winter months, when outdoor temperatures are cooler, the reduction in relative humidity, due to heating the air to a comfortable working temperature, will be much greater than during the summer. The trend is therefore for static problems to become more acute during the winter. Thus, Northern Hemisphere temperate regions experience more static problems from December to March than at other times of the year. This is especially true in areas with the most severe winters, such as northern sections of the U.S. and Canada.

Superimposed on this trend are daily variations in relative humidity with changing weather patterns. These changes, with the associated changes in severity of static problems, more than anything lead to the idea of an unpredictable phenomenon. Relative humidity can even vary within a plant area, such as inside a machine guard, which still further adds to the confusion; here are some examples:

- Some static dissipative plastics (sometimes referred to as “antistatic”) use additives that rely on atmospheric water to decrease their surface resistivities. If these are used in low relative humidity conditions, they may be just as insulating as the untreated plastic. If they have been specially selected to avoid an ignition hazard due to static, low relative humidity could even mean the unwitting introduction of the ignition source.
- A company was packing a powder automatically by weight into a sack, sized to take the desired weight. Some days the packing machine was inexplicably troublesome. It repeatedly stalled, and each time had to be shut down, cleaned, and re-started, significantly slowing production. An investigation showed relative humidity seriously affected the powder’s electrostatic properties. Furthermore, when highly charged, the repulsion between adjacent particles reduced the bulk density so much that the weight of powder would not fit in the sack. Thus, when properly understood, the problem could be attributed to static, and the apparent random occurrence to changes in relative humidity.

Dealing with Static and Relative Humidity

If static is believed or suspected to be a hazard, or if intermittent problems could be due to static, it is crucial to understand the effect of relative humidity on the electrostatic properties of all the materials involved by making appropriate measurements. Only then will it be possible to propose effective measures for the avoidance of static hazards and solving problems.