Second Correlating Revision No. 12-NFPA 652-2017 [Global Input]

Change the order of Chapters 8 and 9 in the document

Chapter 8 will now be Management Systems

Chapter 9 will now be Hazard Management; Mitigation and Prevention.

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Committee Statement

Committee Statement: This will simplify coordination between technical committees with regards to correlation of the outline of the commodity -specific dust documents. Management Systems are common to all of the documents. The current Chapter 8 in 652, Hazard Mitigation, varies more between the individual commodity specific standards and may be broken into individual chapters. Long term, this will help to correlate the organization of all of the dust documents.

Second Correlating Revision No. 1-NFPA 652-2017 [Section No. 3.3.13]

3.3.13* Dissipative.

A material or a construction that will reduce static charge to acceptable levels. [**77** , 2019]

A.3.3.13 Dissipative.

Typically, a dissipative material is one having a surface resistivity between 10^5 ohms per square and 10^9 ohms per square or a volume resistivity between 10^5 ohm-m and 10^9 ohm-m. The intent is to limit the voltage achieved by electrostatic charge accumulation to a potential that is less than the threshold voltage for incendive discharge. Some applications might require different resistivities to accommodate different charging rates or desired relaxation times.

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Committee Statement

Committee Statement: Addresses ballot comment on consistency of units. Adds clarity to annex material. Also updates the edition date for the extract.

SR-26-NFPA 652-2017

Second Correlating Revision No. 13-NFPA 652-2017 [Section No. 5.5.2]

5.5.2* Mixtures.

If the ~~dust~~ combustible particulate solid sample is a mixture, the approximate proportions of each general category of particulate solid shall be determined and documented on the basis of available information and shall be used to assist in determining representative samples.

A.5.5.2

If the dust sample is a mixture of organic, inorganic, or combustible metals, the amount or concentration of each constituent should be determined by laboratory analysis. Common methods for an analysis of mixture composition include material separation, mass fraction analysis, energy dispersive x-ray spectroscopy, Fourier transform infrared spectroscopy, inductively coupled plasma spectroscopy, and x-ray fluorescence spectroscopy. Unique chemical reactivity issues could include water reactivity, reactivity with extinguishing agents, or other mixture constituents, pyrophoricity, chemical instability, oxidizer, and so forth. For example, for a mixture that contains some metal powder or dust, its potential for water reactivity should be considered based on the safety data sheet (SDS) or other public or company resources. If the potential for water reactivity exists, the entire mixture should be analyzed to determine whether it is water reactive. Generally the chemical category of the particulate can be determined based upon the combustible dust group as outlined in NFPA 499 .

5.5.2.1

Mixtures comprised of more than 10 percent by mass of metallic particulate shall be treated as a metallic combustible dust in accordance with the relevant sections of NFPA 484 .

5.5.2.1.1

It shall be permitted to evaluate metal mixtures per the requirements in 1.1.6.2 of NFPA 484 .

5.5.2.1.1.1

Mixtures containing metals identified as legacy metals (aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium) shall be evaluated per the requirements in 1.1.6.2 of NFPA 484.

5.5.2.2

Mixtures consisting of more than 50 percent by mass wood or wood-based particulate but less than 10 percent metallic particulate shall be treated as a wood dust in accordance with the relevant sections of NFPA 664.

5.5.2.3

Mixtures consisting of more than 50 percent by mass agricultural particulate to be used in foodstuffs but less than 10 percent metallic particulate shall be treated as an agricultural dust in accordance with the relevant sections of NFPA 61 .

5.5.2.4

Any mixture that does not fall under 5.5.2.1 through 5.5.2.3 shall be treated as a chemical dust in accordance with NFPA 654 .

5.5.2.5

Where the mixture contains both combustible and noncombustible materials, the combustible components shall be used as the basis for the mixture classification.

5.5.2.6*

Where components with different chemical compositions do not remain homogeneously mixed, the properties of the individual constituents shall be considered separately.

A.5.5.2.6

In some cases, the particle size or particle density differences of individual components of a mixture can cause segregation in different parts of a process or different areas of a vessel. In such cases, it can be difficult to predict the actual composition of the segregated materials. If the fine material is inert or less energetic than the coarse material, then testing the fine fraction per ASTM E1226, *Standard Test Method for Explosivity of Dust Clouds* , might not produce the highest explosivity values or lowest MIE values.

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Committee Statement

Committee Statement: This points the user to 484 for mixtures containing legacy metals. This addresses correlation issues regarding mixtures between 484 and 652 and addresses the higher hazards associated with legacy metals.

Committee Comment No. 29-NFPA 652-2017 [Section No. 5.5.2]

Second Correlating Revision No. 7-NFPA 652-2017 [Section No. 5.5.4]

5.5.4 Sample Collection.

Dust samples shall be collected in a safe manner without introducing an ignition source, dispersing dust, or creating or increasing the risk of injury to workers.

5.5.4.1*

Samples shall be uniquely identified using identifiers such as lot, origin, composition (pure, mixture), process, age, location, and date collected.

A.5.5.4.1

The more information about a sample that is collected and tested, the more useful it is to manage, monitor stability, or track changes in the process and materials where a hazard is present or absent. Changes in the process or materials that require further testing will have a baseline for explaining any difference in physical hazard. Any dust sample collected from on top of a press should be identified as different from a sample collected from inside a vessel or container if the sample is susceptible to chemical changes (i.e., oxidation, hygroscopic) over time.

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Committee Statement

Committee Statement: Deleting annex material for 5.5.4 as it duplicates the main text.

Second Correlating Revision No. 5-NFPA 652-2017 [Section No. 8.3.11.1]

9.3.11.1

Particle separation devices shall be designed to control fugitive dust emissions per Section 9.6.

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Committee Statement

Committee Statement: Correcting cross reference error in second draft.

Second Correlating Revision No. 2-NFPA 652-2017 [Section No. 8.3.14.6.1]

9.3.14.6.1

Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature, ~~vibration detection, head~~ pulley alignment, and belt alignment.

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Committee Statement

Committee Statement: The committee clarifies that the monitoring requirement applies to pulley alignment. This makes the provision consistent with the analogous requirement in NFPA 61 and adds clarity for the user.

Committee Comment No. 42-NFPA 652-2017 [Section No. 8.3.14.6.1]

Second Correlating Revision No. 3-NFPA 652-2017 [Section No. 8.4.7]

9.4.7* Electrostatic Discharges.

A.9.4.7

Several types of electrostatic discharges are capable of igniting combustible dusts and hybrid mixtures. The requirements in 9.4.7 are intended to protect against the following four types of discharge: Brush, cone (or bulking brush), propagating brush, and capacitive spark.

Brush discharges occur when electrostatic charge accumulates on a nonconductive surface and is discharged to nearby conductor. These discharges have a maximum theoretical discharge energy of 3 mJ–5 mJ, which is sufficient to ignite most flammable vapors and gases. There are no records of brush discharges igniting combustible dusts outside of laboratory settings. In the first edition of this standard, a 3 mJ MIE limit was applied as a minimum criterion for the use of nonconductive system components. The intent of this criterion was to ensure that brush discharges were prevented when the MIE was less than the theoretical upper limit of brush discharge energy. However, even where combustible dusts have MIE values less than 3 mJ, the diffuse nature of a brush discharge makes it a less effective ignition source than the capacitive spark used for determining the MIE value.

Cone or bulking brush discharges occur when resistive solids are transferred into containers where the charge accumulates in the bulk material. The compaction of the charges by gravity creates a strong electric field across the top surface of the material. When the field strength exceeds the breakdown voltage of air, a cone discharge occurs across the surface of the pile terminating at a conductive object (typically the vessel wall.) The energy of a cone discharge is dependent on the size of the container (among other parameters), and discharges up to 20 mJ can occur in process equipment. One particular situation in which cone discharges can occur is in filling FIBCs. For nonconductive containers and vessels such as FIBCs, discharges can occur across the full width (as opposed to the radius or half-width for conductive vessels). For a typical nonconductive FIBC, discharges up to 3 mJ can occur.

Propagating brush discharges occur when the rapid flow of particulate material generates a high surface charge on a thin nonconductive surface. The presence of this charge on one side of the material induces an opposite charge on the other side, essentially forming a capacitor. If the voltage difference across the material exceeds the material's breakdown voltage, then a pinhole channel is created at a weak spot in the material and the charges on the opposite surfaces are discharged through the channel. Propagating brush discharge energy can be on the order of 1000 mJ. Propagating brush discharges cannot occur if the material is sufficiently thick (greater than 8 mm) or has a sufficiently low breakdown voltage (less than 4 kV for films or sheets or less than 6 kV for woven materials). The presence of an external grounding wire on a nonconductive object will not prevent a propagating brush discharge.

Capacitive spark discharges occur when the voltage difference between two conductive objects exceeds the breakdown voltage of the medium between them (typically air). Capacitive sparks can ignite both flammable vapors/gases and combustible dusts.

For more information on electrostatic discharges, refer to NFPA 77 and IEC TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance* .

9.4.7.1 Conductive Equipment.

9.4.7.1.1

Particulate handling equipment shall be conductive unless the provisions of 9.4.7.1.2 are applicable.

9.4.7.1.2

Nonconductive system components shall be permitted where all of the following conditions are met:

(1)* Hybrid mixtures and flammable gas/vapor atmospheres are not present.

A.9.4.7.1.2(1)

This requirement is intended to prevent ignition of hybrid mixtures or flammable gas/vapor atmospheres by brush discharges from nonconductive surfaces.

(2)* Conductive ~~dusts~~ particulate solids are not handled.

A.9.4.7.1.2(2)

This requirement is intended to prevent ignition of combustible dusts by the isolation of conductive particulate solids where they can accumulate charge and create capacitive spark discharges to grounded conductive objects.

~~The MIE of the material being handled is greater than 3 mJ determined without inductance.~~

(3)* The nonconductive components do not result in isolation of conductive components from ground.

A.9.4.7.1.2(3)

This requirement is intended to prevent ignition of combustible dusts by capacitive sparks from isolated process equipment.

(4)* The breakdown strength across nonconductive sheets, coatings, or membranes does not exceed 4 kV, and the breakdown strength across nonconductive woven objects does not exceed 6 kV, when used in high surface charging processes.

A.9.4.7.1.2(4)

~~The potential for propagating brush discharges exists where nonconductive materials with breakdown voltages exceeding 4 kV are exposed to processes that generate strong surface charges such as pneumatic conveying. Such discharges do not occur where the breakdown voltage is less than 4 kV.~~ This requirement is intended to prevent ignition of combustible dusts by propagating brush discharges. Pneumatic conveying is an example of a process operation that can generate high surface charging.

9.4.7.1.3*

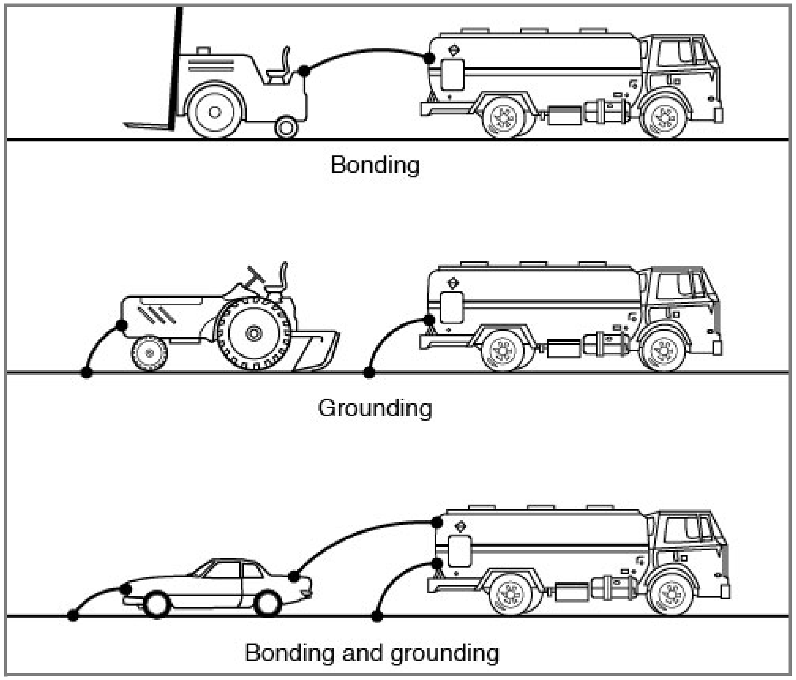
Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided for conductive components.

A.9.4.7.1.3

This requirement is intended to prevent ignition of combustible dusts, flammable gas/vapor atmospheres, or hybrid mixtures by capacitive sparks from isolated process equipment. Where the bonding and grounding system is all metal, resistance in continuous ground paths typically is less than 10 ohms. Such systems include those having multiple components. Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion. A permanent or fixed grounding system that is acceptable for power circuits or for lightning protection is more than adequate for a static electricity grounding system.

See Figure A.9.4.7.1.3 for illustrations of bonding and grounding principles.

Figure A.9.4.7.1.3 Bonding and Grounding.



9.4.7.1.4* Flexible Connectors.

A.9.4.7.1.4

In order to properly specify a flexible connector for combustible dust service, it is necessary to know the end-to-end resistance. The end-to-end resistance is typically not specified by the suppliers of flexible connectors. This makes it necessary for the user to measure it. ISO 8031, *Rubber and plastics hoses and hose assemblies — Determination of electrical resistance and conductivity* , provides methods to determine the end-to-end resistance. For convenience, the following is a brief description of a similar procedure:

(1) It is preferred to measure the actual flexible connector to be used, but if it is too long for this to be practical, a shorter length (for example, 6 in. to 24 in.) can be used. The measured end-to-end resistance per unit length can then be multiplied by the total flexible connector length to get the overall flexible connector end-to-end resistance.

(2) The flexible connector should be placed on a nonconductive surface, such as a rigid sheet of PTFE, polyethylene, or polypropylene. It is important that neither the flexible connector or megohm meter metal connections are touched by the operator's bare skin during the measurement as this will short the circuit. In addition, the rigid polymer sheet and flexible connector should be dry during the measurement.

(3) The leads on a megohm meter should be contacted on the inside surface of the flexible connector at each end. This should be done at several points on the inside surface to ensure that a consistent reading is obtained. Care should be taken to make measurements at the greatest distance from any supporting wires in the flexible connector to avoid measuring the resistance across the wire. The readings should be taken at approximately 500 V.

9.4.7.1.4.1* Retroactivity.

This section shall not be required to be applied retroactively.

A.9.4.7.1.4.1

Flexible connectors wear out over time. The intent of this statement is that existing connectors would be replaced with compliant flexible connectors at the end of their service life.

9.4.7.1.4.2

Flexible connectors longer than 6.6 ft (2 m) shall have an end-to-end resistance of less than 1.0×10^8 ohms to ground even where an internal or external bonding wire connects the equipment to which the flexible connector is attached.

9.4.7.1.4.3*

Where flammable vapors are not present, flexible connectors with a resistance equal to or greater than 1.0×10^8 ohms shall be permitted under either of the following conditions:

(1) The dust has an MIE greater than 2000 mJ.

(2) The maximum powder transfer velocity is less than 2000 fpm (10 m/sec ~~s~~).

A.9.4.7.1.4.3

Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge, do not produce discharge energies in excess of 2000 mJ.

9.4.7.2 Maximum Particulate Transport Rates.

9.4.7.2.1*

The maximum particulate transport rates in 9.4.7.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft^3 (1 m^3~~,~~) and a single feed stream to the vessel meets both of the following conditions:

(1)* The suspendable fraction of the transported material has an MIE of less than or equal to 20 mJ.

A.9.4.7.2.1(1)

The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ. *(See Britton, Avoiding Static Ignition Hazards in Chemical Operations.)*

(2)* The transported material has an electrical volume resistivity greater than 1.0 × 10^{10}ohm-m ~~ohm-m~~ .

A.9.4.7.2.1(2)

The threshold high electrical volume resistivity is usually considered to be 1.0 × 10^{10}ohm-m. Additional information on electrical resistivity can be found in *Avoiding Static Ignition Hazards in Chemical Operations* by L. Britton, with the values for common materials listed in Appendix B.

A.9.4.7.2.1

The limit on particulate discharge rates is due to concern about possible generation of charge accumulation during rapid transport and the subsequent potential for a bulking brush discharge. From Britton, Section 2-6.3.2 in *Avoiding Static Ignition Hazards in Chemical Operations*, the minimum size of a container for bulking brush discharges to occur has not been established, but is probably about 1 m^3.

This section presumes that there are sufficient fine, suspendable particulates in the material so that the head space of the vessel being filled is at or above the MEC during the filling operation. Fine particulates are typically less than 200 mesh (0.075 mm).

9.4.7.2.2*

The maximum particulate transport rate in 9.4.7.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft^3 (1 m^3) and either of the following conditions is met:

(1)* The transported material having an electrical volume resistivity greater than 1.0 × 10^{10} ohm-m is loaded into a vessel containing a powder or dust having an MIE less than or equal to 20 mJ.

A.9.4.7.2.2(1)

The limit on material transport or discharge rates for large particulates that contain no fines into a vessel that contains fines is due to the potential of dust clouds that could still be present in the headspace of the vessel from the previous loading of the fine material or from the influx of the large material causing the fine material to be suspended into the headspace and then subsequently ignited by a bulking brush discharge.

(2)* The transported material having an electrical volume resistivity greater than 1.0 × 10^{10} ohm-m is loaded into a vessel containing a powder or dust having an MIE less than or equal to 20 mJ, followed by a powder or dust having an MIE less than or equal to 20 mJ.

A.9.4.7.2.2(2)

The limit on material transport or discharge rates for large particulates when fine material is added to the vessel later is due to the possibility of a bulking brush discharge occurring in the vessel and the introduction of fine material could create a combustible atmosphere and be ignited by the bulking brush discharge. The time required for any charge on the large particulate to dissipate depends on the material properties, dimensions of the vessel, and a variety of other factors. A hazard assessment could be performed to determine the time after the large particulate has been added in which it would be safe to add the fine material.

A.9.4.7.2.2

The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ *(see Britton, Avoiding Static Ignition Hazards in Chemical Operations).*

9.4.7.2.3*

Where the conditions of 9.4.7.2.1 or 9.4.7.2.2 are met, the maximum permitted material transport rate of particles shall be limited by the following:

(1) 3.1 lb/sec s (1.4 kg/sec s) for particulates larger than 0.08 in. (2 mm).

(2) 12.3 lb/sec s (5.6 kg/sec s) for particulates between 0.016 in. (0.4 mm) and 0.08 in. (2 mm) in size.

(3) 18.3 lb/sec s (8.3 kg/sec s) for particulates smaller than 0.016 in. (0.4 mm).

A.9.4.7.2.3

In *Electrostatic Hazards in Powder Handling*, Glor recommends the following limitations on hopper/silo/equipment filling rates for high-resistivity (> 10^{10} ohm-m) powders that can produce bulking brush discharges. In the case of powders in the presence of granules with a diameter of several millimeters, Glor recommends the filling rate be less than 2000 to 5000 kg/hr (0.56 to 1.4 kg/s). For particles with diameters larger than 0.8 mm, he recommends maximum filling rates of 25,000 to 30,000 kg/hr (6.9 to 8.3 kg/s).

9.4.7.3* Grounding of Personnel.

A.9.4.7.3

NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity.

9.4.7.3.1*

Where an explosive atmosphere exists and is subject to ignition from an electrostatic spark discharge from ungrounded personnel, personnel involved in manually filling or emptying particulate containers or vessels shall be grounded during such operations.

A.9.4.7.3.1

The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitible atmosphere above the settled material in the receiving vessel.

Refer to NFPA 77 for recommendations for how to safely ground personnel.

9.4.7.3.2

Personnel grounding shall not be required where both of the following conditions are met:

(1) Flammable gases, vapors, and hybrid mixtures are not present.

(2)* The minimum ignition energy of the dust cloud is greater than 30 mJ.

A.9.4.7.3.2(2)

Based on information in Britton, *Avoiding Static Ignition Hazards in Chemical Operations*, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 μ fraction of the material (or material passing through a 200-mesh sieve) is typically tested for this purpose. Where a bulk material includes larger particles, the sub-75 μ MIE might be significantly lower than the bulk material MIE. ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, is the test method for determining particulate and dust MIE.

9.4.7.4* Flexible Intermediate Bulk Containers (FIBCs).

FIBCs shall be permitted to be used for the handling and storage of combustible particulate solids in accordance with the requirements in 9.4.7.4.1 through 9.4.7.4.7.

A.9.4.7.4

A more detailed description of FIBC ignition hazards can be found in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*.

9.4.7.4.1*

Electrostatic ignition hazards associated with the particulate and objects surrounding or inside the FIBC shall be included in the DHA required in Chapter 7.

A.9.4.7.4.1

Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the dust hazards analysis. The DHA should also consider that higher rates of transfer into and out of the FIBC increase the rate of charge generation. Consideration should also be given to the possibility of surface (cone) discharges while the FIBC is being filled, regardless of FIBC type.

For additional information on these phenomena, refer to NFPA 77. The use of internal liners in FIBCs can introduce additional electrostatic ignition hazards and should be subject to expert review prior to use.

9.4.7.4.2*

Type A FIBCs shall be limited to use with noncombustible particulate solids or combustible particulate solids having an MIE greater than 1000 mJ.

A.9.4.7.4.2

Type A FIBCs are capable of producing propagating brush discharges that are capable of igniting combustible dusts and flammable vapors/gases. Type A bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type A FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges.

9.4.7.4.2.1

Type A FIBCs shall not be used in locations where flammable vapors are present.

9.4.7.4.2.2*

Type A FIBCs shall not be used with conductive dusts.

A.9.4.7.4.2.2

For this application, conductive particulate solids typically are those materials having bulk resistivity less than 10^6 ohm-m.

9.4.7.4.3*

Type B FIBCs shall be permitted to be used where combustible dusts having an MIE greater than 3 mJ are present.

A.9.4.7.4.3

Type B FIBCs are capable of producing cone (bulking brush) discharges across the full width of the FIBC with maximum discharge energies of ~3 mJ. These discharges are capable of igniting flammable vapors/gases and combustible dusts with MIE < 3 mJ. Type B bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type B FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges.

9.4.7.4.3.1

Type B FIBCs shall not be used in locations where flammable vapors are present.

9.4.7.4.3.2

Type B FIBCs shall not be used for conductive dusts. *(See A.9.4.7.4.2.2 .)*

9.4.7.4.4*

Type C FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Division Group C/D or Zone Group IIA/IIB flammable vapors ~~having an MIE greater than 0.14 mJ~~ or gases, as defined by *NFPA 70* , are present.

A.9.4.7.4.4

Type C FIBCs are capable of producing capacitive spark discharges if the grounding tab is not connected. Type C FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Some Type C FIBCs have an internal coating that can isolate conductive particulate solids from ground, producing the potential for capacitive spark discharges from the conductive material to the grounded conductive elements of the bag. Per IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)* , Type C FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC.

9.4.7.4.4.1

Conductive FIBC elements shall terminate in a grounding tab, and resistance from these elements to the tab shall be or less than ~~10~~ ^{8} or equal to 10 ^{7} ohms.

9.4.7.4.4.2

Type C FIBCs shall be grounded during filling and emptying operations with a resistance to ground of less than 25 ohms.

9.4.7.4.4.3

Type C FIBCs shall be permitted to be used for conductive dusts where a means for grounding the conductive dusts is present .

9.4.7.4.5*

Type D FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Division Group C/D or Zone Group IIA /IIB flammable vapor ~~atmospheres~~ or gases, as defined by *NFPA 70* , having an MIE greater than 0.14 mJ are present.

A.9.4.7.4.5

Type D FIBCs use low energy corona discharges to dissipate static charges from the bag surface. Corona discharges are capable of igniting flammable gases or vapors with MIE less than 0.14 mJ. Type D FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Per IEC 61340-4-4, Electrostatics — Part 4-4: *Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC),* Type D FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC.

9.4.7.4.5.1*

Type D FIBCs shall not be permitted to be used for conductive ~~dusts~~ particulate solids .

A.9.4.7.4.5.1

Type D bags function by corona discharge. Metals or other conductive particulate solids could require additional precautions because, if the particulate is isolated and becomes charged, incendiary sparks could occur during rapid filling and emptying operations. IEC TS 60079-32-1 gives guidance on additional precautions that could be necessary. A risk assessment referencing IEC TS 60079-32-1 could be performed to support the use of Type D FIBCs for conductive particulate solids.

9.4.7.4.6*

Type B, Type C, and Type D FIBCs shall be tested and verified as safe for their intended use by a recognized testing organization in accordance with the requirements and test procedures specified in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, before being used in hazardous environments.

A.9.4.7.4.6

Table A.9.4.7.4.6~~provides a useful guide~~ and Figure A.9.4.7.4.6 provide guides for the selection and use of FIBCs based on the MIE of product contained in the FIBC and the nature of the atmosphere surrounding it. Inner liners for FIBCs are separated into three types. Note that the selection of the type of liner is critical to maintaining classification of the FIBC. Appropriate inner liner selection, where applicable, is addressed in IEC 61340-4-4.

Table A.9.4.7.4.6 Use of Different Types of FIBCs

Bulk Product in FIBC	Surroundings		
MIE of Solids[a]	Nonflammable Atmosphere	Class II, Divisions 1 and 2 (~~1,000~~ 1000mJ ≥ MIE >3 mJ)[a]	Class I, Divisions 1 and 2 (Gas Group C and D) or Class II, Divisions 1 and 2 (MIE ≤3 mJ)[a]
MIE > 1000 mJ	A, B, C, D	B, C, D	C, D[b]
1000 mJ ≥ MIE > 3 mJ	B, C, D	B, C, D	C, D[b]
MIE ≤ 3 mJ	C, D	C, D	C, D[b]

Notes:

(1) Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC, for example, in the case of solvent wet solids.

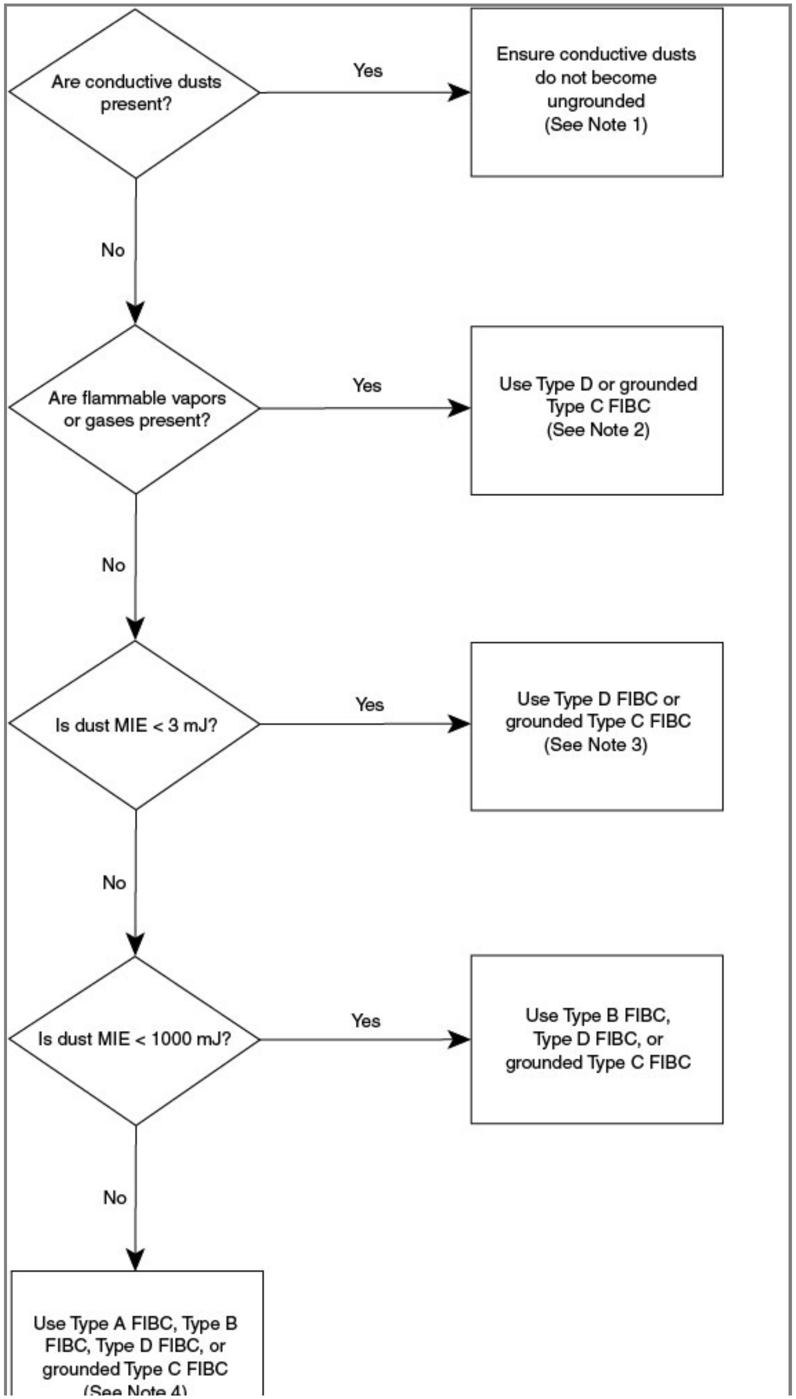
(2) Nonflammable atmosphere includes combustible particulate solids having a MIE greater than 1000 mJ.

(3) FIBC Types A, B, and D are not suitable for use with conductive combustible particulate solids.

[a]Measured in accordance with ASTM E2019, capacitive discharge circuit (no added inductance).

[b]Use of Type C and D is limited to Gas Groups C and D with MIE greater than or equal to 0.14 mJ.

Figure A.9.4.7.4.6 FIBC Selection Decision Tree.


Are conductive dusts present?
Yes
Ensure conductive dusts do not become ungrounded (See Note 1)
No
Are flammable vapors or gases present?
Yes
Use Type D or grounded Type C FIBC (See Note 2)
No
Is dust MIE < 3 mJ?
Yes
Use Type D FIBC or grounded Type C FIBC (See Note 3)
No
Is dust MIE < 1000 mJ?
Yes
Use Type B FIBC, Type D FIBC, or grounded Type C FIBC
No
Use Type A FIBC, Type B FIBC, Type D FIBC, or grounded Type C FIBC

9.4.7.4.6.1

Intended use shall include both the product being handled and the environment in which the FIBC will be used.

9.4.7.4.6.2

Materials used to construct inner baffles, other than mesh or net baffles, shall meet the requirements for the bag type in which they are to be used.

9.4.7.4.6.3

Documentation of test results shall be made available to the AHJ.

9.4.7.4.6.4

FIBCs that have not been tested and verified for type in accordance with IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, shall ~~be~~ not be used for combustible dusts or in flammable vapor atmospheres.

9.4.7.4.7*

Deviations from the requirements in 9.4.7.4.1 through 9.4.7.4.6 for safe use of FIBCs shall be permitted based on a documented risk assessment acceptable to the AHJ.

A.9.4.7.4.7

In special cases it might be necessary to use a type of FIBC that is not permitted for the intended application based on the requirements of 9.4.7.4. For such cases, it might be determined that the FIBC is safe to use provided that filling or emptying rates are restricted to limit electrostatic charging. In the case of conductive combustible particulate solids, the use of a Type A FIBC might be acceptable provided that the maximum ignition energy from the FIBC or charged product within it is less than the MIE of the combustible particulate solids.

9.4.7.5 Rigid Intermediate Bulk Containers (RIBCs).

9.4.7.5.1*

Conductive RIBCs shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided that the RIBCs are electrically grounded.

A.9.4.7.5.1

Conductive containers are generally made from either metal or carbon-filled plastic having a volume resistivity less than 10^6 ohm-m.

9.4.7.5.2*

Nonconductive RIBCs shall not be permitted to be used for applications, processes, or operations involving combustible particulate solids or where flammable vapors or gases are present unless a documented risk assessment assessing the electrostatic hazards is acceptable to the AHJ.

A.9.4.7.5.2

Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the risk assessment and dust hazards analysis when the use of nonconductive RIBCs is being considered. The risk assessment should also consider that higher rates of transfer into and out of the RIBC increase the rate of charge generation, which could result in the ~~propagation of~~ brush discharges, <u>propagating brush discharges,</u> or surface (cone) discharges while the RIBC is being filled. For additional information on these phenomena, refer to NFPA 77.

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Submittal Date: Tue Nov 07 13:21:42 EST 2017

Committee Statement

Committee Statement: Corrects errors in second revision that were identified in ballot -

8.4.7.1.2 (4) - should be 6kV, not 6 V

A.8.4.7.4.5 should read Type D FIBC.

Committee Comment No. 27-NFPA 652-2017 [Section No. 8.4.7]

Second Correlating Revision No. 6-NFPA 652-2017 [Section No. 9.4.1]

8.4.1 General.

~~Unless otherwise specified, the requirements of Section 9.4 shall be applied retroactively.~~

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Submittal Date: Tue Nov 07 14:30:57 EST 2017

Committee Statement

Committee Statement: Statement is being deleted since all of Chapter 9 is retroactive.

Second Correlating Revision No. 11-NFPA 652-2017 [Section No. A.5.2.2]

A.5.2.2

Such an assessment is to determine whether the dust is a combustible dust and if further assessment is necessary. Data can be from samples within the facility that have been tested or data can be based on whether the material is known to be combustible or not. There are some published data of commonly known materials, and the use of these data is adequate to determine whether the dust is a combustible dust. For well-known commodities, published data are usually acceptable. A perusal of published data illuminates that there is often a significant spread in values. It is useful, therefore, to compare attributes (such as particle distribution and moisture content) in published data with the actual material being handled in the system whenever possible. Doing so would help to verify that the data are pertinent to the hazard under assessment.

Subsection 5.2.2 does not require the user to know all these items for the assessment; rather, it reviews the important items in order to determine whether the material data are representative of the material in the facility. Even test data of material can be different from the actual conditions. Users should review the conditions of the test method as well to ensure that it is representative of the conditions of the facility. Where that is not possible, the use of worst-case values should be selected.

Composition and particle size are two parameters that are useful to identify the number and location of representative samples to be collected and tested. *(See Section 5.5 for information on sampling.)*

Refer to Tables A.5.2.2(a) through A.5.2.2(k) for ~~guidance only and not as substitutes for actual test data~~ examples of combustible dust test data . These tables are not all-inclusive. ~~of all combustible dusts and noncombustible dusts.~~ Additionally, material properties and testing methods can provide results that vary from those presented in these tables.

Table A.5.2.2(a) 20-L Sphere Test Data ~~–~~ — Agricultural Dusts

Dust Name	Percent Moisture	Median Particle Size (µm)	Percent < 200 Mesh (%)	P_{max} (bar g)	(1) K_{St} (bar m/sec)	Minimum Explosive Concentration (g/m^3)	Minimum Ignition Energy (mJ)
Alfalfa	2.1	36	83	6.7	94		
Angel Food Cake	4.1	41		7.5	132		
Apple		155	9	6.7	34	125	
Beet root		108	26	6.1	30	125	
Carrageenan	3.8		98	8.5	140		
Carrot	4.0	29	76	6.9	65		
Cereal dust (mixed)	4.4	121		6.7	74	265	
Cheesy pasta sauce mix (corn starch and spices)	7.9	<45	68	7.2	99		45
Chili sauce mix (corn starch and spices)	7.0	79	70	6.6	60		74
Cocoa bean dust	2.3	45	100	7.1	133		
Cocoa powder	3.9	194	14	8.0	162	65	100–180
Coconut shell dust	6.5		51	6.8	111		
Coffee dust – coarse particles	4.8	321	0.4	6.9	55		160*
Coffee dust – fine particles	4	40	100	7.7	158		
Corn (maize)	9.0	165		8.7	117	30	>10
Corn meal	8.2	403	0.6	6.2	47		
Cornstarch – coarse particles	2.2	217	0.1	7.9	186		30–60*
Cornstarch – fine particles		11	100	9.5	141	60	
Cotton		44	72	7.2	24	100	
Cottonseed		245	10	7.7	35	125	
Fudge brownie mix	4.8	221		5.8	43		

Dust Name	Percent Moisture	Median Particle Size (µm)	Percent < 200 Mesh (%)	P_{max} (bar g)	(1) K_{St} (bar m/sec)	Minimum Explosive Concentration (g/m^3)	Minimum Ignition Energy (mJ)
Garlic powder				8.6	164		
Gluten		150	33	7.7	110	125	
Grass dust		200		8.0	47	125	
Green coffee	5.0	45	81	7.8	116		
Hops (malted)		490	9	8.2	90		
Lemon peel dust	9.5	38	73	6.8	125		
Lemon pulp	2.8	180	17	6.7	74		
Linseed		300		6.0	17		
Locust bean gum	1.7		53	7.8	78		
Malt	10.5	72	54	7.5	170		
Milk powder	3.1	41	88	7.5	145		
Oat flour	4.3	180	0.2	6.8	64		
Oat grain dust		295		6.0	14	750	
Olive pellets				10.4	74	125	
Onion powder				9.0	157		
Parmesan sauce mix (corn starch and spices)	6.7	66	60	6.1	45		62
Parlsey (dehydrated)	5.4		26	7.5	110		
Peach		140	17	8.4	81	60	
Peanut meal and skins	3.8			6.4	45		
Peat		74	48	8.3	51	125	
Potato		82	30	6	20	250	
Potato flakes	8.0	249	7.0	6.2	33		
Potato flour		65	53	9.1	69	125	
Potato starch		32	100	9.4	89		>3200
Raw yucca seed dust	12.7	403	5	6.2	65		
Rice dust	2.5		4	7.7	118		40–120*
Rice flour	12.2	45	100	7.7	140	65	>500
Rice starch		18	90	10	190		
Rye flour		29	76	8.9	79		
Semolina	13.6	57	100	7.0	109		
Snack mix spices	8.3	85		6.8	73		
Soybean dust	2.1		59	7.5	125		
Spice dust	10.0		2	6.9	65		
Spice powder	10.0			7.8	172		
Sugar, fine	1.3	45	100	7.6	117	135	38

Dust Name	Percent Moisture	Median Particle Size (µm)	Percent < 200 Mesh (%)	P_{max} (bar g)	(1) K_{St} (bar m/sec)	Minimum Explosive Concentration (g/m^3)	Minimum Ignition Energy (mJ)
Sugar, granulated	2	152	13	6.2	66		
Sugar, powdered	13	45	100	7.0	122		30*
Sunflower		420	10	7.9	44	125	
Tea	6.3	77	53	7.6	102	125	
Tobacco blend	1.0	120		8.0	124		
Tomato		200		1		100	
Walnut dust	6.0		31	8.4	174		
Wheat/rice cereal base	2.8	187		5.7	28	150	
Wheat/rice cereal base regrinds	6.4	217		6.4	29		
Wheat flour	12.9	57	60	8.3	87	60	
Wheat grain dust		80	48	9.3	112	60	
Wheat starch		20		9.8	132	60	25–60*
Xanthan gum	8.6	45	91	7.5	61		
Yellow cake mix	6.1	219		6.3	73		

*The *SFPE Handbook of Fire Protection Engineering*, 4th Edition, Table 3-18.2.

Notes:

(1) Normalized to 1 m^3 test vessel pressures, per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

(2) See also Table F.1(a) in NFPA 68 for additional information on agricultural dusts with known explosion hazards.

(3) For those agricultural dusts without known explosion data, the dust should be tested in accordance with established standardized test methods.

[**61:**Table A.5.2.2]

Table A.5.2.2(b) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen – — Agricultural Dusts

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust HazardClass
Cellulose	33	60	9.7	229	2
Cellulose pulp	42	30	9.9	62	1
Cork	42	30	9.6	202	2
Corn	28	60	9.4	75	1
Egg white	17	125	8.3	38	1
Milk, powdered	83	60	5.8	28	1
Milk, nonfat, dry	60	—	8.8	125	1
Soy flour	20	200	9.2	110	1
Starch, corn	7	—	10.3	202	2
Starch, rice	18	60	9.2	101	1
Starch, wheat	22	30	9.9	115	1

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust HazardClass
Sugar	30	200	8.5	138	1
Sugar, milk	27	60	8.3	82	1
Sugar, beet	29	60	8.2	59	1
Tapioca	22	125	9.4	62	1
Whey	41	125	9.8	140	1
Wood flour	29	—	10.5	205	2

[**68:** Table F.1(a)]

Table A.5.2.2(c) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen – — Carbonaceous Dusts

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Charcoal, activated	28	60	7.7	14	1
Charcoal, wood	14	60	9.0	10	1
Coal, bituminous	24	60	9.2	129	1
Coke, petroleum	15	125	7.6	47	1
Lampblack	<10	60	8.4	121	1
Lignite	32	60	10.0	151	1
Peat, 22% H_2O	—	125	84.0	67	1
Soot, pine	<10	—	7.9	26	1

[**68:** Table F.1(b)]

Table A.5.2.2(d) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen – — Chemical Dusts

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Adipic acid	<10	60	8.0	97	1
Anthraquinone	<10	—	10.6	364	3
Ascorbic acid	39	60	9.0	111	1
Calcium acetate	92	500	5.2	9	1
Calcium acetate	85	250	6.5	21	1
Calcium stearate	12	30	9.1	132	1
Carboxy- methyl- cellulose	24	125	9.2	136	1
Dextrin	41	60	8.8	106	1
Lactose	23	60	7.7	81	1
Lead stearate	12	30	9.2	152	1
Methyl-cellulose	75	60	9.5	134	1
Paraformaldehyde	23	60	9.9	178	1
Sodium ascorbate	23	60	8.4	119	1
Sodium stearate	22	30	8.8	123	1
Sulfur	20	30	6.8	151	1

[**68:** Table F.1(c)]

Table A.5.2.2(e) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen ~~–~~ — Metal Dusts

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Aluminum	29	30	12.4	415	3
Bronze	18	750	4.1	31	1
Iron carbonyl	<10	125	6.1	111	1
Magnesium	28	30	17.5	508	3
Phenolic resin	55	—	7.9	269	2
Zinc	10	250	6.7	125	1
Zinc	<10	125	7.3	176	1

[**68:** Table F.1(d)]

Table A.5.2.2(f) 1 m^3 Vessel Test Data from Forschungsbericht Staubexplosionen (except where noted) ~~–~~ — Plastic Dusts

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
(poly) Acrylamide	10	250	5.9	12	1
(poly) Acrylonitrile	25	—	8.5	121	1
(poly) Ethylene (low-pressure process)	<10	30	8.0	156	1
Epoxy resin	26	30	7.9	129	1
Melamine resin	18	125	10.2	110	1
Melamine, molded (wood flour and mineral filled phenol-formaldehyde)	15	60	7.5	41	1
Melamine, molded (phenol-cellulose)	12	60	10.0	127	1
(poly) Methyl acrylate	21	30	9.4	269	2
(poly) Methyl acrylate, emulsion polymer	18	30	10.1	202	2
Phenolic resin	<10	15	9.3	129	1
	55		7.9	269	2
(poly) Propylene	25	30	8.4	101	1
Terpene-phenol resin	10	15	8.7	143	1
Urea-formaldehyde/ cellulose, molded	13	60	10.2	136	1
(poly) Vinyl acetate/ ethylene copolymer	32	30	8.6	119	1
(poly) Vinyl alcohol	26	60	8.9	128	1
(poly) Vinyl butyral	65	30	8.9	147	1
(poly) Vinyl chloride	107	200	7.6	46	1
(poly) Vinyl chloride/vinyl acetylene emulsion copolymer	35	60	8.2	95	1
(poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer	60	60	8.3	98	1

[**68:** Table F.1(e)]

Table A.5.2.2(g) 20 L and 1 m^3 Vessel Test Data, PVC and Copolymer Plastic Resins and Dusts

-	GP[a] Dispersion	VA[b] Copolymer	Baghouse Dust from GP Pipe (as received)	GP Pipe Resin[c]	Baghouse Dust from GP Pipe (as received)	GP Pipe Resin (as received)	High Molecular Weight Resin (as received)
-	Type of polymerization process						
PVC Resin Sample	Emulsion		Suspension				
Plant designator	A	B	C	C	D	D	E
Test lab	Chilworth	Chilworth	Chilworth	Fike	Chilworth	Chilworth (20 L), Fike (1 m^3)	Fike
Minimum Ignition Energy (MIE), Joules	>10 J	>10 J	>500 mJ	>4653 mJ	>10 J	>10 J	>4468 mJ
Explosion severity, K_{St} (bar-m/s), 20 L test chamber	91	68	84	18	54	9	81
Dust explosion class in 20 L test chamber	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1
Explosion severity, K_{St} (bar-m/s), 1 m^3 test chamber	Not tested	Not tested	Not tested	0	Not tested	0	0
Dust explosion class in 1 m^3 test chamber	Not tested	Not tested	Not tested	ST 0	Not tested	ST 0	ST 0
Particle size, avg. (μm)	1 (est.)	N.A.	N.A.	162	N.A.	158	128
Dust fraction (<75 μm, %)	100	100	100	0.1	97	0	0.6

Note: Sponsored by the Vinyl Institute, 1737 King Street, Suite 390, Alexandria, VA 22314.

[a]GP: General Purpose

[b]VA: Vinyl Acetate

[c]Date for MIE and 20 L test were performed by Fike on sample screened to <150 μm and data for 1 m^3 tests were performed by Fike on 'as received' sample.

Source: Krock, R., et. al., "OSHA's Combustible Dust National Emphasis Program and Combustibility Characteristics Testing of PVC Resins and PVC Dusts," SPE ANTEC, April, 2012.

Table A.5.2.2(h) Explosibility Properties of Metals

Material	Median Diameter (μm)	K_{St} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE(mJ)	MEC(g/m^3)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Aluminum	~7	—	8	—	—	90			Cashdollar & Zlochower4
Aluminum	22	—	—	—	—	—	—	5 (N)	BGIA3
Aluminum	<44	—	5.8	650	50	45		2 (C)	BuMines RI 6516
Aluminum flake	<44		6.1	650	20	45		<3 (C)	BuMines RI 6516
Aluminum	<10	515	11.2	560	—	60	—	—	BGIA3

Material	Median Diameter (µm)	K_{st} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE(mJ)	MEC(g/m^3)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Aluminum	580	Not Ignited	—	—	—	—	—	—	BGIA
Beryllium	4	Not Ignited	—	—	—	—	—	—	BuMines RI 6516
Boron	<44	—	—	470	60	<100	—	—	BuMines RI 6516
Boron	~3	—	6.0			≈110			Cashdollar & Zlochower
Bronze	18	31	4.1	390	—	750	BZ 4		Eckhoff
Chromium	6	—	3.3	660	5120	770		14 (C)	BuMines RI 6516
Chromium	3	—	3.9	580	140	230	—	—	BuMines RI 6517
Copper	~30	Not Ignited							Cashdollar & Zlochower
Hafnium	~8	—	4.2	—	—	~180	—	—	Cashdollar & Zlochower
Iron	12	50	5.2	580		500	—		Eckhoff
Iron	~45	—	2.1	—	—	~500	—	—	Cashdollar & Zlochower
Iron	< 44	—	2.8	430	80	170	—	13 (C)	BuMines RI 6516
Iron, carbonyl	< 10	111	6.1	310		125	BZ 3		Eckhoff
Manganese	< 44	—	—	460	305	125		—	BuMines RI 6516
Manganese(electrolytic)	16	157	6.3	330	—	—	—	—	Eckhoff
Manganese(electrolytic)	33	69	6.6	—	—	—	—	—	Eckhoff
Magnesium	28	508	17.5	—	—	—	—		Eckhoff
Magnesium	240	12	7	760		500	BZ 5		Eckhoff
Magnesium	<44	—	—	620	40	40		—	BuMines RI 6516
Magnesium	<44	—		600	240	30	—	<3 (C)	BuMines RI 6516
Magnesium	~16	—	7.5	—	—	55	—	—	Cashdollar & Zlochower
Molybdenum	<10	Not Ignited							Eckhoff
Nickel	~6	Not Ignited							Cashdollar & Zlochower
Niobium	80	238	6.3	560	3	70		6 (Ar)	Industry
Niobium	70	326	7.1	591	3	50		5 (Ar)	Industry
Silicon	<10	126	10.2	>850	54	125	BZ 3		Eckhoff
Silicon, from dust collector	16	100	9.4	800	—	60	—		Eckhoff
Silicon, from filter	<10	116	9.5	>850	250	60	BZ 1		Eckhoff
Tantalum	<44	—	—	630	120	<200		3 (Ar)	BuMines RI 6516
Tantalum	~10		≈3			≈400			Cashdollar & Zlochower
Tantalum	100	149	6.0	460	<3	160		2 (Ar)	Industry

Material	Median Diameter (µm)	K_{St} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE(mJ)	MEC(g/m³)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Tantalum	80	97	3.7	540	<3	160		2(Ar)	Industry
Tantalum	50	108	5.5	520	<3	160		2(Ar)	Industry
Tantalum	65	129	5.8	460	<3	160		2(Ar)	Industry
Tantalum	21		5.6	430	<3	125		<2(Ar)	Industry
Tantalum	25			400	>1<3	30		<2(Ar)	Industry
Tin	~8	—	3.3	—	—	~450	—	—	Cashdollar & Zlochower
Titanium	36	Not Ignited				BZ 2			BGIA
Titanium	30	—	—	450	—	—	—		Eckhof
Titanium	~25		4.7	—	—	70	—		Cashdollar & Zlochower
Titanium	10	—	4.8	330	25	45		6 (N) 4 (Ar)	BuMines RI 6515
Tungsten	≤1	—	~2.3	—	—	~700	—	—	Cashdollar & Zlochower
Tungsten	~10	Not Ignited							Cashdollar & Zlochower
Zinc (from collector)	<10	125	6.7	570	—	250	BZ 3		Eckhoff
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N2 & CO2	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

(1) Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen

(2) UN Dust Layer Combustibility Categories are as follows: BZ1 No self-sustained combustion; BZ2 Local combustion of short duration; BZ3 Local sustained combustion, but no propagation; BZ4 Propagating smoldering combustion; BZ5 Propagating open flame; BZ6 Explosive combustion.

(3) BGIA is the GESTIS-DUST-EX database maintained by BGIA-online.hvbg.de

(4) Cashdollar, Kenneth, and Zlochower, Isaac, "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," *J. Loss Prevention* in the Process Industries, v. 20, 2007.

[**484:** Table A.1.1.3(b)]

Table A.5.2.2(i) Atomized Aluminum Particle Ignition and Explosion Data

Particle Size(d_{50}) (µm)	BET(m²/g)	MEC(g/m³)	P_{max} (psi)	dP/dt_{max} (psi/sec)	K_{St} (bar·m/sec)	Sample Concentration That Corresponds to P_{max} and dP/dt_{max}(g/m³)	MIE (mJ)	LOC (%)	Most Easily Ignitible Concentration (g/m³)
Nonspherical, Nodular, or Irregular Powders									
53	0.18	170	123	3,130	59	1,250			

Particle Size(d_{50}) (µm)	BET(m^2/g)	MEC(g/m^3)	P_{max} (psi)	dP/dt_{max} (psi/sec)	K_{St} (bar·m/sec)	Sample Concentration That Corresponds to P_{max} and dP/dt_{max}(g/m^3)	MIE (mJ)	LOC (%)	Most Easily Ignitible Concentration (g/m^3)
42	0.19	70	133	5,720	107	1,250 (P_{max}), 1,000 (dP/dt_{max})			
32	0.34	60	142	7,950	149	1,250	10		
32	0.58	65	133	8,880	167	750 (P_{max}), 1,500 (dP/dt_{max})	11	Ignition @ 8.0% Nonignition @ 7.5%	1,000
30	0.10	60					10		
28	0.11	55	140	6,360	119	1,000 (P_{max}), 1,250 (dP/dt_{max})	11		
28	0.21	55	146	8,374	157	1,500	11		
9	0.90	65	165	15,370	288	750 (P_{max}), 1,000 (dP/dt_{max})	4		
7	0.74	90	153	17,702	332	1,000 (P_{max}), 500 (dP/dt_{max})	12		
6	0.15	80	176	15,580	292	750	3.5		
6	0.70	75	174	15,690	294	500 (P_{max}), 1,000 (dP/dt_{max})	3		
5	1.00	70					4		
4	0.78	75	167	15,480	291	1,000 (P_{max}), 750 (dP/dt_{max})	3.5		
Spherical Powders									
63	0.15	120	101	1,220	23	1,250 (P_{max}), 1,000 (dP/dt_{max})	N.I.	Ignition @ 8.0% Nonignition @ 7.5%	1,750
36	0.25	60	124	4,770	90	1,250	13		
30	0.10	60	140	5,940	111	1,000	13		
15	0.50	45	148	10,812	203	1,000	7		
15	0.30	55					8		
6	0.53	75	174	16,324	306	750	6		
5	1.30		167	14,310	269	750		Ignition @ 6.0% Nonignition @ 5.5%	750
5	1.00	70	155	14,730	276	1,250	6	Ignition @ 6.0% Nonignition @ 5.5%	1,250
3	2.50	95	165	15,900	298	1,250	4		
2	3.00	130							

For U.S. conversions: 1 m^2/g = 4884 ft^2/lb; 1 g/m^2 = 0.000062 lb/ft^2; 1 bar/sec = 14.5 psi/sec; 1 bar·m/sec = 0.226 psi·ft/sec.

BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O_2) concentration.

Notes:

(1) The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.

(2) Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*; MIE: ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*; maximum pressure rise (P_{max}), maximum pressure rise rate (*dP/dt*), and deflagration index (K_{St}): ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*; LOC: ASTM E2079, *Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors*.

(3) Particle size data represent the d_{50} measurement determined by the laser light–scattering technique.

(4) Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.

[**484:**Table ~~A.4.3.1~~ A.5.4.1]

Table A.5.2.2(j) Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 mesh (75 μm)]

Explosion Characteristics	Values
Maximum explosion pressure (gauge)	793 kPa (115 psi)
Maximum rate of pressure rise (gauge)	793 kPa/sec (15,000 psi/sec)
Ignition temperature cloud	1040°F (560°C)
Minimum cloud ignition energy	0.04 J (26.4 W/sec)
Minimum explosion concentration	0.328 kg/m^3 (0.03 oz/ft^3)
Limiting oxygen percent for spark ignition*	—

Note: K_{St} values vary for specific particle sizes.

~~[**484:** Table D.2]~~

Table A.5.2.2(k) Selected Combustible Dusts Layer or Cloud Ignition Temperature

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Acetal, linear		G	NL	440
Acetoacet-p-phenetidide	122-82-7	G	NL	560
Acetoacetanilide	102-01-2	G	M	440
Acetylamino-t-nitrothiazole		G		450
Acrylamide polymer		G		240
Acrylonitrile polymer		G		460
Acrylonitrile-vinyl chloride-vinylidenechloride copolymer (70-20-10)		G		210
Acrylonitrile-vinyl pyridine copolymer		G		240
Adipic acid	124-04-9	G	M	550
Alfalfa meal		G		200
Alkyl ketone dimer sizing compound		G		160
Allyl alcohol derivative (CR-39)		G	NL	500
Almond shell		G		200
Aluminum, A422 flake	7429-90-5	E		320

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Aluminum, atomized collector fines		E	CL	550
Aluminum—cobalt alloy (60-40)		E		570
Aluminum—copper alloy (50-50)		E		830
Aluminum—lithium alloy (15% Li)		E		400
Aluminum—magnesium alloy (dowmetal)		E	CL	430
Aluminum—nickel alloy (58-42)		E		540
Aluminum—silicon alloy (12% Si)		E	NL	670
Amino-5-nitrothiazole	121-66-4	G		460
Anthranilic acid	118-92-3	G	M	580
Apricot pit		G		230
Aryl-nitrosomethylamide		G	NL	490
Asphalt	8052-42-4	F		510
Aspirin [acetol (2)]	50-78-2	G	M	660
Azelaic acid	109-31-9	G	M	610
Azo-bis-butyronitrile	78-67-1	G		350
Benzethonium chloride		G	CL	380
Benzoic acid	65-85-0	G	M	620
Benzotriazole	95-14-7	G	M	440
Beta-naphthalene-axo- dimethylaniline		G		175
Bis(2-hydroxy- 5-chlorophenyl) methane	97-23-4	G	NL	570
Bisphenol-A	80-05-7	G	M	570
Boron, commercial amorphous (85% B)	7440-42-8	E		400
Calcium silicide		E		540
Carbon black (more than 8% total entrapped volatiles)		F		
Carboxymethyl cellulose	9000-11-7	G		290
Carboxypolymethylene		G	NL	520
Cashew oil, phenolic, hard		G		180
Cellulose		G		260
Cellulose acetate		G		340
Cellulose acetate butyrate		G	NL	370
Cellulose triacetate		G	NL	430
Charcoal (activated)	64365-11-3	F		180
Charcoal (more than 8% total entrapped volatiles)		F		
Cherry pit		G		220
Chlorinated phenol		G	NL	570
Chlorinated polyether alcohol		G		460
Chloroacetoacetanilide	101-92-8	G	M	640
Chromium (97%) electrolytic, milled	7440-47-3	E		400

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Cinnamon		G		230
Citrus peel		G		270
Coal, Kentucky bituminous		F		180
Coal, Pittsburgh experimental		F		170
Coal, Wyoming		F		180
Cocoa bean shell		G		370
Cocoa, natural, 19% fat		G		240
Coconut shell		G		220
Coke (more than 8% total entrapped volatiles)		F		
Cork		G		210
Corn		G		250
Corn dextrine		G		370
Corncob grit		G		240
Cornstarch, commercial		G		330
Cornstarch, modified		G		200
Cottonseed meal		G		200
Coumarone-indene, hard		G	NL	520
Crag No. 974	533-74-4	G	CL	310
Cube root, South America	83-79-4	G		230
Di-alphacumyl peroxide, 40-60 on CA	80-43-3	G		180
Diallyl phthalate	131-17-9	G	M	480
Dicyclopentadiene dioxide		G	NL	420
Dieldrin (20%)	60-57-1	G	NL	550
Dihydroacetic acid		G	NL	430
Dimethyl isophthalate	1459-93-4	G	M	580
Dimethyl terephthalate	120-61-6	G	M	570
Dinitro-o-toluamide	148-01-6	G	NL	500
Dinitrobenzoic acid		G	NL	460
Diphenyl	92-52-4	G	M	630
Ditertiary-butyl-paracresol	128-37-0	G	NL	420
Dithane m-45	8018-01-7	G		180
Epoxy		G	NL	540
Epoxy-bisphenol A		G	NL	510
Ethyl cellulose		G	CL	320
Ethyl hydroxyethyl cellulose		G	NL	390
Ethylene oxide polymer		G	NL	350
Ethylene-maleic anhydride copolymer		G	NL	540
Ferbam™	14484-64-1	G		150

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Ferromanganese, medium carbon	12604-53-4	E		290
Ferrosilicon (88% Si, 9% Fe)	8049-17-0	E		800
Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)		E	CL	380
Flax shive		G		230
Fumaric acid	110-17-8	G	M	520
Garlic, dehydrated		G	NL	360
Gilsonite	12002-43-6	F		500
Green base harmon dye		G		175
Guar seed		G	NL	500
Gulasonic acid, diacetone		G	NL	420
Gum, arabic		G		260
Gum, karaya		G		240
Gum, manila		G	CL	360
Gum, tragacanth	9000-65-1	G		260
Hemp hurd		G		220
Hexamethylene tetramine	100-97-0	G	S	410
Hydroxyethyl cellulose		G	NL	410
Iron, 98% H2 reduced		E		290
Iron, 99% carbonyl	13463-40-6	E		310
Isotoic anhydride		G	NL	700
L-sorbose		G	M	370
Lignin, hydrolized, wood-type, fine		G	NL	450
Lignite, California		F		180
Lycopodium		G		190
Malt barley		G		250
Manganese	7439-96-5	E		240
Magnesium, grade B, milled		E		430
Manganese vancide		G		120
Mannitol	69-65-8	G	M	460
Methacrylic acid polymer		G		290
Methionine (l-methionine)	63-68-3	G		360
Methyl cellulose		G		340
Methyl methacrylate polymer	9011-14-7	G	NL	440
Methyl methacrylate-ethyl acrylate		G	NL	440
Methyl methacrylate-styrene- butadiene		G	NL	480
Milk, skimmed		G		200
N,N-dimethylthio- formamide		G		230
Nitropyridone	100703-82-0	G	M	430

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Nitrosamine		G	NL	270
Nylon polymer	63428-84-2	G		430
Para-oxy-benzaldehyde	123-08-0	G	CL	380
Paraphenylene diamine	106-50-3	G	M	620
Paratertiary butyl benzoic acid	98-73-7	G	M	560
Pea flour		G		260
Peach pit shell		G		210
Peanut hull		G		210
Peat, sphagnum	94114-14-4	G		240
Pecan nut shell	8002-03-7	G		210
Pectin	5328-37-0	G		200
Pentaerythritol	115-77-5	G	M	400
Petrin acrylate monomer	7659-34-9	G	NL	220
Petroleum coke (more than 8% total entrapped volatiles)		F		
Petroleum resin	64742-16-1	G		500
Phenol formaldehyde	9003-35-4	G	NL	580
Phenol formaldehyde, polyalkylene-p	9003-35-4	G		290
Phenol furfural	26338-61-4	G		310
Phenylbetanaphthylamine	135-88-6	G	NL	680
Phthalic anydride	85-44-9	G	M	650
Phthalimide	85-41-6	G	M	630
Pitch, coal tar	65996-93-2	F	NL	710
Pitch, petroleum	68187-58-6	F	NL	630
Polycarbonate		G	NL	710
Polyethylene, high pressure process	9002-88-4	G		380
Polyethylene, low pressure process	9002-88-4	G	NL	420
Polyethylene terephthalate	25038-59-9	G	NL	500
Polyethylene wax	68441-04-8	G	NL	400
Polypropylene (no antioxidant)	9003-07-0	G	NL	420
Polystyrene latex	9003-53-6	G		500
Polystyrene molding compound	9003-53-6	G	NL	560
Polyurethane foam, fire retardant	9009-54-5	G		390
Polyurethane foam, no fire retardant	9009-54-5	G		440
Polyvinyl acetate	9003-20-7	G	NL	550
Polyvinyl acetate/alcohol	9002-89-5	G		440
Polyvinyl butyral	63148-65-2	G		390
Polyvinyl chloride-dioctyl phthalate		G	NL	320
Potato starch, dextrinated	9005-25-8	G	NL	440

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Pyrethrum	8003-34-7	G		210
Rayon (viscose) flock	61788-77-0	G		250
Red dye intermediate		G		175
Rice		G		220
Rice bran		G	NL	490
Rice hull		G		220
Rosin, DK	8050-09-7	G	NL	390
Rubber, crude, hard	9006-04-6	G	NL	350
Rubber, synthetic, hard (33% S)	64706-29-2	G	NL	320
Safflower meal		G		210
Salicylanilide	87-17-2	G	M	610
Sevin	63-25-2	G		140
Shale, oil	68308-34-9	F		
Shellac	9000-59-3	G	NL	400
Sodium resinate	61790-51-0	G		220
Sorbic acid (copper sorbate or potash)	110-44-1	G		460
Soy flour	68513-95-1	G		190
Soy protein	9010-10-0	G		260
Stearic acid, aluminum salt	637-12-7	G		300
Stearic acid, zinc salt	557-05-1	G	M	510
Styrene modified polyester-glass fiber	100-42-5	G		360
Styrene-acrylonitrile (70-30)	9003-54-7	G	NL	500
Styrene-butadiene latex (>75% styrene)	903-55-8	G	NL	440
Styrene-maleic anhydride copolymer	9011-13-6	G	CL	470
Sucrose	57-50-1	G	CL	350
Sugar, powdered	57-50-1	G	CL	370
Sulfur	7704-34-9	G		220
Tantalum	7440-25-7	E		300
Terephthalic acid	100-21-0	G	NL	680
Thorium (contains 1.2% O)	7440-29-1	E	CL	270
Tin, 96%, atomized (2% Pb)	7440-31-5	E		430
Titanium, 99% Ti	7440-32-6	E	CL	330
Titanium hydride (95% Ti, 3.8% H)	7704-98-5	E	CL	480
Trithiobisdimethylthio- formamide		G		230
Tung, kernels, oil-free	8001-20-5	G		240
Urea formaldehyde molding compound	9011-05-6	G	NL	460
Urea formaldehyde-phenol formaldehyde	25104-55-6	G		240
Vanadium, 86.4%	7440-62-2	E		490

Chemical Name	CAS No.	NEC Group	Code	Layer orCloud IgnitionTemperature(°C)
Vinyl chloride-acrylonitrile copolymer	9003-00-3	G		470
Vinyl toluene-acrylonitrile butadiene	76404-69-8	G	NL	530
Violet 200 dye		G		175
Vitamin B1, mononitrate	59-43-8	G	NL	360
Vitamin C	50-81-7	G		280
Walnut shell, black		G		220
Wheat		G		220
Wheat flour	130498-22-5	G		360
Wheat gluten, gum	100684-25-1	G	NL	520
Wheat starch		G	NL	380
Wheat straw		G		220
Wood flour		G		260
Woodbark, ground		G		250
Yeast, torula	68602-94-8	G		260
Zirconium hydride	7704-99-6	E		270
Zirconium (contains 0.3% O)	7440-67-7	E	CL	330

Notes:

1. Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears in the “Code” column, then the layer ignition temperature is shown. “CL” means the cloud ignition temperature is shown. “NL” means that no layer ignition temperature is available, and the cloud ignition temperature is shown. “M” signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. “S” signifies that the dust layer sublimes before it ignites; the cloud ignition temperature is shown.

2. Certain metal dusts might have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium and thorium dusts can ignite spontaneously in air, especially at elevated temperatures.

3. Due to the impurities found in coal, its ignition temperatures vary regionally, and ignition temperatures are not available for all regions in which coal is mined.

[**499:** Table 5.2.2]

Submitter Information Verification

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Committee Statement

Committee Statement: Updates extracts to reflect 484 changes. Deletes extract tag from Table 5.2.2 (j) as this material was deleted from 484.

Committee Comment No. 17-NFPA 652-2017 [Section No. A.5.2.2]

Second Correlating Revision No. 8-NFPA 652-2017 [Section No. A.8.3.15.2.1]

A.9.3.15.2.1

~~Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.~~ Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

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Committee Statement

Committee Statement: Correcting error in annex material. Correct annex material in analogous section from 654,

Second Correlating Revision No. 9-NFPA 652-2017 [Section No. A.8.3.17]

A.9.3.17

~~Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.~~ Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types. Dryers and their operating controls should be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

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Committee Statement

Committee Statement: Corrects error in annex material from the analogous section in 654