Generation and Control of Static Electricity in Coatings Operations

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Forward

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Technical illustrations and diagrams included in this publication illustrate principles and typical assemblies and are not intended to be prescriptive in nature. Readers are encouraged to use this publication and its accompanying illustrations in conjunction with sound professional judgment in developing equipment, processes and procedures appropriate to their facilities and operations.

New or additional information or measures may be required or desirable, either because of particular or exceptional conditions or circumstances, or because of federal, state or local laws and codes. Finally, users are encouraged to compare the recommendations contained in this document with applicable federal, state and local laws and codes as well as any common industry trade practices.

This document can be used by the reader as a basis to formulate a Static Electricity training program for operators and supervisory personnel responsible for manufacturing operations in coatings facilities. Awareness of static electricity and a basic understanding of how it is generated and how its effects can be mitigated can be a significant factor in the prevention of fires in coating operations.

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Chapter 1 Administration

1.1 Preface

1.1.1 This document is intended for personnel who are responsible for operations involving flammable liquids, gases and powders.

1.1.2 The information in this document will help the reader better understand static electricity — a major source of ignition of fires and explosions. Although the information focuses on coatings operations, the principles apply anywhere flammable liquids, solids and gases are used. Note that this is not a comprehensive course in static electricity or fire prevention, but rather an overview of the basics of static electricity as they relate to flammable liquid and powder handling.

1.1.3 The document addresses the technology and hazards of static electricity and how to identify when static charging is likely to occur. Although static charging cannot be eliminated, limiting the generation and accumulation of electrostatic charges to safe levels can minimize the hazard of electrostatic spark ignition. This document will suggest ways to lower the risk of creating a static spark of sufficient energy to ignite flammable vapors, powders and gases.

1.1.4 The information presented here is, to the best knowledge of the authors, correct and accurate. There is no guarantee, however, that following all of the recommendations in this document will prevent a fire from occurring. The nature of fire is of such complexity that it is impossible to account for all variations and permutations of events and circumstances that could lead to a fire. However, following the advice contained herein will diminish the possibility that a fire incident caused by a static spark will occur.

1.1.5 The authors strongly recommend that the user of this document read it in its entirety before attempting to apply the information contained herein. There is always a risk of misunderstanding when information is taken out of context. If the reader desires more information on these topics, references are listed in the Bibliography (Appendix B).

1.2 Scope This document is part of the Coatings Care® Program of the American Coatings Association (ACA). Coatings Care® is The Paint and Coatings Industry’s Health, Safety, Environmental, and Security Program created by the industry, for the industry. It is a globally recognized program designed to assist industry companies manage their health, safety, environmental, and security responsibilities. The aim of the Coatings Care® program is to protect worker and community health and safety, the environment, and ensure facility security while offering tangible business value.

1.2.1 This document is intended for use by persons responsible for the manufacture of coatings for automotive, architectural, industrial and home use to reduce the hazards of static electricity in these operations.
Chapter 3 Basics of Static Electricity

3.1 Introduction

3.1.1 To most people, static electricity is either a parlor trick (rubbing a balloon and sticking it on a wall) or a nuisance (static cling on clothes). Not many are aware of its hazards, and hardly anyone thinks of the beneficial aspects of the phenomenon called “static electricity,” “electrostatics” or simply “static.” Since the mid-1920s, electrostatic equipment has been used to clean up air pollution from power stations and smelters; today, these same types of devices are available to keep our homes free of pollen and dust. Ink jet printers and dry toner copiers use electrostatics to direct the placement of toner and ink droplets to create images. Automobiles are painted using an electrostatic spray process, which ensures a high quality, even application of paint while greatly reducing overspray that ends up as hazardous waste.

3.1.2 Static electricity has the capability to be quite hazardous. Static electricity is basically a motionless, “static,” “pile” of electrons, which represents a finite, measurable amount of energy. One can think of this pile as being a kind of battery or an unlit match. The hazard of static electricity is created when the energy in this “battery” is dissipated in the form of a spark. If the spark has sufficient energy, and if it occurs in the presence of a flammable mixture of air and fuel vapor or combustible powder, it can cause the mixture to ignite.

3.1.3. The least amount of energy that will cause the spark to ignite the mixture and then propagate away from the site of the spark is called the minimum ignition energy (MIE). The MIE of a fuel vapor and air mixture will change as the ratio of fuel and air varies, but for a typical flammable vapor/air mixture, typically, the MIE is lowest (i.e., the mixture is easiest to ignite) approximately midway between the upper and lower flammable limits (UFL and LFL). Flammable solvent vapors typically have MIE’s in the range of 0.1 to 1.0 millijoule (mJ).
Flammable powders typically have MIE’s greater than 10 millijoules. Figure 1 is a graphic representation of how MIE varies as the volume concentration of fuel vapor and air varies. The Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL) define the flammable range. Provided that the experimental flammability limit values are reliable, flame propagation outside of the “flammable range” is only possible if the conditions of use involve temperatures and/or pressures greater than those used in the experiments. Experimental “flammability limit” values should be applied using an appropriate safety factor as required in the NFPA 69\(^{(1)}\) Standard Practice on Explosion Prevention. Flammability limits are cited for “ambient” conditions of 1 atmosphere absolute and about 25C. If greater temperatures are needed to achieve ignitable mixtures of less volatile liquids, the experimental test temperature should be cited along with the results. As temperature and pressure increase, the flammability limits generally widen and the MIE generally decreases. If the conditions of use significantly exceed those at which the MIE or flammability limits were determined, expert opinion or additional experimental tests may be required. The effects are only significant in equipment or processes that are deliberately heated or pressurized.

3.1.4 The sensation of an electrical shock that people feel from a static discharge is another hazard of static electricity. The shock is usually barely noticeable but, if the amount of stored static electricity is great enough, it can be severe. While static electricity shocks are rarely life threatening, people react differently to these shocks and the consequence of the reaction could be minor or serious, depending on where the person is and what the person is doing at the time. The threshold of shock sensation (the point where a person thinks he/she might have had a shock) is approximately 1.0 millijoule for most people \(^{2}\). This means that a static spark that a person might not...
even feel (1 millijoule or less) can have sufficient energy to ignite flammable vapors (MIE of solvent vapors 0.1 to 1.0 millijoule). **A static discharge so small that it can’t be felt can be the cause of a fire.** In coatings manufacturing static electricity represents a significant ignition hazard.

3.1.5 When dealing with static electricity, one must understand:

1. How it is generated
2. Where it will accumulate
3. How it is dissipated.

3.1.6. Each of these concepts will be discussed in detail in this document.

3.2. **Static Electricity Generation**

3.2.1 Static electricity is generated when electrons are transferred between molecules of dissimilar materials. Four mechanisms for generating static electricity are:

3.2.1.1 **Triboelectrification** – Triboelectrification or “tribo charging” (aka contact charging) is the most frequently encountered mechanism for generating static electricity and is what most people think of when asked to define static electricity. It is a phenomenon that occurs at the interface between the two materials and results in positive and negative electrical charges separating and preferentially accumulating on one or the other surface.

3.2.1.1.1 Triboelectric charging is a very simple process. It is the action of contact and then separation of two dissimilar materials, one of which is a relatively poor conductor, which takes place at the interface between the two materials. Tribocharging occurs everywhere and all of the time; at home and in the workplace. It is a part of nature, and it cannot be stopped.

3.2.1.1.2 When two electrically neutral (uncharged) materials are brought into contact, loosely held electrons at the interface will prefer one surface to the other and will quickly migrate to that surface. When these two materials are then separated, some of the electrons that migrated to the other surface are trapped or captured on that surface, thus leaving one surface with extra electrons and the other surface with a shortage of electrons. The material with the extra electrons now has a negative charge and the material with the shortage of electrons has a positive charge. (A negative charge means that there is a surplus of electrons; a positive charge indicates that electrons were taken away.)

3.2.1.1.3 In Figure 2a, the two materials are electrically neutral; all of the charges on each object are balanced. In Figure 2b, the two materials are brought into contact and some electrons (charges) migrate from one material to the other. At this point, since the materials are still in contact and no energy has been added, the two materials are electrically neutral. In Figure 2c, the two materials are separated and an electrical charge appears on each. The material that lost electrons now has a positive charge and
the material that gained electrons has a negative charge. The charges are equal in magnitude but opposite in polarity.

3.2.1.1.4 Factors that affect the quantity and rate of triboelectric charge generation are:

3.2.1.1.4.1 The number of contact points/contact area and the intimacy of contact. The more contact points or the greater the contact area, the faster the charge can be transferred. As the two materials are pushed closer together, more of the surfaces make contact and thus the opportunity for charge transfer increases (e.g., the denser the carpet pile and the bigger the shoe, the greater the charge transfer will be).

3.2.1.1.4.2 Speed of separation. The faster two materials are separated, the less opportunity there is for the transferred charge to “get back home” and reduce the size of the “equal and opposite” charge on each material. Quickly pulling the backing paper off of a decal (such as a portable tank decal) will result in a greater charge on both the decal and on the backing paper than if the backing paper is removed slowly.

3.2.1.1.4.3 The materials themselves that are in contact with each other. Material “x” may transfer only a small amount of charge when in contact with material “y,” but may transfer a lot of charge when in contact with material “z.” This has to do with the molecular structure of the materials in contact, how tightly the electrons are held to the molecule and how many electrons are available for transfer.

3.2.1.1.5 Some common examples of triboelectric charging are:

1) Walking across a carpet
2) Getting up out of a chair
3) Sliding across a car seat and exiting the car
4) Tumbling clothes in a dryer
5) Petting a dog or a cat
6) Unrolling plastic film
7) Combing or brushing hair.

3.2.1.1.6 This electrostatic charging process goes on whenever people, machines, liquids or solids are in motion. Most of the time, this charge is carried away to the earth, or ground as quickly as it appears and no one ever sees or feels it. The only time that static charge is detected is when it accumulates or is discharged.

3.2.1.1.7 When a person walks across a carpeted floor the foot comes in contact with the carpet. As the foot separates from the carpet, each individual fiber transfers charge to the person’s body. Since a person’s foot will be in contact with hundreds or thousands of individual fibers in the carpet, the amount of charge transferred in each step can be substantial. (See Figure 3)

![Figure 3]

Triboelectrification Walking on Carpet

3.2.1.2 Liquid Shear Charging is the mechanism that causes liquids to become charged, and is also an interface phenomenon. An interface can exist between a liquid and its container (e.g., pipe, vessel), a liquid and a solid in the liquid, between a liquid and gas bubbles, or between two liquids that don’t completely mix with each other. If these dissimilar materials are moving relative to one another (shearing effect), normally balanced positive and negative charges can separate and move preferentially to one or the other material, creating a charge imbalance similar to the effects of tribo charging. An example of this type of charging would occur when a non-conductive liquid flows through an ungrounded conductive pipe. The liquid would be charged one polarity and the pipe would have the opposite polarity. (See Figure 4)
3.2.1.3 *Induction Charging* – This charging mechanism requires no motion between materials. If an ungrounded conductor is placed in the electric field that surrounds highly charged objects, the field will cause a redistribution of the normally balanced positive and negative charges on the surface of the objects, causing an excess or a deficiency of electrons (a charge) to appear on the surface.

3.2.1.3.1 To better understand the concept of induction charging, consider the following example (Figure 5a-5d):

3.2.1.3.2 In Figure 5a, an ungrounded person who is electrically neutral (all charges balanced, no excess positive or negative charges) walks up to a charged pallet of containers that has just had its stretch wrap removed. In Figure 5b, as the person approaches the charged pallet, the mobile charges on the surface of the person’s body will be redistributed by the electric field surrounding the charged pallet. If the pallet were to have a positive charge, mobile negative charges on the person’s body would be pulled to the side of the body closest to the pallet since opposite polarities attract. These charges are now bound, or held in place by the forces of attraction between the opposite polarity charges. The mobile positive charges would be pushed to the furthest point on the person’s body, away from the charged pallet since like polarities repel. This situation causes a charge of positive polarity to suddenly appear on the body without any contact and separation occurring. In Figure 5c, the person, while still standing close to the charged pallet, touches a grounded object and receives a shock, dissipating the positive charge (remember that the negative charge is bound in place by the charge on
the pallet). In Figure 5d, the person walks away from the pallet, has a negative charge and receives a second shock when he touches a grounded object. If the person walked out of the electric field without touching a grounded object, the separated charges on the person’s body would recombine harmlessly without the person ever knowing he had been charged.

3.2.1.4 **Corona Charging** – Corona charging occurs when a nonconductive object or an insulated conductive object is “sprayed” with a stream of positive or negative ions from a highly charged object, thus becoming charged. (Ions are simply molecules that have excess or a deficiency of electrons and thus are charged.) This is the principle behind electrostatic paint spraying. The spray gun has a high voltage “needle” or electrode that emits, or “sprays” charges into the atomized paint leaving the spray nozzle. The charges attach themselves to the spray droplets, giving them a charge. These charged droplets are then attracted to the grounded object.
being painted, resulting in a very efficient and high quality painting process. (See Figure 6)

3.2.2 Tribo charging of solids and shear charging of liquids are the mechanisms most commonly encountered in coatings operations, and these will be covered in detail. Consult the references in Appendix B for additional information on charge generation.

3.3 Charge Accumulation and the Conductive Properties of Materials

3.3.1 Electrostatic charge will not accumulate on conductive surfaces that are connected to ground, but will accumulate on two other kinds of surfaces:

1) Nonconductors/insulators (as used in this document, these two terms are interchangeable) and
2) Isolated conductors/insulated conductors (as used in this document, these two terms are interchangeable and refer to conductors which are not connected to ground.)

3.3.2 The two elements that must be known in order to understand the extent to which static electricity will be generated and accumulated are the degree to which the liquids or solids are conductive and whether or not they are connected to ground. (Note that gases can neither accumulate charge nor cause charging unless (1), entrained solids or mists are present or (2) they contain ions

3.3.3 The defining characteristic of a conductor is that electrical charges (electrons) are able to move through the conductor or over its surface with very little resistance. There is no such thing as a perfect conductor or a perfect nonconductor — everything has some degree of conductance and some degree of resistance. (Resistance is the reciprocal of conductance, and conductivity is the reciprocal of resistivity.) A good conductor, such as wire, has low resistance to the flow of electrons; a poor conductor, such as most plastics, has high resistance to the flow of electrons.
3.3.4 Examples of conductive materials (low resistance to the flow of electrons) are:

1) All metals (even those thought of as having a high resistance, such as the heating elements in a toaster or oven)
2) Ionized liquids
   a) Brine solutions and other mixtures of salts
   b) Acids or acidic solutions
   c) Bases or caustic solutions
3) Polar liquids
   a) Ketones (e.g., MEK, acetone)
   b) Alcohols (e.g., methanol, isopropanol, butanol)
4) People

3.3.5 The defining characteristic of a nonconductor or insulator is that electrons move very slowly through it or over its surface (i.e. they have high electrical resistance, see Figure 7).

3.3.6 Examples of insulating materials (high resistance to the flow of electrons) are:

1) Most glass and porcelain materials
2) Most plastic and polymeric materials
3) Non-polar hydrocarbon liquids (e.g., toluene, xylene, mineral spirits, kerosene, gasoline, naphtha, etc.) CAUTION: These non-conductive liquids represent special hazards. See Chapter 5.2.3.

3.3.7 Liquids exhibit the same range of conductivities as do solid materials; some have high conductivity and some are highly resistive (insulating). Because insulating liquids have a high resistance to the flow of electrons, these liquids will retain an electrical (static) charge for significant periods of time (from seconds to hundreds of seconds) even if these liquids are in grounded metal containers or vessels.

3.3.8 The conductive properties of several common pure liquids are listed in Appendix A 1- Data.

3.3.9 *Surface resistivity* or *volume resistivity* of a material can be measured to determine its degree of conductivity. Resistivity is different from resistance. Resistance is simply “how many ohms from point A to point B.” Surface resistivity, on the other hand, is an inherent property of the material, like density or specific heat, and is measured in units of “ohms per square.” The surface resistivity of a material is typically measured using two identical flat electrodes that are separated by a distance equal to the length of the electrodes. The electrodes make a “square,” thus the term “ohms per square.” With this configuration, the reading will always be the same regardless of the size of the electrodes. ASTM D257, *Standard Test Methods for D-C Resistance or Conductance of Insulating Materials*\(^{(16)}\), is the reference document for resistivity and resistance testing procedures and equipment for insulating materials.
Solid materials are typically classified according to their surface resistivity because electrical charges are added or removed from the surface of a solid material. Liquids, however, have electrical charges throughout the body of the fluid and are therefore typically classified according to their volume resistivities. It is customary to use the inverse of volume resistivity, conductivity, to classify liquids. Liquid conductance is measured in Siemens. Conductance is the opposite of resistance and is not an intrinsic property of a material since it is also dependent on geometry. The Siemens is therefore a reciprocal ohm. The units of volume conductivity are Siemens per meter. One Siemen is the conductance of a material in which an electrical current of one ampere is produced by an electrical potential of one volt (1).

Figure 7 shows the approximate values for surface and volume resistivity and their relationship to conductivity. The overlapping lines on Figure 7 remind the reader that there is no sharp line separating “conductive” from “static dissipating” or “insulating.” Whether or not a liquid or a solid is a conductor or an insulator is very much dependent on the particular circumstances. In one situation, an object might be considered to be a conductor; in a different set of circumstances, this same object might be considered to be an insulator. For these reasons, this information in Figure 7 should be used only as a guide.
Chapter 4 Hazards of Static Electricity

4.1 General Introduction

4.1.1 Static electricity is basically a motionless pile of electrons ("static" = motionless). This pile of electrons represents the finite amount of charge that has accumulated as a static charge on an isolated (insulated) conductor or on a poorly conducting or non-conducting surface. When this small amount of charge is dissipated over a very short period of time (a microsecond or so), the event is described as a "spark." If the amount of electrical charge (energy) in this spark is great enough (i.e., above the MIE) and if this spark occurs in an ignitable mixture of flammable vapor, gas, or dust and air, the result will be a fire or explosion.

4.1.2 Charged isolated conductors are potentially much more dangerous than charged nonconductors because all of the stored energy on the conductor will be dissipated in the form of a spark the instant that the conductor is grounded. Because of this, some isolated conductors are capable of igniting combustible powders and dusts in the absence of flammable vapors. (See Section 5.3 on Isolated (Ungrounded) Conductors)

4.1.3 Charged nonconductors (insulators), on the other hand, represent a smaller hazard because the charges (electrons) will move very slowly across the nonconductor’s surface and therefore the charges from only a small area can travel to the spark. Charged isolated conductors will be hazardous at much lower energy levels (voltages) than will charged nonconductors.

4.1.4 The capacitance of a charged conductive object affects the hazard potential of the object. Capacitance is a measure of how much charge or energy an object can hold. When all of the energy is released from an object with a high capacitance at a given voltage, the energy contained in the spark will be greater than from an object with low capacitance at the same voltage. The unit of capacitance for conductive objects is the Farad. A Farad is an enormous amount of capacitance; most objects have capacitances in the range of pico-Farads (pF, 1pF = 1x10^-12 Farad). Small objects, such as bolts or pipe flanges, will have much less capacitance than larger objects such as people or drums. The amount of static electricity energy stored on a conductive object is determined by the expression:

\[ Q = \frac{1}{2} CV^2 \]

Where Q is energy in joules, C is capacitance in Farads and V is voltage in volts.

4.1.5 To estimate the values of capacitance, the following can be used as a guide: (6)

1) Small metal objects (bolts, scoops, gallon cans): 3 to 10 pF
2) Intermediate sized containers (5 gal. pails, 55 gal. drums): 10 to 100 pF
3) Large metal objects (process vessels, lift trucks, tank wagons): 100 to 1,000 pF
4) People: 100 to 300 pF
4.2 Electrostatic Discharges

4.2.1 When an object has an electrical charge, it is at a higher energy state than objects around it. This electrical charge represents potential energy (or just potential) that can be measured in volts. Given a chance, this energy will equalize itself with its surroundings by a very rapid flow of these excess charges to another conductive object that is at a lower energy state (lower potential). As this stream of electrons suddenly jumps across an air gap, it creates a luminous “plasma channel,” or spark, and often an audible “snap.” The duration of this plasma channel is very brief, typically only a microsecond or so. The energy in a discharge of static electricity is usually expressed in millijoules — a very small amount of energy.

4.2.2 There are four common types of static electricity discharges typically found in coatings operations:

4.2.2.1 Capacitive Discharges (Sparks)

4.2.2.1.1 This type of spark might occur in coatings operations when a charged isolated conductive object, such as a metal container or a metal funnel, is accidentally or intentionally grounded.

4.2.2.1.2 Capacitive discharges occur only between conductors and are typically a microsecond or so in duration. Since electrons can move freely over the surface of conductors, all of the excess electrons have time to get to the spark. In this brief period of time, all of the energy stored on the charged isolated conductive object is dissipated.

4.2.2.1.3 This “capacitive discharge spark” is what is usually thought of as being a “static spark.” Because all of the stored energy is released in this spark discharge, charged isolated (insulated) conductors — basically “pure capacitors” — are hazardous at relatively low voltages. Capacitive spark energy is usually in the millijoule range, although energy in the joule range is possible.

4.2.2.2 Brush Discharges

4.2.2.2.1 This type of discharge might occur when a grounded conductor is brought close to a charged nonconductive surface, such as a plastic pigment bag or the surface of a charged nonconductive solvent.

4.2.2.2.2 Brush discharges occur between a conductor and a charged nonconductor. An example of this type of discharge is the “flash” one sees in a darkened room when removing a sweater. These discharges are not nearly as energetic as discharges of the capacitive type and are typically limited to approximately 5 millijoules \(^{(2)}\). Even though this discharge may feel relatively weak, it has more than enough energy to ignite most flammable vapor/air mixtures. It is unlikely, however, that a brush discharge would have sufficient energy to ignite flammable powder/air mixtures.
4.2.2.3 Corona Discharges

4.2.2.3.1 This type of discharge might occur when sharp pointed electrodes (less than 1mm radius at the point) are inserted into an electric field of sufficient intensity. This is the principle of operation of static-neutralizing “needle bars.”

4.2.2.3.2 Corona discharges are very low energy discharges. They occur when an object is charged up to the level that the electrostatic field intensity immediately above its surface is equal to the dielectric strength or breakdown voltage of air, approximately 3,000,000 volts per meter. Sharp projections from the surface of the object will cause the field to be concentrated at the point of projection. This allows corona discharges to occur at much lower field intensities at the surface of the charged materials. Corona discharges are typically thought to be non-incendiary except in the presence of extremely low ignition energy materials such as carbon disulfide, hydrogen and acetylene. Corona discharges can also ignite some materials that are in an oxygen-enriched atmosphere.

4.2.2.4 Propagating Brush Discharges

4.2.2.4.1 This type of discharge might occur in coatings operations when pneumatically transferring bulk powder into a grounded metal container that has a nonconductive coating or lining, with the powder impinging on the liner. Propagating brush discharges can also occur when mixing non-conductive liquids or solid/liquid mixtures in glass or non-conductive plastic lined vessels.

4.2.2.4.2 Propagating brush discharges are very energetic discharges, typically in the joule range, which are capable of igniting most flammable vapor/air mixtures or flammable powder/air mixtures. For this type of discharge to occur, a grounded conductive surface with a highly charged nonconductive film or coating is required. The film or coating thickness must be less than approximately 8 millimeters (2) and its breakdown voltage less than 4 kV. This type of discharge is typically only encountered in situations where powders are conveyed pneumatically or where large volumes of powders are rapidly transferred. For a more complete description of this type of discharge and the circumstances where it is likely to occur, see References 1, 2, 3, 8, 10 and 13 in the Bibliography.

4.2.2.5 Other Types of Discharges

4.2.2.5.1 There are other types of spark discharges that are associated exclusively with powders. Additional information on these sparks can be found in References 1, 2, 10 and 13 in the Bibliography.
Chapter 5  Static Electricity Hazards in Coatings Operations

5.1  Powders Handling Hazards

5.1.1  General Material Characteristics

5.1.1.1  Handling powders is a frequent source of static electricity, since powders are typically low conductivity solids. The rate of static generation is determined by four factors:

1) Potential number of points of contact (or particle size)
2) Intimacy of contact
3) Speed of separation
4) The materials themselves

5.1.1.2  With this in mind, it is easy to see why powders are prolific generators of static electricity. Each discreet particle of the powder can be thought of as a contact point, which can and will separate from other particles and from the container and accumulate charge. (See Figure 8)

5.1.1.3  While most powders are very poor conductors (essentially non-conductors) there are some semi-conductive and even some conductive powders. Various forms of powdered metals such as zinc and aluminum are used routinely in coatings manufacturing. Since these materials are conductive they must be handled via grounded equipment (e.g. chutes, funnels, etc.). Powders containing small amounts of

Figure 8
Dumping Powders
residual solvents or other liquids may well be semi-conductive or even conductive. Powder manufacturers and vendors can be a source of information on powder conductivity.

5.1.1.4 A good rule of thumb is that all powder-handling operations are capable of generating hazardous amounts of static electricity. For example:

1) Transferring pigments and other powders from non-static dissipating plastic bags or bags that have removable non-static dissipating liners;
2) Transferring pigments and other powders from FIBC’s (Flexible Intermediate Bulk Containers also known as “super-sacks”). With these containers, it is possible to dump up to 2000 pounds of powder in a few seconds;
3) Pneumatically transferring powders;
4) Cleaning powder spills with a vacuum cleaner or dust exhaust system;
5) Bagging powders for shipment.

5.1.1.5 Flowing powders can charge isolated conductors, such as people or ungrounded metal containers, to dangerous levels very quickly. The flowing powder will build up a static charge on the product that is leaving the container and an equal and opposite charge on the container itself. In addition, the charged container and/or powder can induce a charge on nearby isolated conductors. Airborne powder that is charged will cause ungrounded (insulated) conductors to become charged as the floating powder settles on them.

Case History – Flowing Powders
The following is an incident that occurred as a result of powder flowing over an isolated conductor:

An operator was adding a powdered initiator to a reactor feed tank that contained a mixture of equal parts of methyl ethyl ketone and toluene, using a metal funnel inserted into a charging port. The operator assumed that the funnel was grounded since it was resting on the grounded metal feed tank, so he didn’t attach a separate ground wire to the funnel. As the initiator was being dumped into the feed tank, a “bridge” of powder blocked the funnel outlet. The operator picked up the funnel in his gloved hands and dropped it several times to dislodge the powder bridge. Shortly thereafter, a flame was observed around the base of the funnel between the funnel and the charging port.

The investigation determined that the powder flowing through the ungrounded funnel was able to charge the funnel to a hazardous level in the length of time it took to lift the funnel and drop it back down — a few seconds. Proper bonding and grounding would have prevented this incident.

5.1.1.6 Although powders typically have a minimum ignition energy several orders of magnitude greater than those of flammable gases or vapors, “hybrid mixtures” of powders and vapors will typically have ignition energies that are more in the range of
the flammable vapors than in the range of the powders. Powders with as little as 0.5 percent residual solvent in them should be considered to be hybrid mixtures. Processes where hybrid mixtures are known or suspected to exist should be carefully evaluated for hazard potential.

When dealing with powder ingredients, there is a wide array of packaging options. For example, powder ingredients are shipped in:

- paper bags
- paper bags with loose plastic liners
- paper bags with sewn-in plastic liners
- paper bags with metal foil linings
- plastic bags
- plastic bags in boxes
- fiber drums
- fiber drums with plastic bags
- fiber drums with paper bags
- fiber drums with plastic or metal foil linings
- flexible intermediate bulk containers (FIBCs) or bulk bags
- and others

5.1.2 FIBC’s

5.1.2.1 Flexible Intermediate Bulk Containers, or FIBC’s, are large (typically ½ to 3 cubic meter) bags made of (typically) woven polypropylene split tapes. These containers are used extensively in industry to ship, store, handle, etc, a wide range of powders. In the Coatings Industry, these FIBC’s are used for pigments such as TiO₂, calcium carbonate, etc, fillers such as talc, barytes, etc and for resin ingredients such as pentaerythritol, azelaic acid, etc. In many cases these powders are added to vessels containing flammable liquids or combustible liquids that have been heated above their flash point. Since these containers are essentially large plastic bags, they can become electrostatically charged as they are filled or emptied. Any charged nonconductor (e.g. plastic bag) is a potential ignition source when placed in an ignitable mixture of flammable vapors or gasses.

5.1.2.2 If no flammable vapors or gases are present in the area where the FIBC is to be filled or emptied, there can be no hazard of an ignition due to a discharge of static electricity from a charged non-conducting surface (e.g. plastics or polymeric materials) unless there is oxygen enrichment or if an extremely sensitive powder is present or if explosives are present \(^{(1,2,3,4,9,10)}\) or if the bag is rapidly filled with highly charged combustible powder.

5.1.2.3 Electrical discharges from charged non-conductive surfaces are called “brush discharges”. This type of discharge has a limited amount of energy, up to about 5 millijoules and has not been shown to be capable of igniting combustible powders, even ones with very low minimum ignition energy (less than 1 mJ). The primary hazard from nonconductors such as FIBC’s in non-Class I areas is the fact that, when charged, they create an electric field that will induce a charge on any ungrounded conductor that happens to enter that field \(^{(10)}\).
5.1.2.4 There are currently 5 different types of FIBC available commercially:

5.1.2.4.1 **Type A** - This type of FIBC is constructed of woven polypropylene, it may or may not have a liner and it has no special features to prevent or mitigate the accumulation of static electricity on its surface. This type of bag is not recommended for use in areas where ignitable mixtures of vapors or gases and air are present and it is not recommended for use with “sensitive” organic powders. “Sensitive” powders are finely divided solid materials having a Minimum Ignition Energy (MIE) of 3 mJ or less.

5.1.2.4.2 **Type B** - This type of FIBC is constructed much the same as the Type A bag, with the exception that the Type B FIBC has an electrical breakdown voltage of 6 kV or less. This will prevent a propagating brush type of discharge if the FIBC is resting on or contacting a grounded conductive surface. This type of FIBC is suitable for locations where only powders having an MIE of 3 mJ or greater and no flammable vapors are present.

5.1.2.4.3 **Type C** - This type of FIBC is conductive. Type C FIBC’s may be made using a conductive cloth or may be made from a material having conductive elements woven in to it. However the FIBC is made, it must have a resistance to ground from any point on the bag to the designated grounding location of less than $10^8$ ohms (100 meg ohms). This type of FIBC may be used in any location provided it is properly grounded. **CAUTION:** Where Type C FIBC’s are not grounded, ignition of combustible dusts are possible, even in the absence of flammable vapors.

5.1.2.4.4 **Type D** – This type of FIBC, also referred to as a “Dissipating” type of FIBC, is constructed with isolated conductive elements woven into the fabric of the bag and will dissipate a static charge that has accumulated during an operation where the FIBC has been filled or emptied. This type of FIBC is not conductive but it is suitable for use in most locations where flammable vapor/air mixtures are normally present, i.e. Class I, Div. 1 areas. This type of FIBC utilizes the mechanism of corona discharge to limit the accumulation of electrical charge to a “safe” level. Since these bags do become charged to field intensities as high as 20 thousand volts per inch or greater, it is possible for ungrounded conductive objects within 1 to 2 meters to become inductively charged and thus become potential ignition sources.

5.1.2.4.5 **Induction Charging From FIBC’s** - Charged, ungrounded conductive objects are quite capable of accumulating sufficient energy to ignite combustible powders. It is necessary, therefore, that all conductive objects in areas where combustible powders are handled must be grounded. It is impossible for a properly grounded conductor to accumulate a static charge. A type C FIBC, when properly grounded will not become charged when handled, filled or emptied. Type A, type B, and type D cannot be grounded and are potential sources of charge induction for ungrounded conductors in the immediate vicinity of the FIBC.

5.1.2.4.6 The Type D FIBC, as described above, dissipates charge via Corona discharge from the isolated conductive elements woven into the fabric of the bag. This Corona discharge does not begin until a certain “threshold voltage” is reached. Typically
this voltage is in the range of 3000 volts to 5000 volts. As the FIBC continues to be charged by either the filling or the emptying of the bag, the voltage continues to rise and the Corona discharging increases. The electric field of the bag never reaches the "safe limit" of charge accumulation. After the filling/emptying operation is completed, the electric field of the bag decreases (by the continuing Corona discharge) rapidly to the "threshold voltage" at which point, the Corona discharge ceases and normal charge decay mechanisms dissipate the remaining charge. The entire time the FIBC is at an elevated energy level, it is capable of inducing charges on nearby conductors that are not grounded.

**CAUTION:** Type D bags that become wet or soiled can become hazardous in use due to the fact that the wet or soiled area may become a charged isolated conductor. This condition is thought to have been the cause of at least one FIBC ignition incident.

**5.1.2.4.7** It should be understood that, at the present time, there are no standards regulating FIBC construction, markings, or features. Given this lack of standardization, it is essential that end-users ensure that the FIBC being used is a safe package. See also: Performance Test Method IEC Std. 61340-4-4:2005\(^{(29)}\). Until adequate standards are available, the end user of FIBC’s may need to seek advice from experts in the field if they themselves are not knowledgeable about the hazards of these containers. The European document on static electricity, CENELEC TR 50404, *Code of Practice for the Avoidance of Hazards Due to Static Electricity*, \(^{(32)}\) and recent work by Britton, et al \(^{(39)}\) offer excellent advice on FIBC testing and FIBC selection criteria.

**5.1.2.4.8** Appendix D gives additional guidance on selecting an FIBC for a specific application.

**5.1.3 Powders in Plastic Bags** When transferring powders from non-static dissipating plastic bags, or from bags of unknown conductivity, the rate of charge generation is proportional to the rate of powder transfer. When transferring powders in areas where flammable vapors may be present, the following additional precautions should be taken:

**WARNING!!** The powder transfer should be stopped if signs of static buildup are encountered (e.g., hair on the forearms standing up, shocks or audible "snaps" of static discharge).

**5.1.3.1** All-plastic bags and bags with removable plastic liners: Ordinary plastic bags should not be used in the vicinity of open hatches where flammable vapors may be present. If used, static dissipating bags must be confirmed to have surface resistivity of between \(1 \times 10^{9}\) and \(1 \times 10^{11}\) ohms per square when tested in accordance with ASTM D257, *Standard Test Methods for D-C Resistance or Conductance of Insulating Materials*\(^{(16)}\). As a further confirmation, laboratory or field testing can be done. Static Dissipating plastic bags should exhibit electric field intensity at the bag surface during product transfer, of less than 5 kV/cm (12.5 kV/inch). (See Appendix C, Question 16.) In situations where the use of a plain plastic bag is necessary and unavoidable, materials should be transferred to a grounded conductive container (e.g., metal) in a non-hazardous location.
5.1.3.2 When possible, powdered materials in plastic bags should be transferred to a grounded metal container in a safe (non-hazardous) location.

5.1.3.3 All conductive objects in the vicinity of the powder transfer operation should be grounded. This includes such things as:
- Metal scoops
- Metal funnels
- Metal chutes
- Metal fittings on ventilation or dust extraction hoses
- Metal carts
- Personnel handling the powders

5.1.3.4 When transferring powders from non-static dissipating plastic bags, or from bags of unknown conductivity, do not shake the bag to remove the last little bit of powder; shaking causes very high levels of static generation as the layer of powder on the plastic is suddenly separated from the bag.

5.1.3.5 Experience has shown that limiting the addition rate to approximately 100 lb. per minute (two, 50 pound bags) will minimize static generation. To the extent possible, add each bag of powder evenly over a 30 second period rather than in a 50 pound “slug”.

5.1.3.6 Stretch or shrink wrap should be removed from pallets of powder bags prior to bringing the materials into electrically classified areas. Removal should take place in an electrically unclassified area, such as a warehouse.

5.1.3.7 When handling plastic bags of powders, avoid rubbing or brushing the bags or any other type of excessive manipulation or handling.

5.1.3.8 Ventilation should be provided to extract airborne dust from the dumping operation. This dust not only can cause housekeeping and occupational health problems, but is a potential source of charging for ungrounded conductors and nonconductors when it settles on them.

5.1.3.9 In some cases, it may not be possible to reduce the risk of ignition by static discharge. In these situations, consideration should be given to reducing or replacing the oxygen in processing equipment with an inert gas such as nitrogen. This technique is known as “Inerting”. NFPA 69, Explosion Prevention Systems (11), is a source of additional information on this process.

Note: Transferring powders into low conductivity flammable liquids should be done only after a thorough hazards analysis. See section 5.2.3 for additional advice on this topic.

5.1.3.10 Powders should only be added to a mixing vessel or a high-speed disperser that contains a Class I liquid where the liquid has a conductivity greater than 1000 picosiemens per meter or the entire vapor space of the vessel is inerted. If no powder or other second phase is present during mixing and the vessel is not inerted, the conductivity should be at least 50 picosiemens per meter. Regardless of the
conductivity of the liquid, the entire vapor space of the vessel should be inerted if the rotating agitator blades break the surface of the liquid (10).

5.1.3.11 Manual dumping of powders or particulate solids directly into a vessel that contains an ignitable atmosphere should be avoided (15).

5.1.3.12 Solid materials should not be added directly to a vessel that contains a Class I liquid either from plastic bags that are not static dissipating or from rigid plastic containers that are static dissipating. As defined in this standard, static dissipating means “having a surface resistivity between $10^8$ ohms/square and either $1.0 \times 10^9$ or $1.0 \times 10^{11}$ ohms per square with the upper limits being given for 23 C and 50% or 20-30% RH, respectively. Likewise, solid materials should not be added directly to a vessel that contains a Class I liquid from Type A or Type B flexible intermediate bulk containers (FIBCs or “bulk bags”) or from FIBCs that have plastic liners that are not static dissipating. Static dissipating plastic bags should be marked “STATIC DISSIPATING” by the vendor, who should also certify that the bags meet the above-referenced specifications.

5.1.3.13 It is recognized that situations may arise where the use of a plain, non-static dissipating plastic bag is necessary and unavoidable. A thorough risk assessment, conducted by knowledgeable persons, should be completed before proceeding with this operation. Steps that can be taken to mitigate the hazards of this operation include;

1. Minimize handling/rubbing of the bags.
2. Transfer the powder from the plastic bag into a grounded conductive container.
3. If possible, move the transfer operation to a non-hazardous location.
4. Remove stretch/shrink wrap from pallets in an unclassified area such as a warehouse.
5. Transfer only 25 kg (50 lb) of powder at a time (13).
6. Transfer the powder at as slow a rate as practical.
7. Do not shake bags after emptying.
8. Provide local exhaust to minimize fugitive dust.
9. Ground personnel performing this operation.
10. Ground all conductive objects in the vicinity of the transfer operation.

5.2 Liquid Handling Hazards

5.2.1 General

In grounded metal systems such as are found in typical coatings manufacturing operations, the conductivity of a liquid is the primary determining factor in how quickly accumulated charge can be dissipated from the liquid. Liquids that have a conductivity of 50 pico-Siemens per meter (pS/m) or less are thought of as low conductivity liquids and will dissipate charge very slowly. Liquids that have a conductivity of 10,000 pS/m or greater are thought of as being conductive and will dissipate charge very rapidly (13).
5.2.2 Handling Conductive Liquids

5.2.2.1 Liquids having conductivities of 10,000 pS/m or greater are considered to be “conductive” liquids in typical coatings operations.

5.2.2.2 Conductive liquids typically will not accumulate hazardous levels of static electricity in normal coatings operations. Exceptions to this “rule of thumb” include operations involving spraying, excessive splashing, misting, high velocities, etc.

5.2.3 Handling Low Conductivity Liquids

5.2.3.1 Handling a low conductivity liquid is a frequent source of static sparking and flammable vapor ignition. Low conductivity liquids will accumulate static charge from liquid shear charging at the pipe or vessel wall in much the same manner that low conductivity solids such as plastics accumulate charge by contact and separation with conductors such as metallic conveying systems and people. Just as with the plastics, the charge in a low conductivity liquid cannot be dissipated by grounding. Low conductivity liquids are typically derived from distilling or fractionating hydrocarbon feed stocks. Toluene, xylene, hexane, heptane, naphtha, mineral spirits, gasoline, kerosene and jet fuel are examples of low conductivity liquids.

5.2.3.2 Low conductivity liquids will accumulate charge simply by flowing through a pipe or hose, or by being agitated. Factors affecting the charging rate of these liquids are liquid velocity, the amount of turbulence in the liquid, entrained solids, gas bubbles or an immiscible second phase (liquids that do not dissolve into each other). Once charged, the only way to dissipate the charge is either by adding sufficient quantities of a compatible conductive liquid or by time-dependent dissipation or “charge relaxation time”. [see next section]

5.2.3.3 Charge relaxation time is a measure of the amount of time it takes for the charge to dissipate to a safe level and is a function of liquid conductivity and dielectric constant (See Appendix C, Question 29). With conductive liquids such as ketones and alcohols, the relaxation time is in the microsecond to milliseconds range; the relaxation time for low conductivity liquids is in the range of seconds to hundreds of seconds.

5.2.3.4 Brush discharges can occur from the surface of low conductivity liquids when a rising level of this charged liquid in a container approaches a grounded metal projection into the tank, such as a thermo-well, fill pipe, level probe or a grounded metal gauging rod held by an operator.

5.2.3.5 When low conductivity liquids flow through ungrounded metal components of a transfer line, such as a hose, metal fittings on the hose can become charged. When the fitting touches a grounded surface, a spark will occur. This has been the source of ignition in several fire incidents that resulted in significant property loss and injuries to personnel.

5.2.3.6 Since charge generation is affected by the speed of separation, it follows that charge generation is closely tied to the liquid velocity. A universally accepted “safe”
velocity for low conductivity liquids or liquids with an unknown conductivity is 3 ft./sec.; at this velocity, the liquid will not accumulate a significant static charge (25).

### Case History – VM&P Naphtha

The following is a fire incident involving an above ground storage tank containing a low conductivity solvent that occurred as a result of inadequate bonding and grounding.

A tank farm supervisor started the transfer of the final compartment of a tanker-trailer containing VM&P naphtha (<$1.3 \times 10^{-7}$ micromhos/cm or <$1.3 \times 10^1$ picosiemens/meter – See Table A-1) into a 15,000 gallon above-ground storage tank when there was an explosion that sent the VM&P tank rocketing into the air. The entire tank farm eventually caught fire and numerous other tanks subsequently ruptured. The incident triggered an evacuation of approximately 6,000 local residents; destroyed the tank farm; and significantly interrupted the company’s business. Eleven residents and one firefighter received medical treatment.

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Key Findings by the U.S. Chemical Safety and Hazard Investigation Board (CSB)
The CSB determined that several factors likely combined to produce the initial explosion:

- The tank contained an ignitable vapor-air mixture in its head space.
- Stop-start filling, air in the transfer piping, and sediment and water (likely present in the tank) caused a rapid static charge accumulation inside the VM&P naphtha tank.
- The tank had a liquid level gauging system float with a loose linkage that likely separated and created a spark during filling.
- The MSDS for the VM&P naphtha involved in this incident did not adequately communicate the explosive hazard.

The CSB recommended to companies with tanks that may contain ignitable vapor-air mixtures and that are equipped with conductive loose linkage level floats that they should take one or more of the following measures:

- Use an appropriate gas to inert tank head spaces.
- Inspect and replace, as appropriate, floats with level measuring devices that will not promote sparks inside the tank.
- Modify floats so that they are properly bonded and grounded (see below)
- Reduce the liquid flow (pumping) velocity.
- Remove any slack in the tape connected to the float mechanism that could allow a spark gap to form.

The CSB recommended to companies that prepare MSDSs to update the MSDSs to

- Identify and include a warning for materials that are static accumulators and that may form ignitable vapor-air mixtures in storage tanks.
- Include a statement that bonding and grounding may be insufficient to eliminate the hazard from static-accumulating flammable liquids, and provide examples of additional precautions and references to the relevant consensus
guidance (e.g., NFPA 77, Recommended Practice on Static Electricity (2007), and API Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008)).

- Include conductivity testing data for the materials that are static accumulators and that may form ignitable vapor-air mixtures in storage tanks.

Note: For all intents and purposes in this document a “static accumulating liquid” is a “low conductivity liquid” as defined in paragraph 5.2.1 above.

Case History - Toluene
The following incident is representative of one that has occurred many times in the coatings industry.

An operator needs a small quantity of toluene (less than 5 gallons). The operator takes a metal 5-gallon pail with a plastic handle (and without an attached ground wire) and hangs the pail on the end of the pipe that supplies toluene to the area. The plastic handle on the pail handle effectively insulates the pail from the grounded pipe, and the end of the pipe extends into the pail. The operator opens the valve and starts the flow of toluene into the pail at a high flow rate, which causes considerable splashing, turbulence and air entrainment in the pail. Before the pail is full, the toluene vapor ignites. The probable cause of the fire is either that:

- The toluene became highly charged by the high liquid velocity, turbulence, splashing, etc. As the liquid level approached the grounded pipe extending into the pail, a brush discharge from the liquid surface to the pipe ignited the toluene vapor.

- The pail became inductively charged by the highly charged toluene and there was a spark from either the metal handle to the pipe or from the body of the pail to a nearby grounded object, igniting the solvent vapor.

This fire could have been prevented by grounding the metal pail prior to the start of liquid flow and keeping the flow rate of the toluene to 3 ft./sec. or less to reduce turbulence, splashing and air entrainment to a safe level.

5.2.3.7 Splash filling (i.e. free fall) of low conductivity flammable liquids (See Figure 9) should be eliminated to the maximum extent practical by submerging fill pipes below the liquid level in the vessel. Submerging fill pipes in vessels with agitators may not always be possible; in this case, diverters, which direct the discharge of liquid down the side of the vessel, should be considered. In bulk filling operations, the velocity of the
incoming low conductivity liquid should not exceed 3 ft./sec. until the pipe outlet is covered; the velocity may then be increased to 15 ft./sec. Appendix A-3 Data lists the flow rates for various pipe sizes that will result in a velocity of 3 ft./sec. and 15 ft./sec.

5.2.3.8 Toluene is a low conductivity flammable liquid that figures prominently in coatings processes and products. Toluene's vapor pressure is such that one is assured of a flammable vapor/air mixture at the ambient temperatures found in most coatings facilities. The Lower Flammability Limit (LFL) of toluene is 1 percent (vol./vol.) and is reached at a temperature of 40 F/4 C. The Upper Flammability Limit (UFL) is 7 percent and is reached at a temperature of approximately 98 F/37 C. Therefore, the vapor is ignitable in the vapor space of an open or closed container at any temperature between 40 F and 98 F. In addition, as with most other flammable liquids, the most easily ignitable toluene vapor/air mixture occurs approximately halfway between the LFL and the UFL; the temperature corresponding to this concentration is approximately 65ºF. Therefore, at typical ambient conditions and even in a closed vessel, toluene will always be in the flammable range and simultaneously at its most easily ignitable concentration. Since toluene can be rapidly charged by pouring, agitating, pumping, etc., and since the liquid itself cannot be grounded, it is not surprising that there have been many fire incidents associated with toluene —many of which could be prevented with a better understanding of static electricity.

5.2.3.9 One option for mitigating the static hazards associated with low conductivity liquids is to raise the conductivity of the liquid. This can be accomplished by either blending the low conductivity liquid with a conductive liquid (e.g., alcohol, ketone) or by adding a static dissipating additive into the low conductivity liquid.
5.2.3.10 When blending a low conductivity liquid with a conductive one, the “rule of thumb\(^1\),” which works most of the time, is that the amount of conductive liquid should be at least 15-20 percent of the volume of the poorly conductive liquid. A conductivity measurement is needed to assure that the conductivity of the blend is adequate.

5.2.3.11 The other method of increasing liquid conductivity is to add a small amount of commercially available “conductivity enhancer” or “antistatic additive.” These additives are used in very low concentrations, typically in the parts per million range, and are usually added to the liquid by the supplier. The users of these products should be aware that the functionality of these additives will be reduced over time (they plate out on tank and pipe walls and can be leached out by water). Some filter systems, especially clay filters, may remove these compounds.

5.2.3.12 When handling low conductivity solvents, the following precautions should be taken:

1) Ground all conductive (metal) objects that come in contact with the low conductivity liquid, such as funnels, scoops, hose fittings, pails and other metal containers. This is the single most important precaution to take to prevent fires resulting from static electricity ignition.

2) Minimize the free fall of low conductivity liquids. Ideally, these liquids would be transferred using a fill pipe that discharges below the surface of the liquid with the flow velocity limited to about 3 ft./sec. until the pipe outlet is fully submerged. Where this is not possible, direct the liquid to the wall of the receiving container to ensure that the stream does not break up. Always remember that “slower is better” to minimize static charge generation.

3) When agitating low conductivity liquids, keep the rotational velocity of the liquid as low as the process will allow; minimize splashing in the vessel or air entrainment (vortexing) and avoid the use of high speed, high shear agitators for these liquids.

4) When possible, leave the closed and grounded containers and vessels of recently transferred low conductivity solvents undisturbed so the charge can be dissipated through relaxation. Several minutes will usually be sufficient for charge dissipation; however, keep in mind that longer relaxation time means less retained charge.

5) In some cases, it may be necessary to inert equipment where low conductivity flammable liquids are being processed. Inerting is a procedure whereby the oxygen in the equipment (e.g., mixing tank, filter, centrifuge) is replaced with an

\(^1\) Author’s personal experience
inert gas such as nitrogen in order to eliminate the possibility of a fire or explosion. NFPA 69, Explosion Prevention Systems gives details on inerting.

5.2.4 Filtration

5.2.4.1 Filtration is a source of extreme charge generation in low conductivity liquids. Microfilters, defined as filters having a pore size of less than 150 microns, can increase the rate of charge generation in these liquids by a factor of 200X to 300X or more. (22)

5.2.4.2 The mechanism of charge generation in filters is quite complex. Basically, a filter separates a stream of liquid into many, many small streams. It forces these small streams through passages in the filter media that have very small cross-sectional areas. Since the total surface area of even an externally small filter is very large, the amount of contact and separation and hence static generation is also large. Coarse strainers will not cause excessive charging of low conductivity liquids; however, coarse strainers will act like potentially hazardous micro filters as they become filled with filtrate.

Case History - Filtration
The following is an incident that occurred as a result of using an unenclosed filter bag at the end of a pipe.

An operator was filling a paint product into gallon cans using a volumetric filling machine. The feed reservoir for the filling machine was an open tub. For quality reasons, the line from the paint mixer had an unenclosed bag filter at the end of the pipe, hanging over the reservoir from a metal retainer.

After the batch was filled out, the operator washed the mixer with toluene (batch wash instructions called for a mixture of toluene and conductive methyl ethyl ketone, but the MEK was not added). After washing the mixer, the wash solvent was drained through the fill line to the filling machine to clean the reservoir and the machine. Since the filter bags were still in place, all of the wash was run through the filter bags into the reservoir. The operator was in the process of pouring a partially filled can of product into the wash when the reservoir ignited. The operator received first and second degree burns on his hands and face.

The most likely ignition source was a static discharge from the filter bag to the can that the operator was holding. This incident would have been prevented by the use of a grounded metal enclosure around the filter and the use of a conductive wash solvent or solvent blend.

5.2.4.3 Precautions to be taken when filtering low conductivity liquids with micro filters:
1) If filters are located in pipelines, remember that these devices can cause rapid charging of low conductivity liquids. Locate them as far upstream as possible to allow for “relaxation” after the filter. Ideally, filters should be located so that the liquid will be retained in the pipeline for approximately 30 seconds after the filter.

2) Because flow through a filter can charge a low conductivity liquid, filter media used in this application should be enclosed in a grounded metal enclosure. Ensure that internal metal parts are also grounded. These enclosures are available from larger filter equipment manufacturers. Open (unenclosed) filters, especially bag-type filters that can be tied onto the end of a pipe or hose, should not be used with low conductivity solvents. While the risk of static generation is minimized if a conductive liquid is being filtered with an end-of-line bag-type filter, a static ignition hazard can be created if the mixer wash that follows is a low conductivity solvent (e.g., mineral spirits or naphtha). (See References 2 and 13 for additional details on this hazard.)

5.2.5 Cleaning Small Parts & Portable Equipment With Solvents

5.2.5.1 Cleaning small parts and portable equipment with solvents, either using an automatic device or manual cleaning, is a potentially extremely hazardous task relative to static generation and spark ignition of solvent vapors. Significant static electricity charging can occur during cleaning by contact and separation resulting from the following activities:

1) Solvent spraying, which can involve high liquid velocities
2) Stream impingement on the object being cleaned
3) Misting
4) Rubbing
5) Brushing

5.2.5.2 Simply using a solvent-soaked wiper to clean a part shares these static generation problems. When these activities are coupled with the use of a poorly conductive flammable solvent, as is often the case, the result can be a serious incident. Note that the use of a nonconductive Class II (combustible) cleaning solvent such as mineral spirits in a vessel that contains vapors in the flammable range can generate enough static electricity to ignite the vapors.

5.2.5.3 When it is necessary to perform manual cleaning of parts, etc., with Class I solvents, the following are some precautions that should be considered:

1) Use conductive solvents (conductivity greater than 10,000 picosiemens per meter);
2) Use natural bristle brushes for cleaning. Natural bristles include materials like Palmyra, Tampico, Bamboo, Horse Hair and Hog Bristle. Brushes made with bristles of synthetic polymeric materials such as polyethylene, polypropylene, nylon, polyester, etc., should be avoided;
3) Ground the conductive objects being cleaned;

4) Maintain good ventilation to remove or dilute solvent vapors to prevent the buildup of a flammable vapor/air mixture, keeping in mind that ventilation may fail or otherwise be only partially effective in keeping the flammable concentration below the lower flammable limit;

5) If a low conductivity solvent has been used, allow objects that have been cleaned to sit undisturbed for 10 minutes if possible, to allow for relaxation of accumulated charge.

5.2.6 Cleaning Large Vessel Interiors

5.2.6.1 The cleaning of large vessel interiors using flammable or combustible liquids has been done in the coatings industry for many years. In many cases, it is thought to be the only way to adequately clean these vessels. Vessel cleaning is an operation that brings together all of the parts of the Fire Triangle – there is fuel present in the vessel in the form of flammable vapor/air mixtures, there is oxygen present in the air that was drawn into the vessel as it was emptied, and there are multiple ignition sources present including

- Splashing
- Rubbing
- Brushing
- Spraying
- Etc

5.2.6.2 Cleaning the interior surfaces of tanks is beyond the scope of this document. The variety of vessel geometry, agitator designs, instrumentation, cleaning liquid, product to be removed, etc makes it impractical to offer specific guidance on this topic.

5.3 Hazards of Isolated (Ungrounded) Conductors

5.3.1 Isolated ungrounded conductors represent the most significant risk of static ignition in coatings operations. As stated in Chapter 5 “Hazards of Static Electricity,” charged isolated conductors are more hazardous than charged non-conductors or poor conductors because, on an ungrounded conductor, all of the charge (energy) that has accumulated on its surface can be discharged in a single spark. In contrast, a charged poor conductor (insulator) releases its charge (energy) from only a small part of its surface and so the energy release will be relatively lower. This means that isolated conductors are capable of incendive sparks at much lower energy levels than nonconductors.

5.3.1.1 Conductive objects typically include anything made of metal; polar liquids such as methanol and acetone; strongly ionic liquids such as acids, bases, brine and other solutions containing salts; conductive polymers; and people. Although ungrounded isolated conductors are the greatest hazard in coatings operations, they are the easiest
to control once they are identified. When a conductor is grounded, it is no longer a static electricity hazard. It is impossible for a properly grounded conductor to accumulate a charge of static electricity.

5.3.1.2 The difficult part of correcting this hazard is identifying where the isolated conductors are. Everyone sees the drum or pail that is not grounded. However, not everyone recognizes that the metal chime on a fiber drum and the metal rod used to gauge the level in a tank are isolated conductors that also need to be grounded. Other frequently overlooked isolated conductors are mobile equipment such as hand trucks and powered materials handling equipment, scales and people.

5.3.1.3 Scales, hand trucks, pallet jacks, carts, and other mobile equipment must be grounded after they have been moved. Semi-permanent equipment, such as shelving, grating and metal desks in areas where flammable liquids, gases and solids are handled in open containers may be isolated conductors and therefore should be grounded. The safest procedure to follow in areas where flammable liquids or powders are handled is simply: EVERYTHING METAL SHOULD BE GROUNDED.

5.3.1.4 Powered Materials Handling Equipment (PMHE) that is used in areas where flammable or combustible solids, liquids or gases are handled must be rated for use in those areas. One reason for requiring special PMHE in electrically classified (hazardous) areas is to safely eliminate the static charge that will accumulate on them as they roll across the floor. If insulated from ground, PMHE will become an isolated conductor. It is possible for the PMHE to accumulate several thousand volts while rolling only a short distance. Since PMHE, which are rated General Purpose, lack the grounding required on PMHE used in classified areas, they become isolated conductors and contact with a grounded object will result in a potentially incendive spark. PMHE rated for use in classified areas, however, are designed with built-in grounding by means of a grounding strap that drags on the floor and/or conductive tires. Note that grounding equipment is only one of the many essential features which makes PMHE acceptable for use in electrically classified areas; simply providing a grounding strap for General Purpose PMHE does not make the PMHE suitable for use in these areas.

5.3.1.4.1 With these grounding systems, it is necessary that the PMHE operate on floors that will adequately conduct electrical charges to ground. Suitable surfaces include clean, bare (uncoated) concrete, metal decking or grating, or any floor surface that has a measured resistance to ground of $1 \times 10^9$ ohms or less. Floor surfaces that are usually unsatisfactory include painted concrete (except for special conductive paints); concrete that is covered with paper or cardboard; floors with layers of sweeping compound or powders on them; any floor that has a measured resistance to ground of greater than $1 \times 10^9$ ohms or greater. See 5.5.3.2 for information on testing floor conductivity.

5.3.1.4.2 Guidance on this subject can be found in NFPA 35, *Standard for the Manufacture of Organic Coatings*¹⁰ and in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use*, Conversions, Maintenance, and Operation. Requirements for industrial trucks can be found in American National Standards Institute (ANSI)/UL 583, *Standard for Electric Battery*
5.3.1.5 One particular “ungrounded conductor” that is frequently encountered in coatings operations is the metal nozzle or fitting (such as a Kamlok® or similar connector) on the end of a hose. These ungrounded conductors can be rapidly charged when a low conductivity liquid flows through the hose at velocities greater than 3 ft./sec. and over the years have been the cause of numerous coatings operations fires and fatalities. Hoses equipped with metal end fittings must have electrical continuity between the fittings. This continuity can be accomplished by using either an internal or external bonding cable connecting the two ends of the hose or a conductive or static dissipating hose. It should never be assumed that the metal end fittings are bonded just because a hose has an internal metal wire-stiffening coil. Electrical continuity should be confirmed routinely by testing, especially for hoses equipped with internal bonding of the end fittings.

5.4 Hazards of Plastic & Other Nonconductors

5.4.1 Plastics and other nonconductors appear in coatings operations in many forms and in many unsuspected places. Examples are:

1) Packaging
   o Pail and drum liners
   o Stretch/shrink wrap
   o Bags, pails, drums, sling bags
   o Vinyl decals on portable tanks
2) Synthetic fiber clothing
3) Furniture (plastic, fiberglass)
   o Synthetic upholstery
4) Personal Protective Equipment (PPE)
   o Synthetic material coveralls
   o Vinyl aprons
   o Boots, shoes
   o Gloves
5) Sample containers
6) Trash can liners

5.4.1.1 Nonconductive plastics and other nonconductive materials should be avoided in areas where flammable vapors, gases or powders may be present since static charges can accumulate on nonconductors. However, it is not always possible to completely eliminate nonconductors, so the following lists some of the ways to reduce the static hazard associated with these materials:

1) When it is necessary to use plastic sheeting, bags or liners in an area that is electrically classified, only plastics that have been specially formulated to be static dissipating should be used. To be static dissipating, a plastic film must have a surface resistivity between \(10^6\) ohms/square and either \(1.0 \times 10^9\) or 1.0
11 ohms per square with the upper limits being given for 23 C and 50% or 20-30% RH, respectively. Following the procedures in ASTM D257\textsuperscript{(16)}.

**Note:** It is important to have assurances from the supplier of the static dissipating plastic bags that the bags meet these specifications or equivalent specifications.

2) Remove shrink and stretch wrap from materials in a non-hazardous area and let them “relax” for a few hours before bringing them into electrically classified areas.

3) When dumping plastic bags of powders, the bag should not be shaken to remove residual powder. Shaking can result in a very rapid high level of charge generation.

4) Avoid rubbing, brushing, or excessively handling plastic bags of ingredients.

5) Ensure that all conductors in the vicinity of powder transfer operations are grounded, including people.

6) Where possible, substitute grounded conductors for nonconductive objects (e.g., use a grounded metal drum for trash instead of a plastic drum).

7) Because of the risk of generating a static discharge, articles of clothing or PPE (e.g., jackets, aprons, coveralls) should not be removed in areas where flammable vapors may be present.

8) If floors in electrically classified areas must be coated, use static dissipative or conductive coatings.

5.4.1.2 **Fiber drums containing liquids or solids:** These containers typically are constructed with metal stiffening rings (chimes) at the top and bottom of the container. Normally, only one chime needs to be grounded. The reason for this is that the cardboard material of the drum is normally semi-conductive, except for situations where the ambient humidity is under 10 – 20%. In low humidity situations such as arid climates or very cold outside temperatures, the resistivity of the fiber drum should be measured. If the measured resistivity is greater than $1 \times 10^{11}$ ohms per square or if the resistivity in low humidity conditions is unknown, both metal chimes should be grounded during emptying.

5.4.1.3 **Paper bags and paper bags with non-removable plastic liners:** Are usually not hazardous, but environmental conditions (e.g., extremely low or extremely high humidity) or the materials being handled may cause a static hazard. A static hazard can result from a high humidity situation if, for example, bags are stored outside overnight and dew causes them to become wet. The bags become conductors and could become hazardous isolated conductors as they are being emptied. The static electrification for removable plastic-lined paper bag/contents combinations should be measured. (See Appendix C, Question 16, and Appendix B reference 19)
5.4.1.4 Plastic bottles and nonconductive drum liners: Are subject to the hazard of charge induction as a result of contact (tribo) electrification. Precautions must be taken to minimize contact charging or to neutralize contact charges before use. Because of possible contact charging, plastic drum liners should not be removed from drums in or near areas where a flammable vapor concentration may exist. Removal of plastic bottles from plastic bags may cause high contact charging. Electric field intensities greater than 5 kV/cm (12.5 kV/inch) at the surface of the bottle or liner should be neutralized before a conductive flammable liquid is put into the bottle. It is also important to avoid charging a plastic bottle that contains even a small quantity of a conductive, flammable liquid. For additional details on this hazard. (See References 11 and 13 in the Bibliography.)

5.4.1.5 Stretch-wrap: Should be removed from pallets in a location where a flammable vapor concentration is not present. Stretch-wrap is usually highly charged when removed.

5.4.1.6 Semi-bulk bags (FIBCs): Bags that contain metallic or conductive plastic filaments must be grounded during product transfer. (See section 5.1.2. for additional Information on FIBC’s)

5.4.1.7 Conductive plastic liners and containers: Although most plastic materials are nonconductive, some conductive plastic liners and containers are commercially available. Conductive plastic materials must be grounded during product transfer in flammable locations. (See Appendix C, Questions 13 and 14.)

5.5 Personnel Static Control

5.5.1 The human body is an electrical conductor which, when insulated from ground, can accumulate a static charge in excess of 10,000 volts. This charge can be generated by contact (tribo) electrification, (e.g., walking across an insulating floor, contacting a charged conductor, getting up out of a chair, participating in various physical activities). Clothing, especially if made of poorly conductive synthetic fibers, can easily accumulate an electrostatic charge via contact with other materials. If an article of clothing is removed, a charge will be produced both on the clothing being removed and on the remaining clothing. On an ungrounded (isolated) human body, this charged clothing could induce a potentially hazardous electrostatic charge on the person wearing it.

5.5.1.1 In general, clothing will not contribute to the hazard potential of a person as long as the person’s body is adequately grounded and the clothing is not removed. If the person is grounded, his/her body will not be charged by the removal of clothing, but the clothing will be charged.

5.5.1.2 In situations where ignitable vapor, solids or gas mixtures exist, there is potential for ignition by sparks produced by the contact of an insulated, charged human body with a grounded object. The accumulation of hazardous levels of static electricity on the body can be prevented by grounding all personnel who work in electrically classified (hazardous) areas.
5.5.1.3 The easiest method of grounding personnel is to have them wear electrostatic dissipating (ESD) or, more simply, static dissipative (SD) footwear. Static dissipative footwear is designed so that the wearer will be electrically connected to the surface that he or she is standing on.

5.5.2 Static Dissipating Shoes

5.5.2.1 ASTM F 2413-05, Standard Specification for Performance Requirements for Foot Protection(20), defines the requirements for SD footwear. For most coatings operations, SD footwear provides adequate conductivity between the floor and the person wearing the footwear. SD shoes must have a resistance between the floor and the person wearing the footwear of not more than $1 \times 10^8$ ohms and a minimum resistance of $1 \times 10^6$ ohms. This minimum level of resistance is necessary to prevent an electrocution hazard if the wearer accidentally contacts energized electrical circuits.

5.5.3 Static Dissipating Floors

5.5.3.1 In order for the SD footwear to be effective, flooring should have a resistance to ground of $1 \times 10^9$ ohms or less. This level of conductivity is easily achieved on clean bare concrete. Floors that are made of other materials should be tested to ensure that they are adequately conductive. If floors cannot meet the minimum conductivity requirement, alternate systems may be used such as grounded metal plates or grounded conductive floor mats at workstations.

5.5.3.2 Although there is currently no consensus standard for floor conductivity testing for the coatings industry, one procedure for testing floor conductivity is ANSI/ESD STD 97.2-2006, Floor Materials and Footwear – Voltage Measurement in Combination with a Person(27).

5.5.4 Personnel Grounding Straps

5.5.4.1 Another effective way to directly ground personnel is to use personal grounding straps that directly connect the person to ground by means of a wrist strap or similar device. The wrist strap holds a metal disk against the wearer's skin and has a length of wire to connect the person to a ground. These grounding straps should have at least a one megohm resistance between the person and ground to prevent electrocution. Personal grounding straps are routinely used in the electronics industry to prevent damage to sensitive electronic circuits caused by static discharges from people. Personnel grounding straps should be tested for continuity routinely, and visually inspected for mechanical integrity each time they are used.

5.6 Portable Wheeled Equipment: All portable wheeled equipment, if used in Class I, Div. 1 areas, should be grounded. Portable carts that are isolated due to their wheel materials should also be grounded. To reiterate the basic static electricity principal, all metal equipment and objects should be grounded. UL 583 (see reference # 17) provides guidance for conductive tires on powered industrial trucks in hazardous areas.
Chapter 6 Measuring Equipment

6.1 Measuring Static Electricity

6.1.1 Only personnel who have a thorough understanding of the principles of electrostatics and electrostatic hazards should measure static electricity and the various electrostatic properties of materials and objects. Static hazard assessment is very much dependent on the particular circumstances of the situation in question. Without a thorough understanding of electrostatic principles and electrostatic hazards, it might be concluded that a particular situation is “safe” when, in fact, it is quite hazardous.

6.1.2 Static electricity measurements require special instruments designed for that purpose. Ordinary voltmeters, ammeters, and resistance meters are useless for this job. For these reasons, this document will not provide detailed information on electrostatic measurements beyond the guidance provided on acceptable electrostatic field intensity levels and floor conductivity for various applications.

6.1.3 Instruments are available that can measure:

1) Electrostatic Field Intensity: An Electrostatic Field Intensity Meter is a versatile, relatively inexpensive and easy-to-learn tool for detecting the presence of accumulated static charge when used in accordance with the manufacturers’ instructions.

WARNING! Since this instrument is handheld, care must be exercised so that neither the instrument nor the person holding it will be the cause of a static spark while it is being used.

2) Resistivity/Conductivity: (1) Special instruments are required (commercially available) (2) Measurements must be consistent with procedures and equipment spelled out in ASTM D257, Standard Test Methods for D-C Resistance or Conductance of Insulating Materials\(^{16}\). Resistivity instruments should be capable of making measurements in the range of \(10^4\) ohms per square up to \(10^{12}\) ohms per square or greater.

3) Resistance: Instrument must be capable of making measurements in the range of \(10^4\) to \(10^{14}\) ohms at 100 volts or greater.

4) Liquid Conductivity: Instrument must be capable of making measurements in the pico Siemen \((10^{-12}\) mho\) range. Ordinary laboratory liquid conductivity meters measure in the range of micro-mhos \((10^{-6}\) mhos\) and are not suitable to make these measurements.

5) Voltage: Special instruments are required (commercially available).

6) Current: Instrument must be capable of measuring current in the range of \(10^{-6}\) to \(10^{-9}\) amperes.
7) Capacitance: Instruments are commercially available.

6.1.4 These measurements, taken and interpreted by a knowledgeable person, are used to determine the degree of hazard presented by a particular situation.

6.1.5 Many of the instruments used to make electrostatic measurements are better suited for the laboratory than for use in the field. As with any instrument or other electrical device used in electrically classified (hazardous) areas, care should be taken to insure that the device or instrument is rated for use in that area.
Chapter 7 Mitigating the Effects of Static Electricity

7.1 Precautions

7.1.2 Experience has shown that failure to ground and bond, or inadequate grounding and bonding, are the most frequent causes of fires where static electricity was determined to be the source of ignition.

7.1.3 The most important action that an individual can take to control static electricity is to connect conductive objects to ground prior to starting any activity which is known or suspected to generate static electricity, each time, all of the time.

7.1.4 The most important action that an organization can take to prevent fires in which a static electricity discharge is the ignition source is to “institutionalize” grounding and bonding. Procedures, training, use of correct equipment and auditing performance are among the steps needed to ensure that personnel bond and ground correctly each time, all of the time that they are engaged in activities where static generation potential exists.

7.2 Grounding and Bonding

7.2.1 The terms “grounding” and “bonding” are often misunderstood.

7.2.1.1 Bonding occurs when two or more conductive objects are electrically connected in a way that energy levels are equalized and all of the objects are at the same electrical potential. Since bonded objects are at the same potential, there can be no transfer of energy (static discharge) between them. However, even though these bonded objects are at the same potential, they may be at a higher potential than objects around them. In a situation where the potential between the bonded conductive objects and another object are different, a static discharge (spark) can occur when one of the bonded objects comes into contact with an object of different potential, such as a grounded object or a person.

7.2.1.2 Grounding is a special form of bonding where a conductive object is connected, literally, to the ground (earth). When a conductive object is adequately grounded, it is impossible for it to accumulate an electrical potential (energy).

7.2.2 Figure 10 depicts the “water tank analogy” that can be used to better understand the difference between grounding and bonding. In the top picture, two containers are at different electrical potentials (perhaps because of how they were handled). In the middle picture, the two containers are bonded and the potential, while the same on each, is not zero relative to the earth. In the bottom picture, the containers are grounded, and the potential on both becomes zero; this is the non-hazardous state.
7.2.3 Examples of locations that can be used for ground connections are:

1) Ground busses that are connected to earth grounds (metal rods driven into the ground)
2) Building structural steel (ground connection should be confirmed)
3) Process vessel or equipment that is bolted or welded to building steel
4) Grounding rods driven into the ground (see NFPA 70(12) for details)

7.2.4 Grounding and bonding connections and devices should be routinely tested to confirm continuity and integrity. Maximum resistance to ground should be 10-ohms or less (check state and local codes). With all-metal systems and tight connections, it should be easy to achieve this level of resistance to ground. While a resistance of up to 1 megohm (1,000,000 ohms) is generally low enough for static charge removal (2,4,10,11,14,16) resistance this high in all-metal systems with tight connections usually indicate problems such as corrosion, loose or broken connections or a buildup or coating of poorly conducting materials somewhere in the system. If the grounding path includes non-metallic components, such as conductive or static dissipating polymers as
are found in many “conductive” FIBC’s, a ground resistance of approximately 100 megohms may be normal.

7.2.5 A grounding assembly typically consists of a clamp to attach the assembly to the object being grounded and a wire or cable to attach the clamp to the ground “source.” The recommended clamp has opposed, sharpened steel points and has a strong spring holding the points together. The sharpened steel points are necessary to penetrate through layers of insulating material that may be on the object being grounded, such as paint, rust, resin, or dirt. The cable attached to the clamp should have good flexibility and mechanical strength. It is not necessary for the cable to be made of copper. When attaching the ground clamp to an object or surface, it is a good practice to rock the clamp back and forth a few times to allow the points to penetrate any insulating material that might be present. Things that will interfere with or reduce the effectiveness of grounding systems include:

1) Use of clamps with dull or flattened points
2) Use of clamps with weak springs
3) Failure to keep clamps clean
4) Loose connections at either end of the cable
5) Damaged or broken cable

7.2.6 Grounding cable assemblies should be visually inspected prior to each use using the above list of possible defects and the resistance tested periodically—Defective assemblies should be taken out of service immediately and repaired. A good procedure is to measure the resistance to ground of actual grounding situations in the facility, particularly the grounding of drums, pump carts, portable tanks, etc. A field check is an instructive way to demonstrate good vs. poor grounding.

7.2.7 When grounding several objects, (e.g. a tank with a pump, a scale, a filter, and a metal pail or drum), a ground wire can be attached to each individual conductive object or all the objects can be bonded together with a ground wire to one of the objects. There are illustrations in Appendix F of grounding and bonding in various situations.

7.2.8 In certain situations it may be deemed necessary to verify beyond visual observation the physical condition and effectiveness of a grounding installation to ensure that a secure grounding connection has been made, e.g. tank wagon loading/unloading, grounding of conductive FIBC’s, etc. If there is a need to ensure that a safe ground connection has been made there are self testing electronic systems available that monitor the status of the ground connection and notify the system user if the ground connection is secure or if it has been lost.

7.3 Humidification

7.3.1 The generation and accumulation of static electricity is lessened in areas of high humidity. In high relative humidity situations (60 percent - 70 percent R.H or greater), a slight buildup of moisture will take place on solid surfaces thus turning nonconductors into marginal conductors. This layer of moisture can be as little as one molecule thick.
Humidity is not, however, a recommended method of static control. The issues with humidity as a means of static control are:

1) Humidity is only effective as a means of controlling static in very high relative humidity situations, typically 60 percent to 70 percent. This is not a comfortable environment for people to work in;
2) Humidity has no effect on liquids;
3) Certain polymeric materials, i.e., Teflon®, polyolefins, etc., are not affected by humidity;
4) Heated surfaces, such as motors, machinery, conveyors, etc., are not affected by humidity because moisture cannot accumulate on these surfaces;
5) In winter months, especially in cold climates, it is extremely difficult to add enough moisture to ambient air in factories to get the relative humidity up to the point where it will affect static accumulation.
## Appendix A Data
### A-1
#### Electrical Conductivity Of Some Pure Liquids

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Temperature, (°C)</th>
<th>Micromhos/cm</th>
<th>Picosiemens/meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>15</td>
<td>1.7</td>
<td>1.7 x 10^6</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>25</td>
<td>1.1 x 10^-2</td>
<td>1.1 x 10^6</td>
</tr>
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<td>4.8 x 10^7</td>
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</tr>
<tr>
<td>Acetophenone</td>
<td>25</td>
<td>6 x 10^-3</td>
<td>6 x 10^5</td>
</tr>
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<td>Acetyl bromide</td>
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<td>Acetyl chloride</td>
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<td>4 x 10^-1</td>
<td>4 x 10^7</td>
</tr>
<tr>
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<td>2.4 x 10^6</td>
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<td>&lt;2 x 10^3</td>
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<td>1 x 10^6</td>
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<td>5 x 10^-3</td>
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</tr>
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<tr>
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<td>---------------------</td>
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</tr>
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<td>Petroleum*</td>
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<td>$3 \times 10^{1}$</td>
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<td>Phenol</td>
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</tr>
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<td>Isopropyl alcohol</td>
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<td>Xylene*</td>
<td>--</td>
<td>$&lt;1 \times 10^{-9}$</td>
<td>$&lt;1 \times 10^{-1}$</td>
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</tbody>
</table>

**NOTES:**

1. 1 conductivity unit (C.U.) = 1 picosiemens per meter (pS/m)
2. 1 micromho per cm = $10^8$ C.U
3. 1 micromho per cm = $10^{-6}$ mhos per cm
4. *Conductivity of benzene can vary widely
5. Conductivity values for typical solvents can vary significantly from values given in above table

* **Substances bolded** are less than 10000 pS/m. See paragraph 5.2.
## Minimum Ignition Energies

<table>
<thead>
<tr>
<th>Compound</th>
<th>MIE (mJ)</th>
<th>AIT °F</th>
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</thead>
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<tr>
<td>Acetaldehyde</td>
<td>0.13**</td>
<td>446</td>
</tr>
<tr>
<td>Acetone</td>
<td>0.19**</td>
<td>869</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>0.16</td>
<td>898</td>
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<tr>
<td>Benzene</td>
<td>0.20</td>
<td>550</td>
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<tr>
<td>Carbon Disulfide</td>
<td>0.009</td>
<td>194</td>
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<tr>
<td>Cyclohexane</td>
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<td>473</td>
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<tr>
<td>Diethyl Ether</td>
<td>0.19</td>
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<tr>
<td>Ethyl Acetate</td>
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<td>0.23**</td>
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<tr>
<td>Xylene</td>
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</table>

*AIT = Auto Ignition Temperature  
** MIE calculated using the Heat of Oxidation Method (40)

MIE data from NFPA 77, *Recommended Practice on Static Electricity*, 2000  
## A-3

### Recommended Maximum Flow Rates (*)

<table>
<thead>
<tr>
<th>Schedule 40 Pipe Size Diameter, Inches</th>
<th>Flow Rate GPM at 15 Ft./Sec.</th>
<th>Flow Rate GPM at 3 Ft./Sec.</th>
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<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>8</td>
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<tr>
<td>1½</td>
<td>95</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>31</td>
</tr>
<tr>
<td>2½</td>
<td>220</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>345</td>
<td>70</td>
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<tr>
<td>3½</td>
<td>460</td>
<td>93</td>
</tr>
<tr>
<td>4</td>
<td>595</td>
<td>120</td>
</tr>
</tbody>
</table>

**Note *:** information taken from API Recommended Practice 2003, 6th Edition (25)
Appendix B

Bibliography


15) NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids*


19) A. Tewarson, A Study to Determine the Electrostatic Hazard of Medical and Surgical Products and Packages, Factory Mutual Research, FMRC Serial No. 21270, 1974.

20) ASTM F 2413-05, Standard Specification for Performance Requirements for Foot Protection, March 2005


26) ANSI/ESD STM 97.1 – 2006, Floor Materials and Footwear – Resistance Measurement in Combination with a Person, Electrostatic Discharge Association

27) ANSI/ESD STM 97.2 – 2006, Floor Materials and Footwear – Voltage Measurement in Combination with a Person, Electrostatic Discharge Association


Appendix C

Questions and Answers – Static Electricity Hazards Grouped According to Chapter Subject Matter

Chapter 1

Q1) Which is the greater charge generator, the plastic itself, or the separation of contents from the plastic bag?

A1) Plastic bags can accumulate significant static electrification when they are handled or brushed, but the greater hazard is usually the separation of contents from the bag. Different bag contents will cause different levels of electrification.

Chapter 2

None

Chapter 3

Q2) Usually static is generated by the separation of two dissimilar materials. Clear plastic bags, however, can generate static when shaken. How is this charge developed?

A2) For electrical charges to be separated via triboelectrification, the surfaces must be dissimilar and must come into contact, then separate (see the “Triboelectrification” section). Everyone has witnessed, however, that seemingly identical plastic bags will cling to each other or will cling to themselves. This behavior is attributed to slight differences, perhaps in impurity concentration, from point-to-point on the surface of the bag. These very minor differences between one part of the bag and another part of the bag that is in contact with it can cause the charges to separate and accumulate at the points where these differences occur.

Q3) Does particle size and shape affect the amount of static electricity energy generated when dumping dry material out of a bag or drum?

A3) One can expect to see greater electrification with smaller, spherical particles and with material that has a high concentration of fines. It is possible for bag or drum electrification to produce sparks with sufficient energy to ignite flammable vapor.

Q4) When dumping a powdered, chipped or plastic (beads) material from a paper or nonconductive plastic bag, is there sufficient static electricity energy generated to create a spark capable of igniting a flammable atmosphere?
Experience indicates that there is usually no ignition hazard in the dumping of chipped or plastic (beads) material from a paper bag. All-plastic bags or paper bags with a removable plastic liner should not be used to transfer powders in locations where flammable vapor may be present. Chipped or beaded material tends to cause less charging than powder, but electrostatic tests should be conducted if these materials will be dumped from either all-plastic bags or paper bags with a removable plastic liner in areas where flammable vapor/air mixtures are expected.

Does static charge accumulation on clothing cause a hazard in the coatings industry?

Clothing, even multiple layers of clothing, is not a static hazard as long as the wearer is grounded by means of conductive footwear and conductive flooring or another personnel grounding system. Without this grounding, clothing can, under certain conditions, generate enough static to present a hazard. It is especially important that garments not be removed in locations where flammable vapor is present. Any sensation of static shocks by a person in such a location is a serious matter that should be reported immediately to supervision. Clothing static is not typically an ignition hazard in an environment that contains only dust however; induction charging of nearby ungrounded conductive objects may constitute an ignition hazard.

Can the charging of organic powders by pneumatic conveying cause an ignition hazard?

During pneumatic conveying, most powders become charged, with finer particle size, lower moisture content and high velocities contributing to greater charging. Measures to protect against static charging should include:

- Proper bonding and grounding of all conductive parts of the conveying system.
- Use of internal spiral conductors, properly bonded and grounded, in all flexible nonconductive hoses.
- Careful review of all hoppers, bins, silos, etc., that receive the conveyed powder to ensure that there are no “spark promoters,” e.g., pipes, probes, braces, or similar conductive objects that extend toward the surface of the collected dust. Conductive objects that extend only a few inches from the wall of the collector (e.g., level probes) are unlikely to cause a hazard.
- Avoid the use of non-conductive coatings on pneumatic conveying lines and surfaces upon which the powder flow may impinge.
- Insure that conductive internal components of dust collectors, air/product separators, etc. are properly grounded. In particular, filter bag support cages must be properly grounded.

What static hazards are encountered when bubbling compressed gas through solvent filled pipes to clean them?
A7) If the solvent has low conductivity, such as toluene, xylene, hexane and mineral spirits, the turbulence created by the air bubbles passing through the pipe will cause the solvent to quickly become charged to a hazardous level. When this solvent is drained, it may still be highly charged and can be the source of a brush discharge if a grounded electrode (like a person’s finger or the end of a pipe) approaches the surface of the liquid. It is also possible that the charged solvent will cause inductive charging of nearby ungrounded conductors if the solvent is in a nonconductive hose.

Q8) The energy contained in static discharges is expressed in units of “millijoules.” How can I describe the “size” of a millijoule?

A8) A millijoule is a very small amount of energy. The threshold of shock sensation — the point at which a person just barely feels a shock or thinks he or she may have felt a shock — is at an energy level of about one millijoule. For a typical person, this much energy is achieved at a potential of approximately 3,000 volts. The minimum energy required for the ignition of hydrocarbon vapors (at ideal conditions) is approximately 0.25 millijoules. This means that a static discharge that can barely be felt has several times the amount of energy required for ignition.

Q9) Please explain the resistivity units of “ohms per square” as mentioned in the section on “Charge Accumulation and the Conductive Properties of Materials.”

A9) An early method for determining a material’s resistivity was to measure the resistance between two parallel electrodes of equal length that were separated by a distance equal to the length of the electrodes. The electrodes formed a “square,” hence the units “ohms per square.” Using this electrode configuration, the test result will be the same regardless of the size of the electrodes. This instrument setup, if done in accordance with the procedures set forth in ASTM D257, will result in accurate measurements. There are other instrumentation arrangements for measuring resistivity included in the standard, such as using concentric ring electrodes, which will also give accurate results.

Q10) What are “Siemens” and why is this unit used for conductance rather than the more recognizable unit “mho”?

A10) The siemens, thought to have been named for Sir William Siemens (1823-1883), was adopted in the early part of the 20th century as Standard International (SI) unit of conductance. The units of the siemens are coulombs per joule (amperes per volt in the English system). Conductance is the inverse of resistance, so a siemens is an inverse ohm, also referred to as a “mho”. The mho is considered by the scientific community to be an archaic and outdated term and is seldom used today in literature.
Q11) Are there hazards in the workplace that are associated with static electricity other than static ignition of flammable vapors?

A11) Yes. A person getting up out of a chair can generate from 5,000 to 10,000 volts on his or her body. Shocks at these energy levels feel more like pinpricks and typically result in startled reflex reactions like dropping things or quickly jerking ones body away from the source of the shock. Depending on what the person is doing at the time, an incident or injury could result.

Q12) Does “higher (more) charge” always mean that an object will have a higher voltage?

A12) In general, for a given conductive object, more charge accumulation will result in the object having a higher voltage, higher electrostatic field intensity, and greater stored energy. If two objects, for example a one-gallon can and a 5-gallon pail, have the same amount of charge on them, the larger object (the pail) will have a lower voltage. The reason for this is that the pail has more capacitance than the can. From the formula $Q = \frac{1}{2} CV^2$, if the amount of charge, $Q$, is held constant and the capacitance, $C$, is increased, the voltage, $V$, must decrease. Additional information can be found in the “Hazards of Static Electricity” section and References 1, 2, 3, 7, 9,12, and 13.

Chapter 5

Q13) The conductivity requirement for a liquid to be considered a “conductive” liquid has changed significantly from the previous edition of this document. What has changed?

A13) The conductivity of liquids ranges from about $10^{-2}$ pS/m up to about $10^{10}$ pS/m, 12 orders of magnitude. To simplify the task of characterizing liquids, lines have been drawn on this continuum to define the “Conductive region,” the “Static Dissipating” (or Semi-Conductive) region and the Non-Conductive region. These lines were drawn arbitrarily and reflected the knowledge, experience, and judgment of the individuals and organizations that drew them. These lines have changed over the years. In 1988, in NFPA 77, section 4-1.7 it states “If the conductivity of a liquid under use conditions is greater than 50 pS/m, any charges that are generated will dissipate without accumulating to a hazardous potential.” In the same document, in Appendix B, it states “A liquid with conductivity of about 100 pS/m may be termed “high conductivity for most purposes. In 2000, NFPA 77 defined conductive liquids as having conductivities greater than $10^4$ pS/m.

When the 2000 edition of this document, Generation and Control of Static Electricity in Coatings Operations, was written 1000 pS/m was thought to be adequate and was consistent with other codes of practice such as the CENELEC document TR 50404, Code of Practice for the Avoidance of Hazards Due to Static Electricity, The British Standard on Static Electricity BS 5958, and others. In 2009 – 2010, the CENELEC document will be replaced with a new code of practice issued by the IEC (International Electrotechnical Commission). This new
document defines a “conductive” liquid as having a conductivity of $10^4$ pS/m or greater.

This change in the international and domestic codes of practice along with 2 recent publicized incidents involving “conductive” liquids (10,000 to 50,000 pS/m) makes a very strong argument for the decision to change the definition of “conductive” liquid in this document to 10,000 pS/m.

Q14) How can one determine if a plastic bag is suitable for use in areas where flammable vapor/air mixtures are normally expected (e.g., Class I, Div. I areas)?

A14) Ordinary plastic bags should not be used in Class I, Div. 1 areas because of the possibility that they will generate a static spark of sufficient energy to ignite the flammable vapor that is likely to be present. Unfortunately, it is virtually impossible to visually determine if a plastic bag is suitable for these areas. Typically, conductive bags are carbon loaded and are black in color, but black is a very popular color for plastic bags that have no special treatment or composition that would make them conductive. The only way to definitively determine if a plastic bag is suitable for these areas is to test it (or have it tested). The tests that will determine if a plastic bag is suitable for use in hazardous areas - is Surface Resistivity

Surface Resistivity is determined with commercially available, easy-to-use instruments. Plastics that have a surface resistivity of $1 \times 10^{11}$ ohms per square or less at 70°F and 20 percent - 30 percent relative humidity will have adequate surface resistivity to prevent the accumulation of hazardous levels of static charge. ASTM D257 has information on equipment and procedures for this test. When doing this test “in house,” it should be recognized that there are many factors that may make the results unreliable. For example, if the test is done in a moderate- to high-humidity environment (40 percent - 80 percent R.H.), the resistivity can be as much as several orders of magnitude lower than when measured at 20 - 30 percent R.H. Surface contamination can also have a profound effect on resistivity, usually lowering it.

Regardless of the manufacturer’s designation for plastics, a plastic is suitable for use in hazardous areas if it meets the above criteria. One way to avoid the problems of testing in house is to have the vendor of the plastic product test the product and certify that it meets the above criteria.

Q15) How are plastic packaging materials grounded?

A15) Packaging materials that are designated as being conductive or static dissipating should be grounded when being used in classified areas, just as any other conductive object (drum, pail, etc.) should be grounded. “Opposed point” clamps that are recommended for use on metallic objects to provide a connection to ground are not entirely suitable for grounding conductive plastic sheeting. The
points may cause tearing of the plastic film and subsequent loss of contact between the clamp and the material being grounded. An alternate to the opposed point clamp for plastic sheeting is a clamp with flat or corrugated gripping surfaces that tightly grips the plastic film.

Conductive FIBC’s (Flexible Intermediate Bulk Containers) should be grounded by attaching the appropriate grounding clamp to the designated grounding tab.

Q16) Can a multi-layer paper bag of powder (e.g., a plastic sheet sandwiched between two or more paper layers) create additional static beyond that generated by the flowing powder when being filled or dumped?

A16) No.

Q17) What about a paper bag that has a removable plastic bag inside of it?

A17) Experience indicates that a composite bag of paper and a plastic layer creates no additional static hazard as long as the liner is attached to one or more of the paper layers. It makes no difference whether or not the plastic layer contacts the material. An all-plastic bag or paper bag with a removable plastic liner may be hazardous when dumped in a flammable vapor-air environment.

In the case of either plastic-lined, plastic-coated, or all-plastic bags, one should measure the static electrification of the bag immediately after emptying a new product. The humidity level should be the lowest that will be encountered in the area where the operation takes place. Electric field intensities greater than 5 kV/cm (12.5 kV/inch) indicate a potential hazard. Note that this testing should be done in an area where there are no flammable vapors present.

Q18) Do both metal chimes of a fiber drum need to be grounded?

A18) Normally, only one chime needs to be grounded. The reason for this is that the cardboard material of the drum is normally semi-conductive, except for situations where the ambient humidity is under 10 – 20%. In low humidity situations such as arid climates or very cold outside temperatures, the resistivity of the fiber drum should be measured. If the measured resistivity is greater than $1 \times 10^{11}$ ohms per square or if the resistivity in low humidity conditions is unknown, both metal chimes should be grounded during emptying.

Q19) Are there plastic floor coverings on the market that dissipate static?

A19) There are numerous products that are made to increase the conductivity of floors in work areas. These products include conductive floor tiles, coatings, mats, etc. These products should have a reliable path to ground to be effective and should be routinely tested to confirm that conductivity and ground connection are intact.

Q20) Are there marking requirements for non-static-producing plastic materials?
A20) There are few requirements for marking either non-static-producing (conductive) plastics or static dissipating plastics. The only reliable way to be sure of the conductive properties of a particular plastic material is to test it. See Question 1 for information on resistivity testing of plastic materials.

Q21) Do “static dissipating” plastic bags/liners have a shelf life?

A21) Tests have shown that static dissipating plastic bags can retain their static dissipating properties for several years. There are, however, conditions under which the special properties of these bags may be shortened to as little as a few days or weeks.

Plastic films are typically made to be static dissipating by the addition of a material that attracts atmospheric moisture to the surface of the plastic, thus making the plastic slightly conductive. In very low humidity conditions, such as in cold environments, the amount of moisture that can be attracted to the plastics surface may not be sufficient to give the desired level of resistivity. A plastic film that is found to be adequately “static dissipating” at moderate to high humidity (over 40 percent RH) may exhibit no static dissipating properties at low humidity (less than 30 percent RH). Another problem with this kind of film is that some types of powders, especially certain pigments, when packaged in static dissipating plastics, will cause the plastic to rapidly lose its static dissipating properties. The cause of this phenomenon is not completely understood, but it is thought that the powders rapidly adsorb the static dissipating additive from the plastic’s surface, causing the plastic to behave like a non-static dissipating plastic. When in doubt, measure the bags’ conductivity or charge decay time.

Inherently Dissipative Polymers (IDPs), which have permanent non-migrating antistat agents, are a recent innovation that eliminates many of the shortcomings of traditional antistat agents.

Q22) From the standpoint of static generation, how much “free fall” of flammable or combustible solvents is considered to be “too much?”

A22) Free falling solvents should be avoided where possible. The amount of hazard from this activity increases proportionally with the height of the “free fall.” Free falling a flammable solvent a few inches presents a minimal (but not zero) ignition hazard. Free falling a flammable solvent a few feet presents a substantially greater risk of ignition, especially for low conductivity solvents. See the section on Handling Low Conductivity Solvents for an explanation of the hazards of this activity.

Q23) What are the conditions under which open bag filters represent a fire risk?

A23) As stated in the section on filtration only low conductivity liquids will be charged when passing through a micro-filter (typically, bag or other filters with a pore size of 150 microns or less). If a liquid has a conductivity of 10,000 picosiemens/meter or more, there is little likelihood that the liquid will accumulate an electrostatic charge. In general, polar liquids such as alcohols and ketones
are conductive. When in doubt, liquid conductivity can readily be measured using an easy-to-use, commercially available liquid conductivity meter.

Q24) Does the material of construction of a filter bag have any effect on how much static is generated by the filter?

A24) Testing has shown that the material of construction of a filter does not significantly affect static generation by the filter. Static generation is mostly affected by pore size and liquid conductivity.

Q25) Can an open bag filter be used to filter a nitrocellulose lacquer product?

A25) Yes. Nitrocellulose lacquers, by their formulation, typically contain a high percentage of polar solvent and will be conductive. If there is a question about the conductivity of a particular product, it can be easily measured.

Q26) What if an open bag filter touches the base of an open metal funnel during the filtration process?

A26) If the liquid is conductive and the funnel is grounded, there is no static hazard because the funnel and the filter bag will be connected electrically and, thus, will both be at the same potential. If the liquid is not conductive and the funnel is not grounded, the funnel and the filter bag will not be electrically connected. In this situation, the static charge on the surface of the filter bag will induce a charge on the ungrounded funnel. If the charge is great enough, the funnel will be a potential ignition source.

Q27) Can a static dissipating product be applied to the surface of a plastic bag or other low conductivity material, and does this antistat have a shelf life?

A27) Topical (applied to the surface) antistats can be used to temporarily increase the surface resistivity of a low conductivity material. These topical antistats usually are sprayed onto a surface; commercial aerosol sprays that are marketed to eliminate “static cling” are examples of this kind of product. These products typically are conductive liquids and, after evaporation, the residue will attract atmospheric moisture. It should be noted that this type of antistat is easily removed by rubbing or wiping and can be washed away by water or other liquids. It should not be relied on for a long-term solution to a static accumulation problem. No data are available on the shelf life of the static dissipating product itself.

Q28) Can an antistat material be added to a solution to raise its conductivity, thus reducing the likelihood that it will accumulate a static charge?

A28) Yes. There are commercial products that will raise the conductivity of a liquid. See the section “Handling Low Conductivity Liquids” for more information.
Q29) We make a low pH product that contains a conductive liquid. It is filled into plastic pails. How can I eliminate the static charge on the empty pails?

A29) The plastic pails will become charged as they are pulled apart or “un-nested.” A charged pail will induce a charge on the conductive liquid contents. If there is a flammable vapor/air mixture present above the liquid and if the level of charge is sufficient, there is the potential for a spark from the charged liquid. Wiping the outside of each pail with a cloth dampened with water will temporarily raise the conductivity of the surface of the plastic and allow the separated charges to recombine, thus eliminating the static hazard. Although this technique will work using any conductive liquid, water is recommended since it is not flammable. *Under no circumstances should plastic surfaces be wiped or rubbed with nonconductive solvents; this has been the source of many fires.*

Q30) What is “Relaxation Time” and how is it calculated?

A30) The rate at which static charge is dissipated from a liquid is called **Relaxation Time**. Relaxation time is the time in seconds it takes a liquid to dissipate its accumulated charge from its initial level to 1/e (e = the base of Naperian logarithms or 2.71828) of the initial charge. This works out to be approximately 37% of initial charge. A liquid’s relaxation time is proportional to its dielectric constant and inversely proportional to its conductivity and is represented by the formula -

\[
T = \frac{\varepsilon_0 \varepsilon_r}{\kappa}
\]

Where
- \(T\) = Relaxation Time (Seconds)
- \(\varepsilon_0\) = Permittivity of Free Space (8.85 x 10\(^{-12}\) Farads/meter)
- \(\varepsilon_r\) = Dielectric Constant
- \(\kappa\) = Liquid Conductivity (S/m)

Since the dielectric constant of most hydrocarbon based liquids is approximately 2.0, Relaxation Time for these liquids can be approximated by the formula

\[
T = \frac{18}{\kappa}
\]

In 5 relaxation time periods, the initial charge is essentially reduced to zero. In this formula, \(\kappa\) = Liquid Conductivity in pS/m.

Q31) Why was the use of the charge decay test (Federal Test Standard 101C, Procedure 4046) to determine the electrostatic classification of plastic sheeting materials deleted from this document?

A31) After reviewing the 2 test procedures, FTS 101C, M 4046 and ASTM D257, it was concluded that the use of surface resistivity (ASTM D-257) rather than charge decay time (FTS 101C) was a more widely accepted method of
classification. No national or international code or standard could be found that used charge decay time to classify sheet materials electrostatically. See Appendix D for a more thorough discussion of this topic.

Q32) Does the agitation of liquids present any static hazards?

A32) It is unlikely that the agitation of conductive liquids in grounded metal vessels will result in any appreciable accumulation of static charge. On the other hand, the agitation of low conductivity liquids may present significant static hazards, even in grounded metal vessels.

Q33) Will adding cushioned insoles to the inside of ESD footwear eliminate or minimize their effectiveness?

A33) Based on resistivity measurements that have made of shoes of hundreds of workers in different coatings facilities, the presence or absence of insoles, the composition of the persons socks, or the age of the shoes has no significant effect on the level of resistance between the person’s skin and the surface he (she) is standing on. This is due to the fact that feet sweat and the humidity/moisture level inside of the shoe pretty much insures continuity between everything that is in the shoe (foot, sock, insole, orthotic device, etc). If a person were to put on a new pair of SD shoes with fresh socks and then immediately step onto a shoe resistance-measuring device he would probably get a high reading. After a few minutes, to allow the moisture inside the shoe to increase, the resistance reading might be acceptable. ESD insoles may also be available and are preferred.

Chapter 6

Q34) What is the purpose of ASTM D257?

A34) The title of this standard is “Standard Test Methods for D-C Resistance or Conductance of Insulating Materials” and it defines a standardized set of procedures and equipment for making these measurements. Test results obtained from equipment and procedures complying with this standard can be compared with confidence to other results obtained using the same standard, even if the results were obtained by a different organization at a different time. When purchasing conductivity testing equipment or when asking a laboratory to determine the resistivity of a specimen, it is unnecessary to specify the equipment and the procedures; simply ask the lab or the vendor to comply with ASTM D257. Copies of this standard can be obtained directly from the American Society For Testing and Materials (www.ASTM.org).

Q35) Do air-driven diaphragm pumps present any static electricity hazards in electrically classified locations?

A35) Diaphragm pumps of metal construction must be grounded. Pumps constructed of plastic or polymeric materials present some unique hazards. All conductive
parts (metal fasteners holding the pump together, mufflers, etc.) must be grounded. In addition, all conductive objects within one to two meters of the plastic pump must be grounded; this would include people. Users should consider the need for an all metal or conductive plastic construction.

Chapter 7

Q36) What is the best way to protect against static when filling a solvent based paint into plastic 5-gallon pails, or when dispensing liquids from these containers?

A36) The safest way to handle solvent based coatings products is in grounded metal containers. Occasionally, however, a paint material must be packaged in a plastic container rather than a metal one because of the corrosive nature of the product, the possibility of contamination, etc. In these cases, the following precautions should be considered:

- If the conductivity of the paint product is low or unknown or if there are filters in the fill line, the filling velocity of the liquid should be limited to 3 ft./sec.
- The filling line should extend to the bottom (or close to the bottom) of the container being filled.
- Remember the hazards of “induction charging” and ground conductive objects in the immediate vicinity of the pail.
- If a static charge is detected on the empty plastic pails, wiping the outside of the pail with a water-dampened cloth can neutralize it.

Q37) What type of grounding clamp should be used when attaching a ground wire to a conductive plastic material?

A37) See answer to Question 2

Q38) How can static charge generation on semi-bulk bags (FIBC's/Flexible Intermediate Bulk Containers) that are used for handling pigments or resins be neutralized?

A38) There is, as yet, no effective method for neutralizing static on nonconductive, semi-bulk bags. This has led to the introduction of FIBC's with metallic or carbon filaments for static control. Bags with interconnected conductive filaments must be grounded before dumping.

Q39) If a powdered, flaked, chipped or bead-shaped dry material is in a metal container, would bonding the container to the receiving vessel be an effective way to dissipate any static electricity buildup during dumping?

A39) Bonding the container to the receiving vessel would eliminate any ignition hazard from the metal container. It would not dissipate static charges from the dry material being dumped, but those charges typically do not create an ignition hazard unless flammable vapors are present.
Q40) Do lined (phenolic, epoxy, etc.) metal containers need any special type of grounding prior to being filled or emptied?

A40) Nonconductive linings will not significantly affect the dissipation of charge from a liquid as long as the lining is “thin.” (“Thin” is typically taken to be less than 2-4 mils)\(^7\) If a lining or coating is thicker than 2mm, the container, if metal, should be grounded and the precautions for handling plastic containers should be followed (see Question 7). For additional information, see References 2 and 6. All metal containers should, of course, be grounded.

Q41) How do you test the conductivity of floors?

A41) Static dissipating footwear is not effective in draining static electricity from a person’s body unless the person is standing on a floor that has sufficient conductivity to take the accumulated charge to ground. Floors are typically tested using special resistance testers called “meggers” or some other type of high impedance resistance meter capable of measuring resistance at as much as 500 volts. These meters are available commercially. ANSI/ESD 97.1 2006, *Floor Materials and Footwear – Resistance Measurement in Combination with a Person*, published by the Electrostatic Discharge Association, gives information on how to test floors. The resistance to ground for floors in coatings and related operations should be no greater than 1x10\(^9\) ohms.

Q42) What is the recommended frequency of testing the resistance of ground paths dedicated to static electricity ground paths?

A42) NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, 2002 Edition, in section 20.4, *Frequency of Tests*, states that “frequency of testing will generally coincide with the frequency of maintenance… In general, this cycle can range from 6 months to 3 years..”. Annually is a reasonable ground path testing frequency.

Q43) Is there a recommended procedure to test ground paths?


Q44) What is an acceptable value for resistance in an all-metal grounding system?

A44) Typically, in an all metal grounding system with tight connections, 10 ohms or less should be readily achievable. State or local electrical codes may vary from this and should be followed. See section 9.2.4 of this document for additional information.
Appendix D

Summary of Pro’s and Con’s for Different FIBC’s

**Type A**

Pro  
(1) Inexpensive  
(2) Can be re-used  
(3) Can be used if no flammable vapors are present and conductors within 2 meters are grounded  
(4) Can be used with powders having an MIE of greater than 1000 mJ

Con  
(1) Cannot be used where flammable vapor/air mixtures are or may be present (Class 1, Divisions 1 & 2)  
(2) Conductors within 2 meters of the bag must be grounded to avoid induction charging (includes personnel)  
(3) Cannot be used with powders having a MIE of less than 1000 mJ  
(4) Offers no protection from Propagating Brush Discharge

**Type B**

Pro  
(1) Offers all of the Pro items of a Type A bag  
(2) Offers protection from propagating brush discharges  
(3) Can be used for combustible powders having MIE > 3 mJ

Con  
(1) All of the limitations of the Type A FIBC apply  
(2) Not for use with combustible powders having MIE < 3 mJ  
(3) Cannot be used where flammable vapors are present

**Type C**

Pro  
(1) Can be used in all situations, including presence of flammable vapor/air mixtures and with powders having a MIE of less than 3 mJ  
(2) No Induction charging hazard for ungrounded conductors within 2 meters

Con  
(1) If not properly grounded, this type of FIBC presents a significant static electricity hazard

**Type D**

Pro  
(1) Can be used in most * locations where flammable vapor/air mixtures are present or where powders having a MIE of less than 3 mJ are present  
(2) These FIBC’s do not need to be grounded
* - Type D FiBC’s are tested, according to IEC 61340-4-4, with a gas mixture having a MIE of 0.14 mJ. If Type D bags are to be used in an atmosphere having a MIE less than 0.14 mJ, they should be tested with a gas having the anticipated MIE or having a lower MIE.

Con

1. Bags must be tested according to IEC 61340-4-4 prior to being used with a particular powder.
2. Conductive objects as close as 2 meters must be grounded to eliminate induction charging hazards (See Induction Charging, below)
3. Bags must be certified per IEC 61340-4-4 test procedures
Appendix E

Using Surface Resistivity Versus Charge Decay Time for Electrostatic Classification of Solid Materials

In the ACA document, *Generation and Control of Static Electricity in Coatings Operations*, 2002, static dissipating plastics are defined as having the following properties when measured at 70º F and a relative humidity of 20-30 %.

a. A surface resistivity no greater than \(1 \times 10^{11}\) ohms per square following the procedures in ASTM D257, or
b. A charge decay time of no greater than 0.5 seconds to go from 5000 volts to 500 volts following the procedures in Federal Test Standard 101C, *Test Procedures for Packaging Materials*, Procedure 4046, *Electrostatic Properties of Materials*.

Questions have been raised by some users of this document as to why there are two procedures, is one procedure preferred over the other and is one a better indicator of the suitability of a plastic material for an application where the use of an “static dissipating” plastic is indicated.

**Background**

Resistivity is a measure of how quickly electrical charges can move across or through a particular material. Since charge transfer occurs at the surface of solid materials, surface resistivity is typically used to characterize a material rather than volume resistivity. Plastic or polymeric materials are typically non-conductive, that is they have a surface resistivity greater than \(1 \times 10^{12}\) ohms per square. At this level of resistivity, charges move very slowly and are able to accumulate. When sufficient charge is accumulated on the surface of a non-conductive material and a suitable electrode approaches it, a discharge is possible. In many coatings operations, discharges from the surface of non-conductors are potential ignition sources.

The Electrostatic Hazards Community and the EOS/ESD (Electrical Overstress/ElectroStatic Discharge) Community, consisting primarily of electronic component manufacturing and packaging, appear to have differing opinions as to the definition of the term “Static Dissipating”. The Electrostatic Hazards Community defines “Static Dissipating” in terms of surface resistivity. Typically, a material is said to be “static dissipating” if it has a surface resistivity between \(1 \times 10^9\) and \(1 \times 10^{11}\) ohms per square. As stated above, resistivity is a measure of how rapidly charge can dissipated. The ESD Community defines “Static Dissipating” as “having to ability to resist triboelectric charging”. In both communities, the electrostatic properties of material surfaces are characterized by measurement of its surface resistivity. There is no national or international code or standard that specifies charge decay time as a means to characterize the electrostatic properties of a solid material. There is no “universal” consensus as to what range of charge decay times defines a particular material as conductive, static dissipating, or insulating.
Resistivity Test
ASTM D-257, *Standard Test Methods for D-C Resistance or Conductance of Insulating Materials*, has been used for many years by both the EOS/ESD and the Electrostatic Hazards communities to classify packaging materials as either insulating or "static dissipating". Although this procedure has some shortcomings, it is still used in a wide range of industries to classify packaging and sheet materials made of synthetic and natural materials by measuring their surface resistivity. The shortcomings of this test include:

- This test assumes that the material being tested is homogeneous and not a composite.
- D257 offers the use of several different fixtures to measure surface resistivity
- The fixtures specified in D257 use a relatively high pressure (20 –100 psi) applied to the test sample. Most of the time this does not represent actual use.
- D257 specifies a relatively high voltage (500 V or higher) for relatively long periods of time (---). When used to measure conductive or semi-conductive materials, this high voltage can result in a relatively high current flow that can affect the surface of the material.

Surface resistivity is specified as the means to classify these materials in virtually all codes and standards worldwide.

Charge Decay Test
Federal Test Standard 101C, Method 4046, *Electrostatic properties of materials*, seems to appear in several versions. There is -


FTS 101C, 4046 does not appear to be available through any standards organization nor through any document company. The purpose of this procedure is to test packaging materials used in the electronics industries.

For all of the above reasons, the best, most consistent, and understandable way to define a solid or sheet material's propensity to dissipate electrostatic charge is its surface resistivity. The use of the charge decay time test, Federal Test Standard 101C, Method 4046, while it may be a technically superior way to characterize a materials ability to dissipate electrostatic charge, is not commonly understood nor is it used in applicable texts, technical papers, applicable codes or standards.
# Appendix F

## Drawings of Typical Grounding and Bonding Assemblies

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#1/0-1/C stranded, bare copper wire building static grounding "bus" typical arrangement, routed as close to grounding point as possible.

NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

1/4" Flexible bronze or stainless steel ground-cable of required length.

GROUND ROD CONNECTOR

5/8" x 8' ft. length (min.) ground rod (per NFPA 70 material requirements), driven into earth at building. See text for conductivity requirements.

NOTE: AS AN ALTERNATE TO A GROUND ROD, CABLE CAN BE ATTACHED TO GROUNDED BUILDING STEEL.

GROUND CONNECTION OF BUILDING
GROUND BUS – TYPICAL ASSEMBLY

TA-1
TYPICAL ASSEMBLY NO. 1

LATEST REVISION DATE: 12/1/09
PERMANENT — FIXED, EQUIPMENT GROUND EXTENSION TO BUILDING GROUND "BUS" TYPICAL ASSEMBLY

NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

#10-1/2 STRANDED BARE COPPER WIRE (OR SOLID BUS BAR) BUILDING STATIC GROUNDING "BUS" TYPICAL ARRANGEMENT.

1/8" BRONZE OR STAINLESS STEEL GROUNDING CABLE OF LENGTH REQUIRED TO REACH EQUIPMENT TO BE GROUNDED.

SEPARATE STRANDS OF WIRE AND MAKE CONNECTION WITH 1/4"-20 BOLT, WASHER, AND LUG. INSERT INTO ANCHOR AND TIGHTEN FOR GOOD CONTACT.

TA-2
TYPICAL ASSEMBLY NO. 2

LATEST REVISION DATE: 12/1/09

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INSERT CABLE END INTO CLAMP AND TIGHTEN LOCKING SCREW UNTIL CABLE AND CLAMP ARE SECURELY LOCKED TOGETHER. DO NOT USE SOLDER FOR THIS CONNECTION.

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE CUT TO LENGTH REQUIRED.

STAINLESS STEEL CONTACT POINTS

BOLT HOLE

INDENTED CONNECTION

INSERT CABLE INTO LUG. INDENT LUG WITH MANUFACTURER'S TOOL DESIGNED FOR THAT PURPOSE. DO NOT USE SOLDER.

NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

SMALL GROUND CLAMP
TYPICAL ASSEMBLY

TA-3
TYPICAL ASSEMBLY NO. 3

LATEST REVISION DATE: 12/1/09

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NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

NOTE: LARGE CLAMPS USED WITH TANK TRUCKS SHOULD INCLUDE PULLAWAY HARNES ASSEMBLY.

INSERT CABLE INTO LUG. INDEBT LUG WITH MANUFACTURER’S TOOL DESIGNED FOR THAT PURPOSE. DO NOT USE SOLDER.

1/8” FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE.

BOLT HOLE

INDENTED CONNECTION

INSERT CABLE END INTO CLAMP AND TIGHTEN LOCKING SCREW UNTIL CABLE AND CLAMP ARE SECURELY LOCKED TOGETHER. DO NOT USE SOLDER FOR THIS CONNECTION.

CABLE LOCKING SCREW

OPTIONAL QUICK RELEASE HARNES ASSEMBLY

STAINLESS STEEL POINTS WITH DOUBLE BRASS NUTS AND LOCKWASHERS.

LARGE GROUND CLAMP
TYPICAL ASSEMBLY

LATEST REVISION DATE: 12/1/09

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BUILDING STATIC GROUNDING "BUS" (MOUNTED ON WALL).

SEPARATE STRANDS OF WIRE AND MAKE CONNECTION WITH 1/4"-20 BOLT, WASHER, AND LUG. INSERT INTO ANCHOR AND TIGHTEN FOR GOOD CONTACT.

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE CUT TO LENGTH REQUIRED.

SMALL GROUNDING CLAMP AND CABLE.

"ROCK" THE CLAMP TO ENSURE THAT STAINLESS STEEL POINTS PENETRATE PAINT, RUST, OR ACCUMULATED MATERIALS.

SMALL GROUNDING CLAMP ATTACHED TO APPROPRIATE CONTAINER CONNECTION POINT

PORTABLE CONTAINER

NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

BUILDING GROUND "BUS" EXTENSION TO PORTABLE CONTAINERS — TYPICAL ASSEMBLY

TA-5
TYPICAL ASSEMBLY NO. 5

LATEST REVISION DATE: 12/1/09

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GROUNDING "TAP" CONNECTION TO
BUILDING GROUND "BUS" – TYPICAL ASSEMBLY

NOTE:
GROUND CONTINUITY OF ALL PIPING,
equipment, devices, cables and
connections must be checked for
electrical continuity at the time
of installation and should be
tested at least annually
thereafter.

PIE STRAP

BUILDING STATIC GROUNDING "BUS"
(MOUNTED ON WALL).

WALL ANCHOR

METAL GROUNDING TAB
2" WIDE X 3" LONG X 3/16" THICK
(CAN BE COPPER, STAINLESS STEEL,
ALUMINUM, ETC.)
FOR ATTACHMENT OF PORTABLE
GROUNDING CLAMPS.

SMALL GROUNDING CLAMP

1/8" FLEXIBLE BRONZE OR STAINLESS
STEEL GROUNDING CABLE CUT TO
LENGTH REQUIRED

TO PORTABLE EQUIPMENT

LATEST REVISION DATE: 12/1/09

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PIPE CLAMP OF SIZE REQUIRED
(SIZES FROM 1" TO 14").

1/8" FLEXIBLE BRONZE OR STAINLESS
STEEL GROUNDING CABLE CUT TO
LENGTH REQUIRED.

PIPE FASTENED TO GROUNDED
EQUIPMENT

NOTE:
GROUND CONTINUITY OF ALL PIPING,
EQUIPMENT, DEVICES, CABLES AND
CONNECTIONS MUST BE CHECKED FOR
ELECTRICAL CONTINUITY AT THE TIME
OF INSTALLATION AND SHOULD BE
TESTED AT LEAST ANNUALLY
THEREAFTER.

PIPE GROUNDING TAB
TYPICAL ASSEMBLY

BOLT, NUT & WASHERS

METAL GROUNDING TAB
2" WIDE X 3" LONG X 3/16" THICK
(CAN BE COPPER, STAINLESS STEEL,
ALUMINUM, ETC.)
FOR ATTACHMENT OF PORTABLE
GROUNDING CLAMPS.

TA-7
TYPICAL ASSEMBLY NO. 7

LATEST REVISION DATE: 12/1/09

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NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

PIPE CLAMP OF REQ'D SIZE

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE CUT TO LENGTH REQUIRED.

PIPE GROUNDING JUMPERS
TYPICAL ASSEMBLIES FOR SWIVEL JOINT CONNECTIONS

TA-8
TYPICAL ASSEMBLY NO. 8

LATEST REVISION DATE: 12/1/09

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NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

CONTINUOUS CABLE JUMPER LOOP TO NEXT PIPE CLAMP.

PARALLEL PIPING AT DRAIN-OFF STATION.

PIPE CLAMP (USE SIZE REQUIRED BY PIPE BEING GROUNDED).

TWIST CABLE TO SEPARATE WIRE, SPREAD WIRE IN EQUAL HALVES AND INSERT PIPE CLAMP BOLT AND WASHER THROUGH CABLE. PLACE BOLT, WASHER AND CABLE INTO POSITION ON CLAMP, TURN ON OPPOSING NUT AND WASHER AND TIGHTEN UNTIL ASSEMBLY IS SECURE.

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE TO GROUNDING CLAMP.

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE TO BUILDING GROUND CONNECTION.

PIECE GROUNDING CLAMP
TYPICAL ASSEMBLY

TA-9
TYPICAL ASSEMBLY NO. 9

LATEST REVISION DATE: 12/1/09

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TYPICAL GROUNDING

ARRANGEMENT AT DROP VALVE
OF THINNING OR MIXING TANK

NOTE:
GROUND CONTINUITY OF ALL PIPING,
equipment, devices, cables and
connections must be checked for
electrical continuity at the time
of installation and should be
tested at least annually
thereafter.

THINNING OR MIXING EQUIP.
grounded to building cable
ground bus on floor above.

CONDUCTIVE VALVE ASSEMBLY

NORMALLY CLOSED AIR TO
OPEN VALVE ASSEMBLY
(W/PLASTIC PNEUMATIC TUBING)

"DROP VALVE" GROUNDING
ASSEMBLY OF PIPE CLAMP,
CABLE AND METAL TAB.

NOTE:
To minimize static generation,
utilize pipe extension or conductive
hose to limit free fall of flammable
liquid or to direct flow to the side
of the container.

TA-10
TYPICAL ASSEMBLY NO. 10

LATEST REVISION DATE: 12/1/09

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NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

5 CAL METALIC PAIL
WITH GROUNDING CABLE AND CLAMP.

THIS CONNECTION
NECESSARY IF SUCTION PIPE NOT SECURELY ATTACHED BY THREADED CONNECTION

LUGS MOUNTED ON FLANGE BOLT OF PUMP WITH 1/8" STAINLESS STEEL GROUNDING CABLE AND GROUND CLAMP.

FOR ATTACHMENT TO TAB ON BUILDING GROUND BUS.

UL LISTED / APPROVED FLAMMABLE LIQUID DISPENSING PUMP

TYPICAL GROUNDING SYSTEM FOR DISPENSING FLAMMABLE LIQUIDS FROM DRUMS

TA-11
TYPICAL ASSEMBLY NO. 11

LATEST REVISION DATE: 12/1/09

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NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

TYPICAL GROUNDING SYSTEM FOR SMALL VOLUME SOLVENT HANDLING

LATEST REVISION DATE: 12/1/09

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BUILDING STEEL

CONNECT GROUND CLAMP(S) ON MANUFACTURER-PROVIDED GROUNDING TABS (CONSULT SUPPLIER)

TYPE C BAG MESH GROUND MATERIAL

TYPICAL TYPE C FIBC SUPPORT FRAME GROUNDING

LATEST REVISION DATE: 12/1/09

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NOTE:
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ATTACH TO PROPERLY GROUNDED RECEIVING VESSEL.

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE CUT TO LENGTH REQUIRED.

FASTEN LUG TO METAL CHUTE WITH BOLT, NUT AND LOCK WASHER.

NOTE: CHUTE SHOULD NOT BE COATED OR LINED WITH NON-CONDUCTIVE MATERIALS.

TYPICAL ARRANGEMENT
GROUNDING OF HOPPER-TYPE MATERIAL TRANSFER CHUTE

TA-16
TYPICAL ASSEMBLY NO. 16

LATEST REVISION DATE: 12/1/09

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TYPICAL TANKER TRUCK
UNLOADING GROUNDING ARRANGEMENT

NOTE:
GROUND CONTINUITY OF ALL PIPING,
equipment, devices, cables and
connections must be checked for
electrical continuity at the time
of installation and should be
tested at least annually
thereafter.

TYPICAL BULK LIQUID GROUNDING
ASSEMBLY. CONNECT GROUNDING
CLAMP SO THAT THEY ARE IN DIRECT
ELECTRICAL CONTACT (SUCH AS
THROUGH WELDING) TO THE
BULK TANK SUPPORT FRAME

BULK TANK

BULK TANK GROUND BUS

TYPICAL ASSEMBLY NO. 17

NOTE: GROUND ANY
CONDUCTIVE LEVEL MEASURING
DEVICE OR PIPE BEFORE
INSERTING INTO TANK TRUCK.
DO NOT SAMPLE OR GAGE
WHILE FILLING IS IN PROGRESS.

POSITIVE GROUND
DEVICE (WITH STATUS
INDICATION) INTERLOPED TO
TRANSFER PUMP.

UNDERGROUND CABLE TO
BULK TANK GROUND BUS

CABLES TO
BULK TANK
GROUND BUS

NOTE: BEFORE UNLOADING TANK CAR OR TRUCK,
ATTACH GROUNDING CLAMPS FOR 5 MINUTES
BEFORE INSERTING PIPE. AFTER LOADING, KEEP
GROUNDING CLAMPS AND Fill PIPE ATTACHED FOR
5 MINUTES BEFORE REMOVING TO ALLOW FOR
DISSIPATION OF STATIC CHARGES.

LATEST REVISION DATE: 12/1/09

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NOTE:
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APPROVED 2" FLAME ARRESTER VENT PLUG (TYPICAL)

NOTE:
IMPORTANT IDENTICAL GROUNDING ARRANGEMENT REQUIRED FOR EACH PAIR OF DRUMS

1/8" FLEXIBLE BRONZE OR STAINLESS STEEL GROUNDING CABLE CUT TO LENGTH LENGTH REQUIRED.

METALLIC 5 GALLON PAIL

APPROVED SELF-CLOSING METALLIC FAUCET VALVE (TYPICAL)

TYPICAL ARRANGEMENT – FOR STATIC GROUNDING OF 55 GALLON DRUMS IN DISPENSING RACK
NOTE:
GROUND CONTINUITY OF ALL PIPING, EQUIPMENT, DEVICES, CABLES AND CONNECTIONS MUST BE CHECKED FOR ELECTRICAL CONTINUITY AT THE TIME OF INSTALLATION AND SHOULD BE TESTED AT LEAST ANNUALLY THEREAFTER.

FOR DIVERTING FLAMMABLE LIQUIDS TO THE SIDE WALLS OF THE GROUNDING VESSEL.

TYPICAL THINNING TANK SIDE-WALL DIVERTER

TA-19
TYPICAL ASSEMBLY NO. 19

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