INSTALLATION INSTRUCTIONS

Bags With Grounding Straps for Grounding Metal Cages

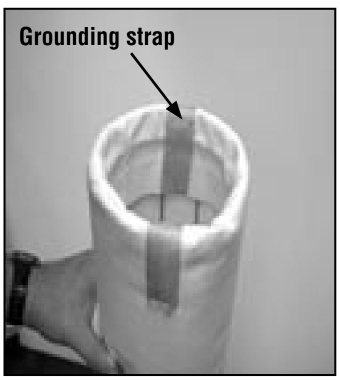
Proper installation of bags and cages is required to ensure that the metal cages are not isolated from ground with the tubesheet (cell plate) in applications that have potential for an explosion hazard.

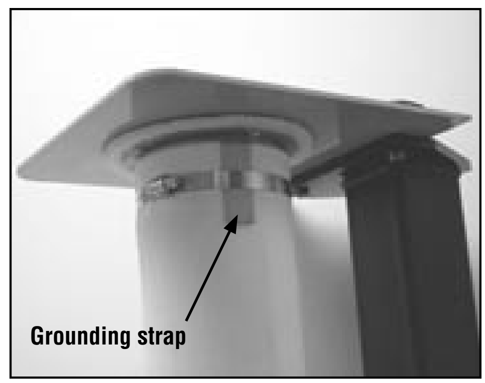
WARNING: The effectiveness of a grounding mechanism depends upon proper installation and connection of the grounding mechanism to an adequately grounded collector component. Failure to properly install and connect grounding mechanism or maintain grounding of the collector component may result in static electricity discharge and possible explosion of dust stream within the collector and serious property damage and/or bodily injury. Proper installation must be verified per Section B of these instructions prior to operating collector.

SECTION A: BAG INSTALLATION

Bottom Load Collectors

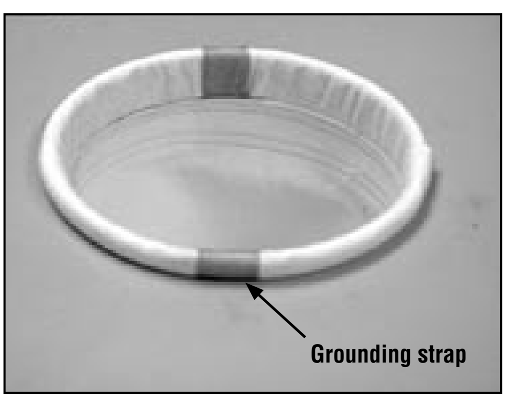
The two grounding straps at the top of the bag are intended to ground the cage and clamp to the metal bag cup/ venturi. Ensure that the bag cup/venturi is cleaned to remove dust and corrosion buildup. Position the cage in the bag so that the split in the cage top is located at 90 degrees from the seam on the bag. This will ensure that both grounding straps will not be located in between the split. Tuck the bag top into the cage top and install bag, cage, and clamp per equipment manufacturer's guidelines. ***WARNING: If bag cup/venturi is plastic, bag must be designed with different ground wire that can be attached to grounding bolt or stud.***

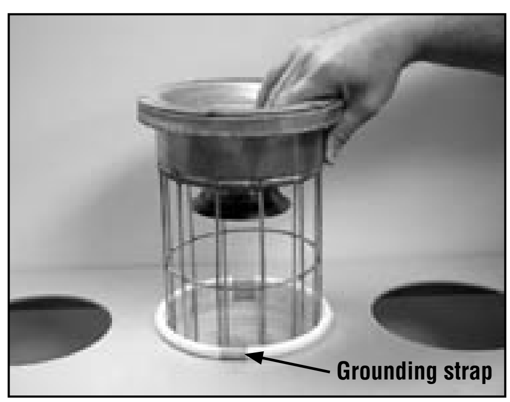




Top Load Collectors with Snapband Bags

The two grounding straps at the top of the bag are intended to ground the cage to the tubesheet. Ensure that the hole is cleaned to remove dust and corrosion buildup. Install bag in hole and insert cage.





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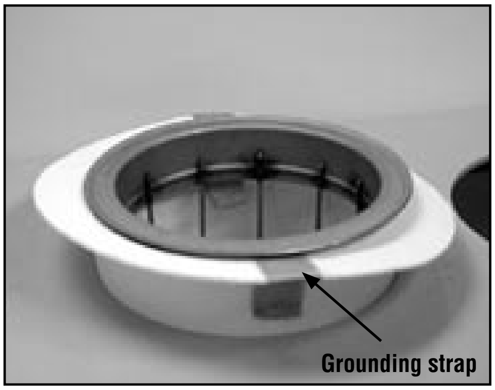
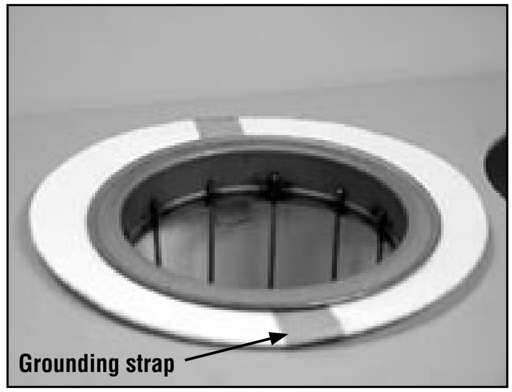
Top Load Collectors with Flange Top or Ring Top Bags

The two grounding straps at the top of the bag are intended to provide a grounding path between the cage and the tubesheet in addition to any ground achieved using the hold-downs. Ensure that the top surface of the tubesheet is cleaned to remove dust and corrosion buildup. Install bag/cage per equipment manufacturer's guidelines.





SECTION B: VERIFICATION OF PROPER GROUNDING

Proper installation must be confirmed by testing to verify $1x10^6$ (1 megohm) maximum resistance at 500 volts between cage and tubesheet (cell plate).

Bottom load collector: testing resistance between cage and tubesheet.

Top load collector: testing resistance between cage and tubesheet.

In addition to the proper installation and grounding of bags and cages, the end user should select an appropriate filter media for use in bags. Refer to the National Fire Protection Association (NFPA) "Recommended Practice on Static Electricity," NFPA 77-2000 edition for more information (www.nfpa.org).

8.13.8 Containers for Sampling.

8.13.8.1 Ignition risk is greatly increased where an ignitible atmosphere is present outside the container; for example, where sampling is directly from a tank or a sample is transferred near a manway, because such a situation can precipitate a large fire or explosion. A grounded metal sample "thief" or glass bottle in a grounded metal sample cage can be used in such cases.

8.13.8.2 Because they are more easily charged than glass, nonconductive plastic containers should be avoided except where used in well-ventilated areas. If outdoor sampling is carried out at sample spigots that are located away from tank openings and in freely ventilated areas and if sampled quantities are 1 L or less, the fire risk is, in most cases, insufficient to necessitate any special procedures other than bonding of metal components.

8.13.9* Cleaning.

8.13.9.1 Containers should be bonded and grounded prior to being opened for cleaning operations such as steaming.

8.13.9.2 Cleaning equipment should be bonded or grounded.

8.14* Vacuum Cleaning. Collecting liquids and solids in an ignitible atmosphere using a vacuum cleaner can create a significant hazard due to ignition from static electric discharge. If it is necessary to use such equipment in a process area, the hazards and the procedures for safe use should be carefully reviewed and clearly communicated to the potential users.

8.15 Clean Gas Flows.

8.15.1 Usually a negligible generation of static electricity occurs in single-phase gas flow. The presence of solids such as pipe scale or suspended liquids such as water or condensate will create charge, which is carried by the gas phase. The impact of the charged stream on ungrounded objects can then create spark hazards. For example, carbon dioxide discharged under pressure will form charged solid "snow." In an ignitible atmosphere, this phenomenon can create an ignition hazard. For that reason, carbon dioxide from high-pressure cylinders or fire extinguishers should never be used to inert a container or vessel.

8.15.2 Gases with very low ignition energies, such as acetylene and hydrogen, that contain suspended material can be ignited by corona discharge where they are escaping from stacks at high velocity. This phenomenon is associated with electrical breakdown at the periphery of the charged stream being vented. Such discharges can occur even if the equipment is properly grounded.

8.16 Plastic Sheets and Wraps.

8.16.1 Nonconductive plastic sheets and wraps, such as those used to wrap shipping pallets, present hazards similar to those of plastic bags. Such sheets and wraps can generate brush discharges from their surfaces following rubbing or separation of surfaces. Isolated wet patches can also create spark hazards.

8.16.2 An additional problem is charging of personnel as they handle plastic sheets and wrap. Plastic sheets and wrap should not be brought into areas that can contain ignitible atmospheres. Plastic pallet wrap can be removed outside the area and, if necessary, replaced by a suitable tarpaulin or other temporary cover. Antistatic wrap is available. Tear sheets (used outside many clean areas) can generate significant static electric charge when they are pulled from a dispenser, and precautions are similar to those for plastic sheets. *(Additional information on handling sheet materials is found in Section 10.2.)*

Chapter 9 Powders and Dusts

9.1 General. Powders include pellets, granules, and dust particles. Pellets have diameters greater than 2 mm, granules have diameters between 420 μm and 2 mm, and dusts have diameters of 420 μm or less. It should be noted that aggregates of pellets and granules will often also contain a significant amount of dust. The movement of powders in industrial operations commonly generates static electric charges. The accumulation of these charges and their subsequent discharge can lead to fires and explosions.

9.2 Combustibility of Dust Clouds.

9.2.1 A *combustible dust* is defined as any finely divided solid material 420 μm or smaller in diameter (i.e., material that will pass through a U.S. No. 40 standard sieve) that can present a fire or deflagration hazard.

9.2.2 For a static electric discharge to ignite a combustible dust, the following four conditions need to be met:

(1) An effective means of separating charge must be present.
(2) A means of accumulating the separated charges and maintaining a difference of electrical potential must be available.
(3) A discharge of the static electricity of adequate energy must be possible.
(4) The discharge must occur in an ignitible mixture of the dust.

9.2.3 A sufficient amount of dust suspended in air needs to be present for an ignition to achieve sustained combustion. This minimum amount is called the *minimum explosible concentration* (MEC). It is the smallest concentration, expressed in mass per unit volume, for a given particle size that will support a deflagration where uniformly suspended in air. *(In this chapter, air is assumed to be the supporting atmosphere unless another oxidizing atmosphere is specified.)*

9.2.4* For a dust cloud to be ignited by a static electric discharge, the discharge needs to have enough energy density, both in space and in time, to effect ignition. However, the term used for discharge ignition, *minimum ignition energy* (MIE), is simply that of the energy in the discharge. The MIE of a dust cloud is the energy in a capacitive discharge at or above which ignition can occur.

9.3 Mechanisms of Static Electric Charging

9.3.1 Contact static electric charging occurs extensively in the movement of powders, both by surface friction between powders and surfaces and by friction between individual powder particles. The charging characteristics of particles often are determined as much by surface contamination as by their chemical characteristics; thus, the magnitude and polarity of a charge are difficult to predict.

9.3.2 Charging can be expected any time a powder comes into contact with another surface, such as in sieving, pouring, scrolling, grinding, micronizing, sliding, and pneumatic conveying. In those operations, the more vigorous the contact, the more charge is generated, as shown in Table 9.3.2. The table shows that a wide range of charge densities is possible in a given operation; the actual values will depend on both the product and the operation.

9.3.3 An upper limit to the amount of charge that can be carried by a powder suspended in a gas exists. This limit is set by the strength of the electric field at the surface of the particle and depends on the surface charge density, as well as the

Table 9.3.2 Typical Charge Levels on Medium-Resistivity Powders Emerging from Various Powder Operations (Before Compaction)

Operation	Mass Charge Density (μC/kg)
Sieving	10^{-3} to 10^{-5}
Pouring	10^{-1} to 10^{-3}
Auger or screw-feed transfer	10^{-2} to 1.0
Grinding	10^{-1} to 1.0
Micronizing	10^{2} to 10^{-1}
Pneumatic conveying	10^{3} to 10^{-1}

Source: BS 5958, *Code of Practice for Control of Undesirable Static Electricity*, Part 1, General Considerations.

particle's size and shape. For well-dispersed particles, the maximum surface charge density is of the order of 10 μC/m^2. This value can be used to estimate maximum charge-to-mass ratios from particle diameter and density information.

9.4 Retention of Static Electric Charge.

9.4.1 Bulk powder can retain a static electric charge, depending on its bulk resistivity and its bulk dielectric constant. The relaxation time is expressed by the following equation:

$$\tau = \varepsilon\varepsilon_0\rho \qquad (9.4.1)$$

where:
τ = charge relaxation time constant (seconds)
ε = dielectric constant of the bulked powder
ε_0 = permittivity of a vacuum (8.845×10^{-12} sec/ohm-m)
ρ = bulk volume resistivity of the powder (ohm-meters)

9.4.2 The ability of a solid to transmit electric charges is characterized by its volume resistivity. For liquids, this ability is characterized by its conductivity.

9.4.3 Powders are divided into the following three groups:

(1) Low-resistivity powders having volume resistivities of up to 10^8 ohm-m, including metals, coal dust, and carbon black
(2) Medium-resistivity powders having volume resistivities between 10^8 ohm-m and 10^{10} ohm-m, including many organic powders and agricultural products
(3) High-resistivity powders having volume resistivities above 10^{10} ohm-m, including organic powders, synthetic polymers, and quartz

9.4.3.1 Low-resistivity powders can become charged during flow. The charge rapidly dissipates where the powder is conveyed into a grounded container. However, if the powder is conveyed into a nonconductive container, the accumulated charge can result in an incendive spark.

9.4.3.2 Where a medium-resistivity powder comes to rest in bulk, the charge retained depends on the resistance between the powder and ground. If the powder is placed in a grounded container, charge retention is determined by the bulk volume resistivity of the powder, which includes the interparticle resistance, as governed by the relationship expressed in Equation 9.4.1. If the powder is placed in a nonconductive container, charge retention is determined by the resistance of the container. The special significance of medium-resistivity powders is that they are relatively safe during handling because they do not produce bulking brush discharges or sparks.

9.4.3.3 High-resistivity powders do not produce spark discharges in themselves, but they can produce other types of discharge, such as corona, brush, bulking brush, and propagating brush discharges *(see Section 5.3)*. High-resistivity powders lose charge at a slow rate, even in properly grounded containers. Many high-resistivity powders are also hydrophobic and, in bulk, are capable of retaining charge for hours or even days. High-resistivity powders, such as thermoplastic resins, can have bulk resistivities up to about 10^{16} ohm-m.

9.5 Discharges in Powder Operations.

9.5.1 Spark Discharge.

9.5.1.1 Where spark discharges occur from conductors, the energy in the spark can be estimated from the following equations or from the nomograph in Figure 5.3.3.3:

$$W = \frac{1}{2}CV^2 \qquad (9.5.1.1a)$$

$$W = \frac{1}{2}QV \qquad (9.5.1.1b)$$

$$W = \frac{1}{2}\left(\frac{Q^2}{C}\right) \qquad (9.5.1.1c)$$

$$Q = CV \qquad (9.5.1.1d)$$

where:
W = energy (joules)
C = capacitance (farads)
V = potential difference (volts)
Q = charge (coulombs)

9.5.1.2 It should be noted that equations 9.5.1.1a through 9.5.1.1d apply only to capacitive discharges from conductors and cannot be applied to discharges from insulators. Discharge energies so estimated can be compared with the MIE of the dust to provide an insight into the probability of ignition by capacitive spark discharge *(see 5.3.3)*. Layers of combustible dusts can be ignited by capacitive spark discharge, which can lead to secondary dust explosions. For a dust layer, there is no correlation with the MIE for dust cloud ignition. Capacitive spark discharges must be avoided by grounding all conductive containers, equipment, products, and personnel.

9.5.2 Corona and Brush Discharge. Where large amounts of powder having medium or high resistivities are handled, corona and brush discharges are to be expected. No evidence is available, however, that a corona discharge is capable of igniting a dust cloud. Likewise, no evidence is available that a brush discharge can ignite dusts with MIEs greater than 3 mJ, provided that no flammable gas or vapor is present in the dust cloud.

9.5.3 Propagating Brush Discharge. Because propagating brush discharges can have energies greater than 1 J, they should be considered capable of igniting both clouds and layers of combustible dusts.

9.5.4 Bulking Brush Discharge.

9.5.4.1 Where powders that have resistivities greater than about 10^9 ohm-m are put into grounded conductive containers, they usually dissipate their charges by conduction at a rate slower than that of the charge accumulated in the loading process. The charge is therefore compacted, and discharges occur from the bulking point (where the particles first contact the heap) to the walls of the container. These discharges are referred to as *bulking brush discharges.* Experience indicates that these discharges are not capable of igniting dusts having MIEs greater than 10 mJ. However, such discharges have been attributed to explosions of dusts having MIEs less than 10 mJ.

9.5.4.2 During the compaction process, the energy in the discharge increases as the particle size increases. Therefore, it can be expected that systems most at risk are those involving pellets having an appreciable fraction of fines (dust).

9.6 Pneumatic Transport Systems.

9.6.1 Pneumatic transport of powdered material through pipes or ducts can produce a static electric charge on both the product being transported and the conduit. This static electric charge remains on the material as it exits the system. Precautions against accumulation of charge should be taken where the material is collected.

9.6.2 Pipes and ducts should be metal and should be grounded.

9.6.2.1 Equipment to which the conduits connect should be metal and grounded to dissipate the charge impressed on it by the transport of the material.

9.6.2.2 Where the use of pipe-joining methods or installation of piping components results in an interruption of continuity of the ground path, one of the following criteria should be met:

(1) A jumper cable should be used to maintain continuity.
(2) An independent ground should be provided for the isolated section of the conduit, as shown in Figure 9.6.2.2.

9.6.3 Nonconductive pipe or ductwork should not be used.

9.6.4 Short lengths of transparent plastic should not be used as flow visualizers, because they have been known to give rise to propagating brush discharges capable of igniting dusts.

9.7* Flexible Hose.

9.7.1 Hose made of nonconductive material that incorporate a spiral stiffening wire should be kept in good repair to ensure that

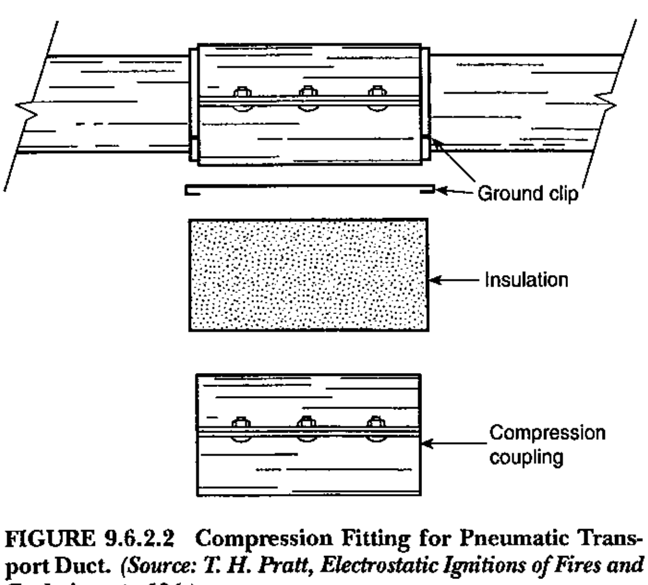


FIGURE 9.6.2.2 Compression Fitting for Pneumatic Transport Duct. ***(Source: T. H. Pratt, Electrostatic Ignitions of Fires and Explosions, p. 136.)***

the internal wire directly contacts the metal end couplings and that the end couplings make a good connection to ground.

9.7.2 Hose with more than one internal spiral should not be used, because it is not possible to determine if one of the spirals has lost its continuity.

9.8 Flexible Boots and Socks.

9.8.1 Flexible boots and socks are commonly used for gravity transfer operations. Flexible boots typically are made of plastic or rubber, while flexible socks typically are made of woven fabric. A nonconductive boot could give rise to either brush discharge or propagating brush discharge. Propagating brush discharge cannot happen with a sock, because of the low breakdown strength of the air gaps in the weave. However, there are conditions where socks can produce brush discharges (e.g., where used with flexible intermediate bulk containers). *(See Section 10.1.6.)*

9.8.2 For combustible dusts, the end-to-end resistance of boots and socks should be less than 10^8 ohms, preferably less than 10^6 ohms, measured with a megohmmeter.

9.8.3 Flexible connections should not be depended on for a bond or ground connection between process equipment. Separate bonding or grounding connections should be used.

9.9 Bag Houses.

9.9.1 As dusts are drawn or blown into a bag house, they necessarily carry with them a static electric charge, the magnitude of which depends on the characteristics of the dust and the process, as illustrated in Table 9.3.2. The charge remains on the dust and accumulates on the surfaces of the bags. It is therefore important to keep all conductive equipment grounded to prevent the induction of this accumulated charge onto conductive components that could have inadvertently become ungrounded. Such induction is particularly true in the case of cage assemblies.

9.9.2 If cage assemblies are not well grounded, capacitive spark discharge can occur from the ungrounded cages to either the structure of the bag house or adjacent cage assemblies. Many times the bags have metal braid pigtails attached to their cuffs, the notion being that the pigtail can simply be brought through the cage and bonded to the tube sheet. This method of grounding the cage is not always successful. Furthermore, the reason for the pigtail is often misunderstood. Because the bag is nonconductive, the bag itself is not grounded. It is therefore useless to extend the metal braid down the entire length of the bag. *(See Figure 9.9.2.)*

9.9.3 Bags and cages should be engineered so that a positive ground connection is always ensured during maintenance, even if personnel are inexperienced or inattentive. One way of ensuring this connection is by sewing two metal braids into the cuffs of the bags, 180 degrees apart. Each braid is continuous and is sewn up the inside of the cuff, across the top, and down the outside of the cuff. This method ensures that the braids always make a positive contact with the cage, the venturi, and the clamp and that such an arrangement withstands the rigors of the operation. In any case, the resistance between the cage and ground should be less than 10 ohms.

9.9.4 No evidence is available that filter bags made from conductive or antistatic fabric are needed to prevent incendive discharges. On the contrary, such bags could create discharge hazards if sections of the fabric become isolated or if a bag falls into the bottom of the bag house.

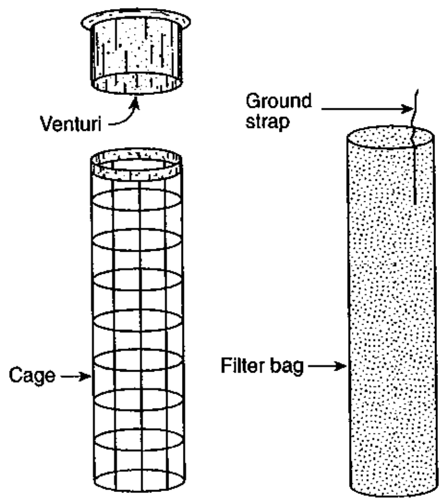


FIGURE 9.9.2 Arrangement of Cage and Filter Bag. *(Source: T. H. Pratt, Electrostatic Ignitions of Fires and Explosions, p. 134.)*

9.10* Hybrid Mixtures.

9.10.1 The term *hybrid mixture* applies to any mixture of suspended combustible dust and flammable gas or vapor where neither the dust itself nor the gas or vapor itself is present in sufficient quantity to support combustion but where the mixture of the two can support combustion. Hybrid mixtures pose particular problems because they combine the problems of the high charge densities of powder-handling operations with the low ignition energies of flammable vapors. The MIE of a hybrid mixture is difficult to assess, but a conservative estimate can be made by assuming that the MIE of the mixture is at or near the MIE of the gas alone. Because hybrid mixtures contain a flammable gas or vapor, they can be ignited by brush discharge.

9.10.2 Powders that contain enough solvent (i.e., greater than 0.2 percent by weight) so that significant concentrations of solvent vapor can accumulate in the operations in which they are handled are referred to as *solvent-wet powders*. Consideration should be given to applying the recommendations of Chapter 8 to solvent-wet powders unless the resistivity of the solvent-wet product is less than 10^8 ohm-m.

9.11* Manual Addition of Powders to Flammable Liquids.

9.11.1 The most frequent cause of static electric ignitions in process vessels is the addition of solids to flammable liquids in the vessels. Even where the vessel is inerted, large additions of solids introduce air into the vessel while expelling flammable vapor from the vessel. The sudden addition of a large volume of solids can also result in static discharge from a floating pile of charged powder.

9.11.1.1 Manual addition of solids through an open port or manway should be done only in 25 kg batches.

9.11.1.2 Batch additions larger than 25 kg [e.g., flexible intermediate bulk containers (FIBCs) *(see 10.1.6)*] should be done through an intermediate hopper with a rotary valve or an equivalent arrangement. The hopper can be separately inerted to reduce air entrainment into the mixing vessel, while expulsion of vapor into the operating area can be avoided by venting the vessel to a safe location.

9.11.1.3 The addition of solids from nonconductive plastic bags can be hazardous, even if the solids are noncombustible (e.g., silica). Bags should be constructed of paper, plies of paper and plastic in which the nonconductive plastic film is covered by paper on both sides, or antistatic plastic. Because grounding clips can be impractical, such bags can be effectively grounded by contact with a grounded conductive vessel or by skin contact with a grounded operator.

9.11.1.4 Fiber drums or packages should not have a loose plastic liner that can leave the package and behave like a plastic bag.

9.11.1.5 Metal chimes should be grounded.

9.11.1.6 Personnel in the vicinity of openings of vessels that contain flammable liquids should be grounded, and special attention should be paid to housekeeping, because accumulation of nonconductive residues (e.g., resins) on the floor or on items such as grounding clips can impair electrical continuity.

9.11.2 Powder should not be emptied from a nonconductive container in the presence of a flammable atmosphere.

9.11.3 Direct emptying of powders from nonconductive plastic bags into a vessel that contains a flammable atmosphere should be strictly prohibited.

9.11.4 Where a thorough understanding of the process exists and where the vessel does not contain an ignitible atmosphere, adding the powder to the vessel before adding the liquid might be practical.

9.12 Bulk Storage.

9.12.1 Where powders are moved into bulk storage (e.g., silos, rail cars, trucks, IBCs, or FIBCs), the powder is compacted by the force of gravity. The compaction process is accompanied by bulking brush discharge, as explained in 9.5.4. In the compaction process, the energy of the discharge increases as the particle size increases. Therefore, the systems most at risk are pellets with an appreciable fraction of fines (dust).

9.12.2 The exact conditions for ignition-capable bulking brush discharge are not well understood. However, the following general factors that are known to increase its probability have been identified by Glor in *Electrostatic Hazards in Powder Handling*:

(1) Increase in the resistivity of the powder greater than 10^{10} ohm-m
(2) Increase in the particle size of the powder greater than 1 mm
(3) Increase in the charge density of the powder greater than 1 μC/kg
(4) Increase in filling rate as follows:
    (a) For granules with a diameter greater than 1 mm to 2 mm, an increase greater than 20,000 kg/hr
    (b) For granules with a diameter of about 0.8 mm, an increase greater than 20,000 to 30,000 kg/hr

Chapter 10 Specific Applications

10.1 Intermediate Bulk Containers (IBCs).

10.1.1 General. The discussion and precautions for powders and granular solids, as set forth in Chapter 9, also apply to operations that involve handling these materials in intermediate bulk containers (IBCs).

GROUND WIRE

DESCRIPTION:

Stainless steel ground wire. Available in knit or braided construction. Stainless steel braid made from type 430 stainless steel. Stainless steel knit made from type 304 stainless steel.

APPLICATION:

To eliminate static electricity from the filter bag. The static can cause a spark discharge that may set off explosion if gas steam in collector is an explosive mixture or flammable.

SPECIFICATIONS:

PART NO.	STYLE	WIDTH		QUANTITY / CASE	
		inches	mm	Feet	Meters
STAINLESS STEEL					
41005	Knit	3/16	4.8	5,000	1525
41007	Knit	3/4	19	1,500	460
41012	Knit	1	25.4	1,300	398
41010	Braid	3/32	2.4	5,000	1524
41011	Braid	5/32	11.8	2,300	700

*** Static removal varies with the type of metal, ground wire (knit or braided) and the type fiber and construction of fabric used in the filter bag.**