OSHA NOTICE

U.S. DEPARTMENT OF LABOR

Occupational Safety and Health Administration

DIRECTIVE NUMBER: TED-01-00-015	**EFFECTIVE DATE: 02/10/2020**
SUBJECT: OSHA Technical Manual – Section IV, Chapter 6, Combustible Dusts	

ABSTRACT

Purpose:	This notice adds technical information specific to combustible dusts to the OSHA Technical Manual (OTM).
Scope:	OSHA-wide
References:	29 CFR 1910.307, Hazardous (Classified) Locations. Combustible Dust National Emphasis Program, OSHA Directive CPL 03-00-008. NFPA 652-2019: Standard on the Fundamentals of Combustible Dust.
Cancellations:	None
State Impact:	None. For State reference only.
Action Offices:	Area Offices
Originating Office:	Salt Lake Technical Center/Health Response Team
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By and Under the Authority of

Loren Sweatt
Principal Deputy Assistant Secretary of Labor

Executive Summary

This chapter (Section IV (Safety Hazards), Chapter 6), provides technical information for Compliance Safety and Health Officers (CSHOs) to evaluate combustible dust hazards and abatement methods. The content is based on current industry practices, research publications, OSHA standards, and consensus standards. The chapter is divided into fourteen main sections and includes seventeen appendices.

Significant Changes

This is a new OTM Chapter, therefore, there are no significant changes.

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OSHA Technical Manual (OTM)
Combustible Dusts

Table of Contents

I. Introduction

This chapter provides technical information to help OSHA Compliance Safety and Health Officers (CSHOs) inspect and investigate workplaces where combustible dust is present. This chapter provides only supportive information and shall not take precedence over the Combustible Dust National Emphasis Program (hereinafter NEP) or other enforcement-related documents. **The NEP is the primary combustible dust inspection document**. CSHOs should read and become familiar with the NEP before referring to this OTM chapter.

Combustible dust inspections can be complicated. CSHOs should complete specific combustible dust training before performing these inspections. Working with other trained and experienced CSHOs and staff may be valuable for CSHOs without experience conducting combustible dust inspections.

CSHOs should recognize *Combustible Dust Characteristics* and *Combustible Dust Hazards* before beginning an inspection. Combustible dusts found at different facilities, or at different locations within the same facility, are seldom the same. The size of the dust particles, alone, can change the dust's characteristics enough to change the type and magnitude of the combustion hazard.

CSHOs should also recognize the *Common Signs that a Combustible Dust Hazard is Present* and should determine how to safely conduct the inspection before proceeding (see *On-Site Inspection Initial Considerations*). In many cases, potentially combustible dusts may be present in various forms in different areas of a facility, or in various locations within equipment (see *Appendices L through P* for examples of typical dust-related process equipment). All of these factors make combustible dust inspections and investigations unique to each facility in both number and complexity of hazards.

Some OSHA standards contain provisions applicable to combustible dusts. See *Scope and Applicability of OSHA Standards Regarding Combustible Dusts*. Where warranted, and when no OSHA standards apply, the general duty clause should be considered to address recognized combustible dust hazards. This requires that CSHOs know and follow the requirements under the general duty clause to gather adequate evidence to support inspection findings (see the *NEP* and OSHA *Field Operations Manual*).

Industry standards contain provisions that apply to many types of combustible dusts and may be referenced in the absence of OSHA standards as evidence of hazard recognition in the industry and the existence of feasible abatement measures. See *Scope and Applicability of Notable Industry Combustible Dust Standards and Guidance*.

Combustible dust inspections should focus on *Combustible Dust Hazards* in three primary areas:

- Hazards associated with housekeeping (See *Housekeeping Considerations*)

- Hazards associated with equipment (See *Combustible Dust Equipment Considerations)*
- Hazards associated with electrical equipment in classified locations (See *Electrical (Hazard) Class II Considerations)*

Each of these inspections are normally done together but can also be done separately. However, when facilities include dust collectors, CSHOs should perform inspections of the dust collectors and systems, as over half of all combustible dust explosions occur within dust collectors. See the *Combustible Dust Equipment Considerations* section for more information about dust collector system inspections.

Collecting representative samples of different types of combustible dusts at the facility is necessary to determine the combustibility/explosibility of the dusts. This testing should be completed whenever possible, following safe sampling procedures. See the following appendices for safe sampling of combustible dusts with different hazards:

- *Appendix G, Procedure for Safe Sampling of Most Combustible Dusts*
- *Appendix H, Procedures for Safe Sampling of Low-MIE Combustible Dusts* (See examples of low-MIE combustible dusts at *Appendix V, Low-MIE Combustible Dusts*)
- *Appendix I: Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*

Once samples are collected, CSHOs need to *Determine the Tests to Request from the SLTC Laboratory* and *Safely Package and Ship the Samples to the SLTC*.

Inspection observations and findings should be thoroughly documented by photos, videos, sketches, notes, drawings, company documents, and/or other means available to support the results.

Case Studies and Lessons Learned have been included in Appendix I, as an aid to CSHOs as needed.

Examples of various combustible dust equipment are provided in Appendices *L* through *P*.

CSHOs should seek help and answers to questions by contacting their supervisors and/or others with experience whenever needed. The HRT and SLTC Laboratory have experts and resources available to assist as needed.

II. Combustible Dust Characteristics[1]

Combustible dusts include particles of any size and shape that present a fire, flash-fire, deflagration, or explosion hazard.[2] These can include powders, dusts, fines, fibers, flakes, chips, chunks, metal sponge, swarf, and turnings. In some cases, combustible dusts can have other hazards that must be addressed (see *Appendix F, Combustible Dusts with Other Hazards*). Common categories of combustible dusts include food, agricultural products, metal, wood, plastics, chemicals, coal, and other carbonaceous material (Table 1).

Table 1: Common categories of combustible dusts (with examples).[3]	
Foods	Flours, starches, sugars, powdered milk, corn meal, cocoa powder, whey, cereal, spices, and gluten.
Agriculture and Grains	Wheat, corn, barley, oats, and soybeans.
Metals	Aluminum, iron, magnesium, nickel, niobium, tantalum, titanium, zinc, and zirconium dusts.
Wood	Sawdust and cellulosic dusts, including dusts from paper, cardboard, paper towels, facial tissue, and other paper products.
Plastics	Resins (e.g., melamine, epoxy, phenolic), polymers (e.g., polyethylene, polyvinylchloride, polyacrylamide, polyacrylonitrile), and copolymers.
Chemicals	Adipic acid, anthraquinone, dextrin, lactose, paraformaldehyde, sodium stearate, and sulfur.
Coal and other Carbonaceous Materials	Bituminous, subbituminous, lignite, charcoal, petroleum coke, and carbon black.
Other	Textiles, biosolids, soap, and pet food.

[1] Some of the tests and test methods for determining combustible dust characteristics are delineated in *Appendix J, SLTC Laboratory Tests*, and *Appendix K, ASTM Test Methods*.
[2] See definitions of combustible dust, combustible metal, and combustible particulate solid in National Fire Protection Association (NFPA) 652-2019, *Standard on the Fundamentals of Combustible Dust*.
[3] These are examples of common combustible dusts within each of the listed categories. This is not an exhaustive list and most dusts in these listed major categories are combustible dusts.

The significance of hazards for any given combustible dust depend on its dust characteristics. This section details generally recognized characteristics of combustible dust.[4]

Dust Chemical Composition

CSHOs should identify the chemical composition of the dust to determine if it could be combustible. Many dusts are known to be non-combustible because the dusts include chemicals and/or compounds that do not react with oxygen (i.e., do not combust). For example, sand (SiO_2) will not combust and therefore will not be subject to combustible dust controls and abatements regardless of other conditions or characteristics.

Important: chemicals and compounds react with oxygen at varying rates and burn with varying energies. Therefore, **knowing the chemical composition of a dust provides a good initial estimate as to the combustible dust hazards.**

Oxidation Potential

Combustible dust oxidation, which includes fires, flash fires, deflagrations, and explosions,[5] can and will eventually occur when sufficient energy is applied. This is referred to as the Minimum Ignition Energy (MIE) or, in chemical terms, the Activation Energy. The combustion will continue until the materials have reached their stable state, which is typically the lowest energy state. Sand, as noted above, is in its stable and lowest energy state, so it will not oxidize any further.

However, many dusts are not in their lowest energy state and are combustible even in partially oxidized form. For example, many iron oxides (such as rust particles), although partially oxidized, can oxidize further when a sufficient ignition source and oxygen are available.

In addition, some materials may have a passivated coating (e.g., a thin oxide layer or anodized surface) which can be eroded or worn away, exposing the bare metal surface.

Dust Size

Per NFPA Standard 652-2019, combustible dust includes finely divided combustible particulate solids that present a flash-fire or explosion hazard when suspended in air. Combustible particulate solids include dusts, fibers, fines, chips, chunks, or flakes. The term combustible dust generally refers to powders, fines, and fibers. Particulate smaller than 500 microns (µm), approximately the size of white granulated sugar, is considered

[4] The characteristics discussed in this chapter are those most likely to be encountered during inspections. However, there are other combustible dust characteristics that may be used by some employers.

[5] Combustion is a form of oxidation. Oxidation is defined as any reaction of a substance with oxygen. An oxidation reaction may or may not result in burning or heat. For example, the formation of rust on metal surfaces is an oxidation reaction but does not result in combustion, but rust dust particles, although partially oxidized, are combustible and will burn when dispersed in air.

by NFPA 652 to have the potential to present a flash-fire hazard or explosion hazard when suspended in air.

NFPA standards note that combustible particulate solids having a minimum dimension greater than 500 µm generally have a surface-to-volume ratio too low to pose a deflagration hazard. However, exceptions occur and combustibility should be determined by testing. This is especially true where dust combustibility can vary significantly depending on a number of conditions including:

- Location within the process
- Type of equipment involved
- Ambient weather conditions
- Equipment maintenance status
- Operator-specific preferences
- Date of last sample testing
- Changes in feed stocks (including length of time in transit)
- Changes in product specifications
- Length of time feed stocks have been in storage
- Changes in process throughput

It is important to recognize that as materials pass through a process, they are prone to further size reduction through various mechanisms of abrasion. Even large particulates that are being conveyed in a process may generate smaller particulates meeting the definition of combustible dust, such as in grain handling.

Combustion occurs when oxygen is available in sufficient concentration to cause the combustible material to oxidize (burn) when ignited. In general, the finer the dust, the greater the total dust cloud surface area. Therefore, a dust cloud with finer particulate will be more combustible and explosive.

Suspended dusts provide greater exposure of dust molecules to oxygen. This reduces the ignition energy needed for combustion by increasing the pre-ignition heating of adjacent dust particles. The rapid heating and ignition of the smaller dust particulate increases the combustion propagation rate to other dust particles. This increased combustion propagation results in the creation of stronger deflagration pressures to which surrounding personnel, equipment, and structures are exposed.

Metal dusts are good examples of the effects of dust size. For example, a piece of aluminum metal will not support combustion, but a cloud of fine aluminum dust will ignite at a low ignition energy and will readily support combustion. If the dust is suspended, resulting in more oxygen present for combustion, a deflagration or an explosion can result. *[Note: Metal dusts are specifically addressed in Appendix I, Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE).]*

Moisture Content

Moisture in dust particles raises the required minimum ignition temperature of the dust because of the heat needed to vaporize the moisture. However, once ignition has occurred, the moisture in the air surrounding a dust particle has little effect on the course of a deflagration.

Moisture content cannot be considered an effective explosion preventive safeguard since most ignition sources provide more than enough energy to vaporize ambient moisture in the air and to ignite the dust. In order for moisture to prevent ignition of dust by common sources, the dust typically has to be so damp that a dust cloud could not be formed.[6]

There is, however, a direct relationship between moisture content and the minimum ignition energy (MIE), minimum explosive concentration (MEC), maximum pressure (P_{max}), and maximum rate of pressure rise (K_{st}). For example, the ignition temperature of cornstarch may increase as much as 122°F with an increase of moisture content from 1.6 percent to 12.5 percent. [*Note: Examples of the impact of moisture on K_{st} are shown in NFPA 652-2019, Table A.5.2.2(a). This table includes combustible dusts with significant moisture content.]*

CSHOs should be aware that where only undried wood particulates (classified as green materials) are collected and conveyed, and where the equipment handling or storing the material is all non-combustible, NFPA 664 indicates that fire and deflagration hazards are considered "nonexistent".[7] Green materials are defined as wood particulate having a moisture content equal or greater than 25 percent by weight (wet basis).

The processing, conveying, and storage of green wood materials can be found in lumber milling and some pallet manufacturing or remanufacturing industries. Note, however, that fugitive emissions from green material processes or equipment can settle on elevated surfaces and eventually dry out (i.e., to less than 25 percent moisture), thus presenting fire and deflagration hazards. Furthermore, dry wood particles can mix with green wood particles resulting in a mixture of less than 25 percent moisture.

Percent Combustible Dust

Many dusts are a combination of dust materials with only some of the dust particles being combustible. The percentage of total combustible dust present will increase or decrease the hazards. Thus, the percent combustible dust in the total dust cloud or pile, affects the overall combustibility. This is an important reason why dust sample testing should be conducted.

Bulk Density

[6] See NFPA *Fire Protection Handbook* (2008).
[7] See NFPA 664-2017, paragraph 8.2.1.3.

Bulk density is a measure of the mass of the dust per unit of volume (lbs/ft^3 or g/m^3), and is used when needed to adjust the layer depth criterion for housekeeping in the NFPA standards. A dust's bulk density is dependent upon, among other things, the particle size, shape, and chemical content of the dust. When combined with the measured volume of dust in a space, this provides an estimate of the total amount of combustible dust in that space.

For example, light-fluffy dusts have a low bulk density. Therefore, the amount of light-fluffy combustible dust in a space is less than the amount of a heavy-thick dust with a higher bulk density. For instance, paper tissue dust has a bulk density of approximately 20 lbs/ft^3 while the bulk density of carbon black is approximately 70 lbs/ft^3. As a result, the layer depth of paper tissue dust will have to be 3-1/2 times the layer depth of carbon black to be equal in mass.

Minimum Explosive Concentration (MEC)

MEC is the minimum concentration of a combustible dust suspended in air (measured in mass per unit volume, oz/ft^3 or g/m^3) that will support a deflagration. MEC is analogous to the lower flammable limit (LFL) for flammable gases. MEC is dependent on many factors, including particulate size distribution, chemistry, moisture content, ignition energy, and shape. Necessary MEC data is often determined by testing or by reference to well-defined, authoritative publications.

Generally, **the lower the MEC the greater the hazard.** Typical MECs for combustible dusts listed in NFPA standards range from 20 g/m^3 to over 250 g/m^3.

Minimum Ignition Energy (MIE)

MIE is the lowest capacitive spark energy (electrical or electrostatic discharge) capable of igniting the most ignition-sensitive concentration of a combustible dust–air mixture. Some solids in dust-form can ignite with very little energy – as low as 1 to 3 millijoules (mJ) in some cases. Necessary MIE data is often obtained by testing or by reference to well-defined, authoritative publications.

Generally, the lower the MIE, the greater the potential for a dust cloud to ignite (see *Appendix E, Low-MIE Combustible Dusts*).

Layer Ignition Temperature (LIT)

Dust LIT is the minimum temperature required to cause self-sustained combustion (catching fire), independent of any other source of heat (such as a spark or flame) for settled dusts on hot objects such as heaters, motors, and dryers. Dust LIT is a function of time, temperature, and the thickness of the layer, and can be several hundred degrees below the dust cloud ignition temperature.

Minimum Autoignition Temperature (MAIT)

MAIT is the minimum temperature at which a dust cloud will auto-ignite when exposed to heated air.

Deflagration Index (K_{st})

K_{st} is a universal value used to characterize and compare the relative explosion severity of a dust cloud. It is a maximum, normalized rate of deflagration pressure rise and is obtained by multiplying the measured change in pressure over time (dP/dt) during the testing event by the testing vessel's volume to the 1/3 power. It is expressed in units of bar-m/s (pressure x velocity). The value is typically used in the design of process equipment and the associated deflagration-explosion, protective-preventive systems. However, K_{st} values generated by the SLTC are not suitable for design purposes. See *Appendix J, SLTC Laboratory Tests* for more information.

K_{st} values change with varying factors such as particle size (the smaller the particle, the higher the K_{st}), dust cloud concentration, and particle agglomeration.[8] Dust agglomeration may result in a decreased K_{st}. Testing should be done on the material being processed to accurately determine the K_{st}.

K_{st} values for combustible dusts typically have a value of between 0 and 300 bar-m/sec (based on published data).[9] SLTC testing to date has an average value for all materials tested of approximately 20 bar-m/sec. The highest Kst value tested by the SLTC was 247 bar-m/sec for a magnesium powder.

OSHA considers a K_{st} of 1.5 bar m/sec as the minimum threshold for an explosion.[10] This 1.5 threshold is noted on the SLTC lab sampling result reports and is included in case files. **However, any combustible dust with a K_{st} value greater than zero can be subject to dust deflagration.**

Maximum Pressure (P_{max})

P_{max} is the maximum measured pressure of the deflagration. P_{max} is also an indication of the explosion severity, along with the K_{st} value. P_{max} is normally expressed in units of bar-g. **<u>The higher the pressure (P_{max}) developed by a dust deflagration, the greater the hazard</u>.** Pressure resulting from a deflagration in a vessel will first result in deformation, followed by an explosion, if the P_{max} exceeds the strength of the vessel.

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[8] Agglomeration is usually the result of charged dust particles clumping together (i.e., smaller particles combining into larger particles) – a condition that changes the characteristics of the dust.

[9] K_{st} values vary widely depending on the characteristics of the dust as discussed in this section.

[10] See ASTM E1515, X1.3.1 "The minimum explosible concentration (MEC) is defined as the lowest concentration for which PR $\geq$ 2.0 and $(dP/dt)V^{1/3}$ [or Kst] $\geq$ 1.5 bar·m/s. The second part of the criterion is added to require that there be some real propagation of the dust flame and not just a pressure rise due to dust burning within the ignitor flame. This additional MEC criterion for the Bureau of Mines 20-L chamber partially corrects for the possible overdriving (see 5.4-5.6) of the 20-L system by strong ignitors."

Pressure Ratio (PR)

The PR of a dust cloud compares the maximum pressure occurring during the test deflagration to the initial atmospheric pressure measured prior to ignition. The maximum pressure is adjusted for the rise due to the igniter itself in air at atmospheric pressure. Traditional values for determining if a material is explosive (ignition criterion) use a minimal value of PR ≥ 2.0.[11]

Availability of Combustible Dust Characteristics for Specific Dusts

Many dusts have published combustibility characteristics that can be useful in providing an initial sense of potential dust hazards. However, this published data should be used only as an initial source and cannot be relied on to adequately or accurately represent actual dust characteristics or hazards at a given location. Resources for published combustible dust data include:

- NFPA 652-2019 (Tables A.5.2.2(a) – (k)
- NFPA 484-2019 (Tables A.1.1.3 (b) and A.5.4.1)
- NFPA 68-2018 (Tables F.1(a)-(e))
- Department of Transportation (DOT) Table 101 found at *49 CFR 172.101*
- Eckhoff, Rolf K., *Dust Explosions in the Process Industries*, 3rd Edition, 2003
- *Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA) GESTIS-Dust Database*[12]

Because no two dusts have exactly the same composition or characteristics, it is essential to **specifically** determine the characteristics of the **actual** combustible dusts at any given facility. To accomplish this, the dusts must be collected (sampled) and then tested at OSHA's Salt Lake Technical Center or at another licensed laboratory using recognized methods.

[*Note: Employers designing or selecting engineering controls for explosion protection purposes also need to rely on the explosion parameters of the dusts in their own processes (e.g., ASTM test methods or equivalent).*]

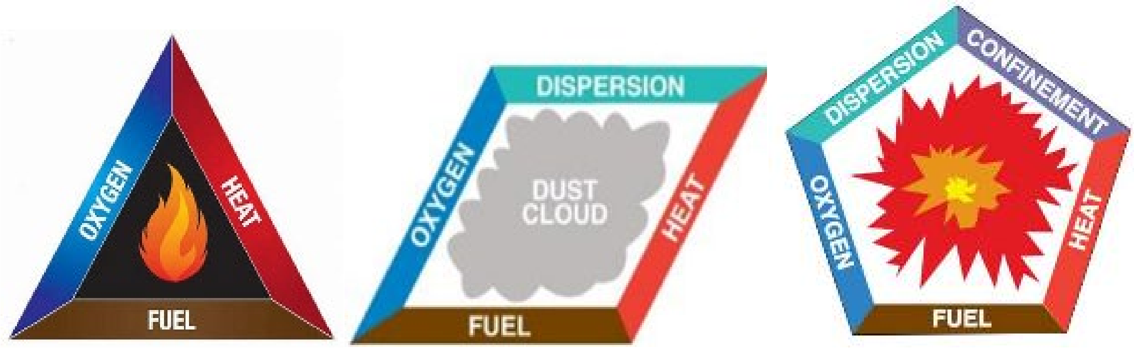
[11] See NFPA Fire Protection Handbook (2008).

[12] This is a database of combustion and explosion characteristics of dusts, which includes important combustion and explosion characteristics of more than 6000 dust samples from virtually all sectors of industry. These were used as a basis for the safe handling of combustible dusts and for the planning of preventive and protective measures against dust explosions in dust-generating and processing plants.

III. Combustible Dust Hazards

Combustible dust hazards exist in three forms: 1) fire, 2) flash fire/deflagration, and 3) explosion.[13] In many cases an initial combustible dust incident can result in a secondary deflagration and/or explosion incident. The hazards associated with these types of incidents are discussed below. [Note: in some cases combustible dusts may present other hazards (see *Appendix F, Combustible Dusts with Other Hazards*) and can produce hazardous products of combustion.]

Figure 1 illustrates the requirements for a dust fire, deflagration, or explosion to occur. A fire requires three elements: oxygen, fuel, and an ignition source. A deflagration requires four elements: the three elements for fire, plus dust dispersion at the right concentrations in air. A dust explosion requires five elements: the four elements for deflagration, plus confinement (enclosure, such as a silo, dust collector, bin, conveyor, bucket elevator, or room), known as the "Combustible Dust Pentagon."



Fire **Deflagration** **Explosion**

Figure 1: Requirements for a dust fire, deflagration, or explosion to occur. (Source: OSHA Publication 3644-04 2013, Firefighting Precautions at Facilities with Combustible Dust)

Fire Hazards

Fires involve potential exposure to heat or flames as well as potential exposure to hazardous byproducts of a fire including smoke and toxic gases. Combustible dusts in a settled pile burn if they come in contact with an ignition source of sufficient energy. This can occur, for example, when dust settles on a hot surface such as a motor or other piece of equipment that generates heat at or above its layer ignition temperature (LIT), as shown in Figure 2. [*Note: For a brief discussion of LIT, see Combustible Dust Characteristics*.]

[13] These definitions can be found at NFPA 652-2019. Combustion is a rapid chemical reaction of a substance with oxygen that burns or produces heat, and in many cases also results in damaging overpressure (an explosion due to deflagration or detonation). A flash fire is a fire that spreads by means of a flame front rapidly through a diffuse fuel (e.g., dust) without the production of damaging pressure. A deflagration is the propagation of a combustion zone at a velocity that is less than the speed of sound. An explosion is the bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration.

Figures 2: Dust accumulation on a fan blower.
(Source: OSHA HRT)

Combustible dusts inside or adjacent to processing equipment can also ignite if exposed to an ignition source of sufficient energy. Ignition sources in processing equipment include:

- impact sparks,
- mechanical heating (friction),
- material self-heating,
- open flames,
- hot work,
- incompatible chemical reactions,
- electrical equipment, and
- electrostatic discharge.

The potential for ignition depends on the specific dust characteristics, as well as the nature of the process and equipment involved.

Often overlooked causes of potential exposure to the hazardous byproducts of a combustible dust fire are the return of exhaust air from an outdoor dust collection system handling combustible dust back into an occupied building, or the direct emission of exhaust air from an indoor system without deflagration controls.

Deflagration and Flash Fire Hazards

Deflagrations and flash fires can occur both inside and outside process equipment (e.g., a room, building compartment, or outdoor location). Deflagrations are essentially expanding fire balls, and involve propagating flame fronts with rapid increases in pressure. Pressures generated in deflagrations are capable of deforming or rupturing vessels or building compartments.

Flash fires are localized ignitions of suspended clouds of combustible dusts and often occur outside of processing equipment, but may not result in significant pressure waves. However, flash fires usually do result in serious flame front exposures.

Flame fronts can contact or envelop workers wherever ignition of a combustible dust cloud occurs. Flame fronts from internal deflagrations can exit vessel openings and expose employees in the vicinity of the vessel. Internal deflagrations are caused by the suspension of combustible dust in the presence of a suitable ignition source. Flame fronts can also propagate through process connections in vessels contacting employees at upstream and downstream process locations.

Pressure increases can also rupture enclosures (e.g., vessels or building compartments) resulting in an explosion with potential struck-by hazards. The pressure can also travel upstream or downstream to connected equipment resulting in additional, and often times, more significant ruptures.

Explosion Hazards

Explosions involve an emitted flame front, pressure wave, and potential projectile fragmentation of the vessel or building compartment. Unburned dust clouds can also be dispersed when vessels explode, followed by a propagating pressure wave and flame front. These unburned dust clouds can then lead to secondary deflagrations or explosions in the associated equipment or building compartments.

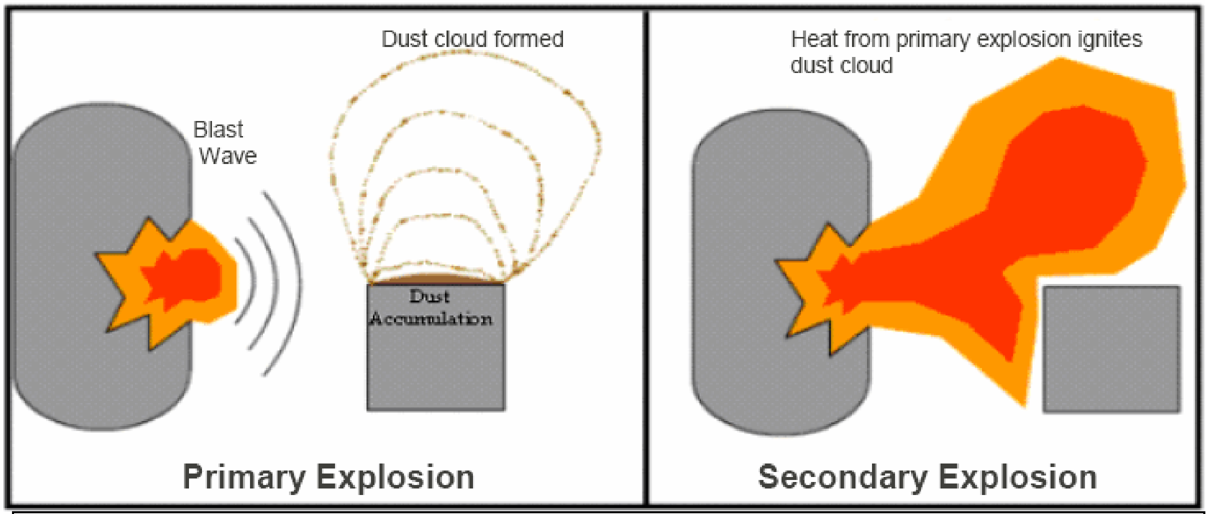
Deflagrations inside of dust processing, conveying, storage, and collection equipment can lead to explosions. Equipment deemed to have an explosion hazard should be designed and equipped with a means of explosion prevention/protection as outlined in NFPA 68 and NFPA 69, and referenced in the commodity-specific NFPA standard applicable to the process.

Explosions can also cause structural damage or collapse of buildings and structures. Therefore, buildings and structures that are, or could be susceptible to combustible dust deflagration and/or explosion hazards should follow applicable design standards such as NFPA 101 and NFPA 5000.

Secondary Deflagration and Explosion Events

Primary deflagrations and/or explosions can lead to secondary deflagrations and/or explosions in equipment or building compartments. Secondary events can occur via the transmission of energy from one vessel or building compartment to another through common connections (e.g., conveyors, piping, ducts, or ventilation).

Secondary events can also occur when significant accumulations of combustible dust (often overhead accumulations) are disturbed, become suspended/airborne, and are ignited (Figure 3). This fugitive dust, if ignited, causes additional deflagrations or explosions, which can be more severe than the original event, due to increased concentrations and quantities of dispersed combustible dust.



Figures 3: A primary explosion resulting in dust dispersion followed by a secondary incident. (Source: OSHA SHIB, Combustible Dusts in Industry: Preventing and Mitigating the Effects of Fire and Explosions)

IV. Common Signs that a Combustible Dust Hazard Is Present

During an inspection, CSHOs should be aware of common signs that a combustible dust hazard is present. In some cases, CSHOs conducting non-dust related inspections may need to expand the scope of an existing inspection or make a referral to address potential combustible dust hazards. These decisions should be made soon after a potential combustible dust hazard has been identified. Pursuit of the combustible dust inspection should be done in accordance with the applicable sections of the *Field Operations Manual (FOM)* and the *NEP*.

Potential indications that a combustible dust hazard is present include:

- Significant visual accumulations of known combustible dusts found on elevated surfaces (due to poor housekeeping practices).
- Implementation of unsafe housekeeping practices, such as the dispersion of known combustible dust clouds through the use of compressed air or other aggressive cleaning methods which may result in dust cloud formations.
- Indoor dust collection systems (such as media dust collectors or cyclones) handling dust known to be combustible and without any recognized means of explosion protection (such as deflagration venting to a safe outdoor location, deflagration venting through a listed dust retention and flame arresting device, or deflagration detection and chemical suppression).
- Outdoor dust collection systems handling dust known to be combustible and without any recognized means of explosion protection, and which may result in exposure to employees working outdoors, taking breaks outdoors, or in the path of an exit door/route.
- Dust collection systems handling dust known to be combustible and without any recognized means of deflagration propagation protection (isolation) to protect upstream work areas or equipment and other vessel openings, such as any material hopper discharge openings or exhaust air ducting (if exhausting indoors).
- Dust collection systems handling dust known to be combustible and which are noted to be either directly exhausting air indoors (indoor collector) or returning exhausted air back indoors (outdoor collector).
- Other equipment (e.g., bucket elevators, size reduction equipment, ovens, dryers, or storage vessels) processing, transporting, storing, or handling dust known to be combustible and which are installed, equipped, maintained, or operated in a manner contrary to manufacturer and/or industry standards.
- Evidence of improper operation or maintenance of dust generating equipment which could result in deflagration or explosion damage to the equipment and/or area.
- Evidence of combustible dust related fire, deflagration, or explosion damage within the facility, or on or within process, transport, storage, or collection equipment.
- Visible dust cloud, or clouds, of dust known to be combustible (such as through leaks in equipment, or transfer points).

- Visible fire damage evident on equipment or building walls.
- Historical information such as incident reports, or frequent or recent fire department responses, that address combustible dust fire, deflagration, or explosion events for which no corrective measures have been put in place.
- Any other information the CSHO is able to document which indicates the likely existence of a combustible dust fire, deflagration, or explosion hazard that is not being adequately controlled by the employer.

Conclusive proof that a dust is combustible requires testing at OSHA's Salt Lake Technical Center Lab or another licensed laboratory. Testing could occur well after an inspection is opened. As a result, in many cases the decision to proceed with an inspection may have to be based on limited initial information. An area office's (AO's) decision to conduct a combustible dust inspection should be made by evaluating the above indicators, while also considering:

- The number of potential ignition sources around visible dusts and dust accumulations.
- Published K_{st} values and other published combustible dust characteristics of known chemicals in the applicable category of dusts at the site.
- Experience within OSHA with similar or relatively similar materials and/or industries. This may include consultation with regional office (RO) and national office (NO) personnel, including personnel in the SLTC Lab and OSHA Health Response Team (HRT) as needed. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]
- Professional judgment as to the potential hazards present. This should include a review of historical data regarding past fires, deflagrations, and/or explosions at combustible dust locations in the facility.

V. Scope and Applicability of OSHA Standards Regarding Combustible Dusts

The following OSHA standards contain requirements applicable to combustible dusts. (Refer to the *NEP* for more discussion on these standards.)

Housekeeping and Related Standards

- 29 CFR 1910.22, *Walking-Working Surfaces General Requirements*, applies to housekeeping on walking-working surfaces in many areas to the extent described in the NEP, except in grain handling facilities (see 29 CFR 1910.272), at explosive and blasting agent operations (see 29 CFR 1910.109), at coal-fired electrical power generating stations (see 29 CFR 1910.269(v)(11)), and in storage areas (see 29 CFR 1910.176).

- 29 CFR 1910.176, *Handling Materials – General*, paragraph (c) applies to housekeeping in storage areas.

- 29 CFR 1910.272, *Grain Handling Facilities*, applies when grain-handling facilities are located at a site. This standard should be used for inspecting grain-handling facilities. However, combustible dust from grain not in a grain handling facility is not covered by 29 CFR 1910.272 (see *Housekeeping Considerations*). *[Note: The Inspection of Grain Handling Facilities Directive (CPL 02-01-004), provides guidance which can also be used when performing combustible dust inspections for grain handling facilities.]*

Equipment Standards Applicable to Combustible Dust

- 29 CFR 1910.94, *Ventilation*, applies to combustible dust hazards from organic and inorganic abrasive blasting operations. See paragraphs (a)(2)(iii) and (a)(4)(i).

- 29 CFR 1910.107, *Spray Finishing Using Flammable and Combustible Materials*, applies when combustible particulates are used or generated in spray finishing operations. As well, subparagraphs 1910.107(l)(4)(i) and (ii) include housekeeping for powder coating operations.

- 29 CFR 1910.109, *Explosives and Blasting Agents*, applies when combustible dusts are explosives or blasting agents as defined in this standard, and is the vertical standard to be used for such inspections. **Important: Do not follow this OTM chapter or the NEP for explosives and blasting agents. Do not collect samples of explosives or blasting agents**.

- 29 CFR 1910.261, *Pulp, Paper, and Paperboard Mills*, applies to dust control for rag and old paper preparation, see (f)(5). This standard also has requirements for sulfur dust explosion hazards, see (g)(1)(i), (g)(1)(iii), and (a)(3)(viii).

- 29 CFR 1910.263, *Bakery Equipment*. See paragraph (k)(2) for sugar and spice pulverizer requirements. See paragraphs (d)(3)(v), (d)(6)(ii), (d)(7)(iii), (d)(8)(i) for fugitive dust emission prevention requirements for flour handling equipment.

- 29 CFR 1910.265, *Sawmills*. See paragraphs (c)(20)(ii) through (vi) on collecting systems, exhaust and conveyor systems, and dust systems.

- 29 CFR 1910.269, *Electric Power Generation, Transmission, and Distribution*, applies to combustible dust inspections at coal-fired electric power generating stations. This standard, see subparagraph 1910.269(v)(11)(xii), should be used for *Electrical (Hazard) Class II Considerations* at coal-fired electric power generating stations.

Electrical (Hazard) Class II Standards

- 29 CFR 1910.307, *Hazardous (Classified) Locations*, covers the requirements for electrical equipment and wiring (consistent with the applicable area classification), which depends on the properties of the combustible dusts, and the likelihood that a flammable or combustible concentration or quantity is present.

  [*Note: Definitions applicable to 29 CFR 1910.307 are found at 29 CFR 1910.399.*]

Other OSHA Standards Applicable to Combustible Dust Inspections

- 29 CFR 1910.132, *Personal Protective Equipment General Requirements*, applies to personal protective equipment (PPE) for dust hazards.

- 29 CFR 1910.178, *Powered Industrial Trucks*, applies to the classification and use of powered industrial trucks in most combustible dust areas.

- 29 CFR 1910, Subpart Q, *Welding, Cutting and Brazing*, applies to these activities when combustible dust hazards are present. [See 29 CFR 1910.252, 253, and 254, specifically.]

- 29 CFR 1910.1200, *Hazard Communication*. Combustible dust is included in the scope of this standard, and is included in the definition of a hazardous chemical.

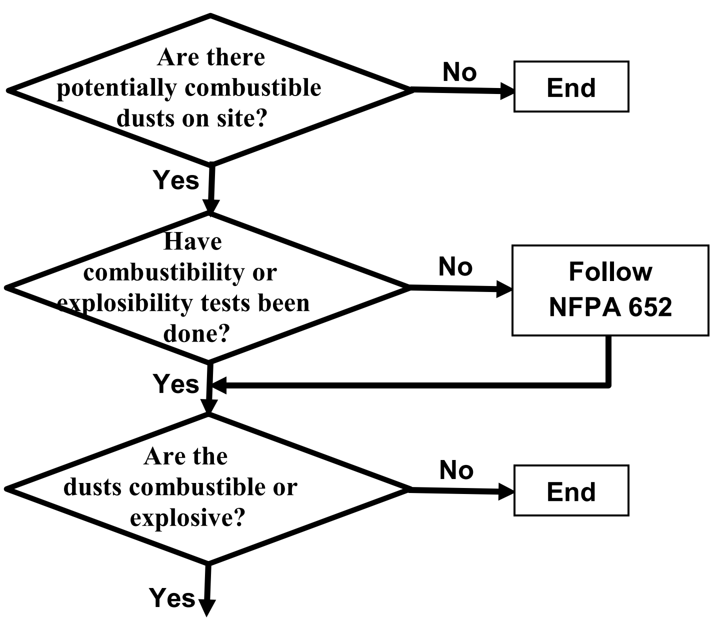
VI. Scope and Applicability of Notable Industry Combustible Dust Standards and Guidance

Notable industry standards include National Fire Protection Association (NFPA), Center for Chemical Process Safety (CCPS), and Factory Mutual (FM Global) standards. This is not an all-inclusive list, but includes many of the most widely used industry standards for combustible dusts.

Industry standards not incorporated by reference in OSHA standards, which represent the opinions of experts who are familiar with combustible dust hazards, are useful in providing evidence of industry recognition of a hazard and describe potential abatement measures available to address the hazard. Industry standards are also useful to employers in their efforts to keep their workplaces safe. However, these industry standards are not binding requirements unless they have been incorporated by reference in OSHA standards. [*Note: the only version of a standard incorporated by reference is the one for the year which is noted in the OSHA standard.*]

NFPA Standards

NFPA standards for combustible dusts have established processes for employers to follow to ensure that equipment, systems, process buildings, and other structures containing combustible dusts are designed, installed, operated, and maintained in a manner that protects workers. This process is outlined in NFPA 652-2019, *Standard on the Fundamentals of Combustible Dust,* and in the *NFPA Commodity-Specific Standards* applicable to the dust(s) at the facility. The following flow chart outlines the general NFPA process (Figure 4). CSHOs may use this flow chart as a guide to applicable NFPA standards when performing combustible dust inspections.



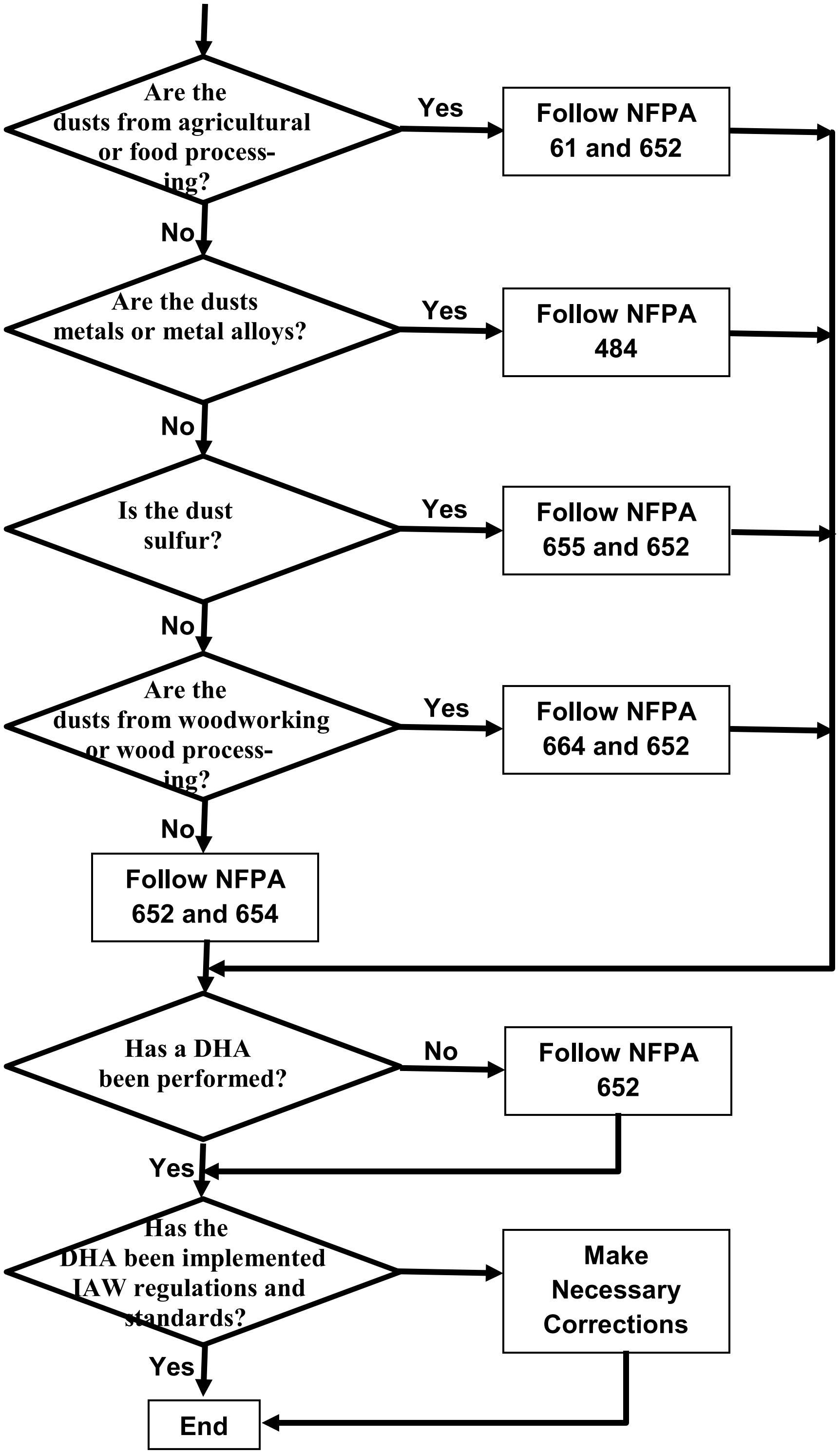


Figure 4: OSHA flowchart of application of NFPA commodity-specific standards.
DHA=Dust Hazard Analysis.
IAW=In accordance with. (Source: OSHA HRT)

NFPA Fundamental Industry Standard[14]

NFPA 652, *Standard on the Fundamentals of Combustible Dust*

CSHOs should review NFPA 652 before looking into other combustible dust standards and recommended practices.

This standard provides the basic principles for identifying and managing fire and explosion hazards of combustible dusts and particulate solids. It also has provisions to manage fire, flash fire, and explosion hazards caused by combustible dusts. It further directs the user to other industry- and commodity-specific NFPA standards with relevant provisions.

NFPA 652 applies to facilities and operations that manufacture, process, blend, convey, repackage, generate, or handle combustible dusts or combustible particulate solids.

NFPA 652 **does not apply to**:

- Storage or use of consumer quantities of combustible dusts on the premises of residential or office occupancies.
- Storage or use of commercially packaged combustible dusts at retail facilities.
- Combustible dusts displayed in original packaging in mercantile occupancies and intended for personal or household use or as building materials.
- Warehousing of sealed containers of combustible dusts when not associated with an operation that handles or generates combustible dust.
- Combustible dusts stored or used in farm buildings or similar occupancies for on-premises agricultural purposes.[15]

The annexes in this standard include tables with specific hazardous combustible dust characteristics, as well as an example dust hazard analysis (DHA), and other useful information.

NFPA Industry Commodity-Specific (Occupancy) Standards

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*

NFPA 33 applies to the spray application of flammable or combustible materials, and to the application of flammable or combustible materials, either continuously or intermittently by any of the following methods:

- Fluidized bed application methods.
- Electrostatic fluidized bed application methods.
- Other means of fluidized application.[16]

[14] For the latest NFPA standards CSHOs should go to the *IHS Website*. Some of these, including earlier versions, are also available on OSHA's global network.
[15] See NFPA 652-2019, Section 1.3, Applicability.
[16] See NFPA 33-2018, Section 1.1, Scope.

NFPA 33 **does not apply to** spray application processes or operations that are conducted outdoors.

[Note: NFPA 33 should not be used to address combustible dust hazards at powder coating operations. 29 CFR 1910.107 is the vertical standard applicable at powder coating operations.]

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*[17]

NFPA 61 addresses protecting life and property from fires, flash fires, and explosions posed by agricultural and food processing combustible dust.[18]

NFPA 61 applies to:

- All facilities that receive, handle, process, dry, blend, use, mill, package, store, or ship dry agricultural bulk materials, their by-products, or dusts that include grains, oilseeds, agricultural seeds, legumes, sugar, flour, spices, feeds, dry dairy/food powders, and other related materials.
- All facilities designed for manufacturing and handling starch, including drying, grinding, conveying, processing, packaging, and storing dry or modified starch, and dry products and dusts generated from these processes.
- Seed preparation and meal-handling systems of oilseed processing plants.

A table in the annex of this standard provides agricultural dust characteristics.

NFPA 484, *Standard for Combustible Metals*

NFPA 484 addresses the production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are capable of deflagrating or exploding. It further has provisions for operations where metal or metal alloys are subject to processing or finishing operations that produce combustible powder or dust. Operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible powder or dust include, but are not limited to, machining, sawing, grinding, buffing, and polishing.[19] This standard also applies to laboratories, recycling, and waste operations.

NFPA 484 **does not apply to**:

- The transportation of metals in any form on public highways and waterways or by air or rail.
- The primary production of aluminum, magnesium, and lithium.[20]

The annexes to this standard include tables of metal explosibility properties.

[17] Note that 29 CFR 1910.272 is a vertical OSHA standard that applies to grain handling facilities and addresses fire and explosion hazards. See 29 CFR 1910.272(a) and (b).
[18] See NFPA 61-2017, Section 1.2, Purpose.
[19] See NFPA 484-2019, Section 1.1, Scope, and Section 1.2, Purpose.
[20] See NFPA 484-2019, Section 1.3, Applicability.

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

NFPA 654 addresses all phases of the manufacturing, processing, blending, conveying, repackaging, and handling of combustible particulate solids or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire, a flash fire, or an explosion hazard.[21]

The purpose of this standard is to prevent explosion hazards involving combustible particulate solids, including hybrid mixtures, and to minimize the resulting damage from a fire or an explosion.[22]

NFPA 654 **does not apply to**:

- Storage or use of consumer quantities of combustible particulate solids on the premises of residential or office occupancies.
- Storage or use of commercially packaged combustible particulate solids at retail facilities.
- Combustible particulate solids displayed in original packaging in mercantile occupancies and intended for personal or household use, or as building materials.
- Warehousing of sealed containers of combustible particulate solids when not associated with an operation that handles or generates combustible dust.
- Combustible particulate solids stored or used in farm buildings or similar occupancies for on-premises agricultural purposes.[23]

NFPA 654 also does not apply to materials covered by other commodity-specific NFPA dust standards, unless otherwise noted in those standards.

The annexes in this standard include details on how to determine the hazards of the combustible dust in any given location. The annexes also provide examples of how to perform layer depth analyses to determine deflagration and explosion hazards. The annexes further include examples of explosion prevention and protection methods, including spark detection, extinguishing systems, and deflagration propagation isolation methods.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*

NFPA 655 may be referenced in conjunction with NFPA 654, and has provisions to eliminate or reduce the hazards of explosion and fire in the processing and handling of sulfur.[24]

NFPA 655 **does not apply to**:

[21] See NFPA 654-2017, Section 1.1, Scope.
[22] See NFPA 654-2017, Section 1.2, Purpose.
[23] See NFPA 654-2017, Section 1.2, Applicability.
[24] See NFPA 655-2017, Section 1.1, Scope, and Section 1.2, Purpose.

- The mining of sulfur.
- The recovery of sulfur from process streams, such as sour gas processing or oil refinery operations, and all its encompassed processes and operations, which include block melting, degassing, and forming.
- The transportation of sulfur.

The annexes in this standard include details on how to determine the hazards of sulfur dust in given locations. The annexes also include examples of how to perform layer depth analyses to determine deflagration and explosion hazards. The annexes further include examples of explosion prevention and protection methods, such as deflagration-propagation-isolation methods and guidelines for housekeeping.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

NFPA 664 has provisions on fire and explosion prevention and protection of industrial, commercial, or institutional facilities that process wood or manufacture wood products, use wood or other cellulosic fiber as a substitute for or additive to wood fiber, or that process wood, creating wood chips, particles, or dust. Woodworking and wood processing facilities include wood flour plants, industrial woodworking plants, furniture plants, plywood plants, composite board plants, lumber mills, production-type woodworking shops, and carpentry shops.[25]

The provisions contained in Chapters 4 through 9 **do not apply to** woodworking operations that occupy areas smaller than 5000 ft^2 (465 m^2), and where dust-producing equipment requires an aggregate dust collection flow rate less than 1500 ft^3/min (1500 CFM, 2549 m^3/hr).[26]

The annexes in this standard include details on how to determine the hazards of the wood dust in any given location. The annexes also include examples of how to perform layer depth analyses to determine deflagration and explosion hazards. The annexes further include examples of performance-based fire protection analyses for the design of buildings, separation distances, spark detection and extinguishing systems, and explosion protection methods (such as deflagration propagation isolation methods).

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*

NFPA 850 provides recommendations for fire prevention and fire protection for electric generating plants and high voltage direct current converter stations, **except for**:
- Nuclear power plants, which are addressed in NFPA 805; and
- Fuel cells, which are addressed in NFPA 853.[27]

[25] See NFPA 664-2017, Section 1.1, Scope, and Section 1.2, Purpose.
[26] See NFPA 664-2017, Section 1.1, Scope.
[27] See NFPA 850-2015, Section 1.1, Scope.

Section 7.4 includes details for handling and controlling coal dusts and other combustible dusts at electric generating plants.

NFPA Industry Prevention and Protection Standards

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 68 applies to the design, location, installation, maintenance, and use of devices and systems that vent the combustion gases and pressures resulting from a deflagration. In doing so, the structural and mechanical damage, and worker exposure, are reduced. NFPA 68 describes both how and when venting should be applied.[28]

NFPA 68 **does not apply to**:

- Detonations, bulk auto-ignition of gases, or unconfined deflagrations, such as open-air or vapor cloud explosions.
- Devices designed to protect storage vessels against excess internal pressure due to external fire exposure or to exposure to other heat sources.
- Emergency vents for pressure generated during runaway exothermic reactions, self-decomposition reactions, internal vapor generation resulting from electrical faults, or pressure generation mechanisms other than deflagration.
- Venting of deflagrations in oxygen-enriched atmospheres, or other oxidants, unless supported by specific test data.[29]

NFPA 68 can be used in conjunction with NFPA 69, which covers explosion prevention and control measures. The choice of the most effective and reliable means for explosion control should be based on evaluating the specific conditions of the hazard and the objectives of protection. Venting of deflagrations only reduces the damage that results from combustion.[30]

NFPA 69, *Standard on Explosion Prevention Systems*

NFPA 69 applies to the design, installation, operation, maintenance, and testing of systems for the prevention and control (protection) of explosions by the following methods:

- Control of oxidant concentration.
- Control of combustible concentration.
- Pre-deflagration detection and control of ignition sources.

[28] The following conditions may necessitate deflagration venting (see NFPA 652-2019):
"(1) If a building or building compartment contains a dust explosion hazard outside of equipment. Such, areas shall be provided with deflagration venting to a safe area in accordance with NFPA 68.
(2) Where an explosion hazard exists within any operating equipment greater than 8 ft^3 (0.2 m^3) of containing volume, the equipment shall be protected from the effects of a deflagration by deflagration venting, deflagration suppression, or deflagration pressure containment."
[29] See NFPA 68-2018, Section 1.3, Applicability.
[30] See NFPA 68-2018, Sections 1.1, Scope, 1.2, Purpose, and 1.3, Application.

- Explosion suppression.
- Active isolation.
- Passive isolation.
- Deflagration pressure containment.
- Passive explosion suppression.[31]

NFPA 69 covers provisions for installing systems for the prevention and control of explosions in enclosures that contain flammable concentrations of gases, vapors, mists, dusts, or hybrid mixtures. It provides basic information for design engineers, operating personnel, and authorities having jurisdiction. Key elements of this standard include the following:

(1) Design system verification through testing.
(2) Design documentation.
(3) System acceptance.
(4) Management of change.
(5) Regular testing and maintenance.[32]

NFPA 69 **does not apply to the following conditions**:

- Devices or systems designed to protect against detonations.
- Design, construction, and installation of deflagration vents as covered by NFPA 68.
- Protection against overpressure due to phenomena other than internal deflagrations.
- Chemical reactions other than combustion processes.
- Unconfined deflagrations, such as open-air or vapor-cloud explosions.
- Rock dusting of coal mines, as covered by 30 CFR 75 – Subpart E.
- General use of inert gas for fire extinguishment.
- Preparation of tanks, piping, or other enclosures for hot work, such as cutting and welding, as covered by 29 CFR 1910 – Subpart Q, NFPA 51B, and other standards for hot work.
- Ovens or furnaces handling flammable or combustible atmospheres, as covered by NFPA 86.
- Marine vapor control systems regulated by 33 CFR 154.
- Marine vessel tanks regulated by 46 CFR 30, 32, 35, and 39.[33]

NFPA 77, *Recommended Practice on Static Electricity*

NFPA 77 applies to the identification, assessment, and control of static electricity for preventing fires and explosions. It provides guidance on controlling the hazards associated with the generation, accumulation, and discharge of static electricity by providing:

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[31] See NFPA 69-2019, Section 1.1, Scope.
[32] See NFPA 69-2019, Section 1.2, Purpose.
[33] See NFPA 69-2019, Section 1.3, Applicability.

- Basic understanding of the nature of static electricity.
- Guidelines for identifying and assessing the hazards of static electricity.
- Techniques for controlling the hazards of static electricity.
- Guidelines for controlling static electricity in selected industrial applications.[34]

This recommended practice applies to static electricity as it relates to gases, liquids, and solids. Annex G contains helpful information for grounding and bonding of typical equipment arrangements found in industry.

NFPA 77 **does not apply** to control of static electricity and its hazards as they might affect electronic components or circuits, which have their own provisions.

NFPA 85, *Boiler and Combustion Systems Hazards Code*

NFPA 85 describes industry-recognized hazards in pulverized coal systems and related engineering controls. This standard applies to the design, installation, operation, maintenance, and training for boiler and combustion systems. Combustible dust is generated as a result of coal unloading, storing, transporting, pulverizing, feeding, and furnace combustion.

Housekeeping is also briefly addressed in the *Maintenance, Inspection, Training, and Safety* section. The provisions for pulverized fuel systems and equipment, including dust collectors are addressed in Chapter 9.

[Note: NFPA 85 should not be used to address combustible dust hazards at coal-fired power plants. See 29 CFR 1910.269 as the vertical standard applicable at coal-fired power plants.]

NFPA 86, Standard for Ovens and Furnaces

NFPA 86 applies to Class A, Class B, Class C, and Class D ovens, dryers, and furnaces; thermal oxidizers; and any other heater system used for processing of materials. Provisions address explosion hazards related to furnaces.[35]

Section 5.3 has provisions on explosion relief (with some exceptions) for fuel-fired furnaces and furnaces that contain combustible dusts. See also Annex A paragraph A1.1.7(1) regarding combustible dust hazards and controls for ovens and furnaces.

NFPA 86 **does not apply to**:
- Coal or other solid fuel–firing systems.
- Listed equipment with a heating system(s) that supplies a total input not exceeding 150,000 Btu/hr (44 kW).

[34] See NFPA 77-2019, Sections 1.1, Scope, and 1.2, Purpose.
[35] See NFPA 86-2019, Section 1.1, Scope.

- Fired heaters in petroleum refineries and petrochemical facilities that are designed and installed in accordance with API STD 560, Fired Heaters for General Refinery Services, API RP 556, Instrumentation and Control Systems for Fired Heaters and Steam Generators, and API RP 2001, Fire Protection in Refineries.
- Fluid heaters as defined in NFPA 87.
- Electric arc furnaces and submerged arc furnaces.

NFPA Structural Standards

Several NFPA standards may be consulted to address structural hazards from fires and explosions, and have provisions for structures of varying types. However, in most cases where structural hazards are an issue, CSHOs should first refer to NFPA 101.

NFPA 101, *Life Safety Code*

NFPA 101 addresses construction, protection, and occupancy features to minimize danger to life from the effects of fire, including smoke, heat, and toxic gases created during a fire. This code establishes facility design criteria for egress to allow prompt escape of occupants from buildings or, where pre-designated through employer training, into safe areas within buildings. NFPA 101 also contains provisions for the design, operation, and maintenance of buildings and structures to ensure safe and adequate means of egress.[36]

NFPA 5000, *Building Construction and Safety Code*

NFPA 5000 addresses the prevention or reduction of worker injury from building or structural failure during combustible dust events by incorporating certain building design features. This code has provisions to safeguard life, health, property, and public welfare, and to minimize injuries by controlling the permitting, design, construction, quality of materials, use and occupancy, location, and maintenance of buildings and structures, and certain equipment.[37]

Other Related NFPA Industry Standards

NFPA 1, *Fire Code*

NFPA 1 covers aspects of fire protection and prevention used in other developed NFPA codes and standards. This code has provisions necessary to establish a reasonable level of property protection from fire, explosion, and other dangerous conditions. NFPA 1 applies to both new and existing conditions.[38]

[36] See NFPA 101-2018, Sections 1.1, Scope, and 1.2, Purpose. *[Informational Note: NFPA 101-2000 is incorporated by reference in 29 CFR 1910.35.]*
[37] See NFPA 5000-2018, Sections 1.1, Scope, and 1.2, Purpose.
[38] See NFPA 1-2018, Sections 1.1, Scope, and 1.2, Purpose.

Many States have adopted NFPA 1 or the International Fire Code (IFC). Both codes incorporate numerous NFPA combustible dust standards by reference.

Chapter 40 of NFPA 1 applies specifically to dust explosion and fire prevention. Other chapters apply to various aspects of combustible dusts and may be useful during inspections.

[Note: NFPA 1 should not be used to address combustible dust housekeeping hazards and for other hazards where vertical standards apply. See Scope and Applicability of OSHA Standards Regarding Combustible Dusts for applicable vertical standards.

NFPA *Guide to Combustible Dusts*

This NFPA publication is useful for employers who are seeking to understand more about the following subjects:

- Explosion fundamentals
- Process hazard analysis
- Fire hazard controls
- Explosion hazard controls
- Dust collection – air/material separators
- Pneumatic conveying
- Bucket elevators
- Safety management systems[39]

This guide is also useful for CSHOs who are seeking to understand more about the prevention and control of combustible dust hazards based on actual incidents.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*

NFPA 51B describes limitations on hot work in areas with potential fire or flash fire hazards associated with the presence of one or more combustible particulate solids (dusts).[40] Annex A includes a sample hot work permit and a decision tree, which include combustible dusts. Annex B describes significant hot work incidents, many of which involved combustible dusts.

NFPA 70, *National Electric Code*

The 2002 edition of NFPA 70, the National Electrical Code, was one of the sources for the OSHA general industry electrical standards addressed in 29 CFR part 1910—Subpart S. In determining electrical area classifications and equipment requirements, the OSHA standard must be followed.

[39] See NFPA Guide to Combustible Dusts, 2012.
[40] SEE NFPA 51B, paragraphs 5.4(3) and (5).

<u>NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids*</u>

NFPA 91 addresses the design, construction, installation, operation, testing, and maintenance of exhaust systems for air conveying of vapors, gases, mists, and particulate solids as they relate to fire and/or explosion prevention, except as modified or expanded upon by other applicable NFPA standards.[41]

Table A.4.2.5 in the annex of NFPA 91 provides valuable information about the range of minimum duct design velocities for various dust types.

NFPA 91 **<u>does not cover</u> exhaust systems for combustible particulate solids addressed in the following OSHA and NFPA standards**:

- 29 CFR 1910.272 (Grain Handling Facilities),
- NFPA 61 (Agricultural and Food Processing),
- NFPA 484 (Combustible Metals),
- NFPA 654 (Combustible Particulate Solids),
- NFPA 655 (Sulfur), and
- NFPA 664 (Wood Processing and Woodworking).[42]

However, the standards listed above may incorporate many of the provisions of NFPA 91.

<u>NFPA 400, *Hazardous Materials Code*</u>

NFPA 400 defines combustible dusts as "high-hazard level 2" hazardous materials. It provides fundamental safeguards for storage, use, and handling of these hazardous materials **except for combustible metals, which are addressed in NFPA 484**.[43]

NFPA 400 is limited to combustible dusts that <u>do not</u> fit into combustible dust categories listed in:

- NFPA 61 (Agricultural and Food Processing),
- NFPA 484 (Combustible Metals),
- NFPA 654 (Combustible Particulate Solids),
- NFPA 655 (Sulfur), and
- NFPA 664 (Wood Processing and Woodworking).

<u>NFPA 496, *Standard for Purging and Pressurizing Enclosures for Electrical Equipment*</u>

[41] See NFPA 91-2015, Section 1.1, Scope.
[42] See NFPA 91-2015, Sections 1.1, Scope, and 1.3, Applicability.
[43] See NFPA 400-2019, Section 1.1, Scope.

NFPA 496 applies to electrical equipment, control rooms, and analyzer rooms in hazardous (classified) locations.

NFPA 496 provides information on the methods for purging and pressurizing enclosures to prevent ignition of a flammable atmosphere within an enclosure. Such an atmosphere may be introduced into the enclosure by a surrounding external atmosphere or by an internal source. With the proper use of purging and pressurizing techniques, electrical equipment that is not otherwise acceptable for a flammable atmosphere may be utilized in accordance with Article 500 or Article 505 of NFPA 70.[44]

NFPA 496 **does not apply to electrical equipment located in**:

- Areas classified as Class I, Zone 0.
- Areas classified as Class III.
- Areas where flammable liquids may be splashed or spilled on the electrical equipment.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

NFPA 499 provides information on how to classify locations to meet the criteria established in NFPA 70, *National Electric Code.* It provides the user with a basic understanding of the parameters that determine the degree and extent of the hazardous (classified) location. It also provides the user with examples of the applications of these parameters.[45]

NFPA 499 also includes a table (Table 5.2.3) of selected combustible dusts with their minimum ignition temperatures (MITs), as well as details on how to determine the hazards of the combustible dusts in given locations. NFPA 499 also includes some examples of how to perform layer depth analyses to determine deflagration and explosion hazards (see Annex A). Annex A also includes examples of housekeeping programs that employers could implement.

Center for Chemical Process Safety (CCPS) Books[46]

The American Institute of Chemical Engineers (AIChE), Center for Chemical Process Safety (CCPS) publishes the following books associated with combustible dusts:

- Guidelines for Safe Handling of Powders and Bulk Solids, November 2004.
- Guidelines for Combustible Dust Hazard Analysis, May 2017.
- Understanding Explosions, July 2003.

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[44] See NFPA 496-2017, Section 1.2, Purpose.
[45] See NFPA 499-2017, Section 1.1, Scope.
[46] CCPS books are available in many OSHA offices and from HRT if needed. Latest editions are available for purchase at the *AIChE/CCPS Website*.

- Deflagration and Detonation Flame Arresters, May 2002.

These books can be used to identify known hazards in the chemical industries or can be used in conjunction with other standards to substantiate review of combustible dust hazards.

Factory Mutual Data Sheets

The following is a list of Factory Mutual (FM Global) Property Loss Prevention Data Sheets that can be useful to CSHOs when performing combustible dust inspections.

- FM Global 5-1, Electrical Equipment in Hazardous (Classified) Locations
- FM Global 5-8, Static Electricity
- FM Global 6-2, Pulverized Coal-Fired Boilers
- FM Global 6-9, Industrial Ovens and Dryers
- FM Global 6-13, Waste Fuel-Fired Boilers
- FM Global 6-17, Rotary Kilns and Dryers
- FM Global 7-0, Causes and Effects of Fires and Explosions
- FM Global 7-10, Wood Processing and Woodworking Facilities
- FM Global 7-11, Conveyors
- FM Global 7-17, Explosion Protection Systems
- FM Global 7-27, Spray Application of Ignitable and Combustible Materials
- FM Global 7-36, Pharmaceutical Operations
- FM Global 7-57, Pulp and Paper Mills
- FM Global 7-73, Dust Collectors and Collection Systems
- FM Global 7-75, Grain Storage and Milling
- FM Global 7-76, Prevention and Mitigation of Combustible Dust Explosion and Fire
- FM Global 7-85, Metals and Alloys
- FM Global 8-10, Coal and Charcoal Storage
- FM Global 8-27, Pulpwood and Outdoor Log Storage

These data sheets can be used alone or in conjunction with other standards to substantiate the review of combustible dust hazards.

FM Global Datasheets can be downloaded without cost. [*Note: Additional FM Global data sheets may be valuable for other specific hazards, processes, or industries*.]

VII. On-Site Inspection Initial Considerations

Combustible dust inspections may involve one or more of the following fundamental components:

- An inspection of general areas of the facility for combustible dust hazards caused by excessive accumulations of combustible dust(s) or excessive fuel loading in each area. Referred to in this chapter as *Housekeeping Considerations*.
- An inspection of dust-associated equipment in the facility that could contribute a fuel and/or an ignition source for a deflagration, explosion, or fire. Referred to in this chapter as *Combustible Dust Equipment Considerations*.
- An inspection of "hazardous (classified) locations" (e.g., Class II, Division 1 and 2 locations) requiring safe and/or approved electrical equipment in these locations to prevent the ignition of a suspended cloud of dust or settled dust layer from the electrical equipment. Referred to in this chapter as *Electrical (Hazard) Class II Considerations*.

Combustible dust characteristics, hazards, process sources, and associated safety requirements can vary widely. Therefore, **it is important to find out as much as possible about the dust(s), the facility processes and equipment, and the associated PPE requirements, at the start of the inspection to ensure your safety while on-site.**

Prior to traveling to the site, CSHOs should prepare a preliminary inspection plan. This plan can change as details from the inspection emerge and progress. *Appendix B, Combustible Dust Inspection Common Structure and Guidance*, can help CSHOs in developing and adapting an inspection plan. [*Note: An inspection plan does not have to be in the form of a written document.*]

It is important to ask appropriate questions and request appropriate up-to-date documents during the inspection. *Appendix C, Common Inspection Questions*, can be helpful to CSHOs throughout the inspection.

Since dust conditions can change dramatically over time, the success of the inspection will depend heavily on observations and documentation of conditions at the beginning of the inspection. It will take time to:

- document observations;
- take photos and measurements;
- request, collect and study provided documents;
- draw pictures and write notes;
- conduct interviews; and
- evaluate the evidence collected.

Plan enough time on site after the opening conference to appropriately document your initial inspection. Several visits may be required to collect all of the evidence needed for a complete inspection.

Combustible dust inspections in many cases can become complicated. When assistance is needed, involve others in your inspection as early as possible. The area, regional, and national offices may be able to provide the expertise needed to support these inspections. The HRT also has resources available, as needed.[47] [*Note: Use of HRT for site visits to perform sampling or other activities must be approved by the RO.*]

Remember to focus on the hazards of the combustible dust. Combustible dust deflagrations require four elements: a combustible dust (fuel); oxygen (air); an ignition source; and, dispersion of the dust cloud. A combustible dust explosion with blast overpressure[48] requires five elements, the four for deflagrations, plus confinement of the dust cloud. The process equipment, the room, or the building alone may provide sufficient confinement. Make sure to consider how all four or five elements are or could be met.

[47] The HRT is located at the Salt Lake Technical Center and is available to assist with inspections as requested by the regional office. See a list of HRT employees, specialties, and resources at: http://intranet.osha.gov/dts/LAP/dts/sltc.html

[48] Blast overpressure is the "bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration." Another type of overpressure (referred to as explosive overpressure) can occur when the dust is in a thick enough layer or dense enough layer, that an explosion occurs when the dust is dispersed in a cloud. See *NFPA Guide to Combustible Dusts* (2012).

VIII. Housekeeping Considerations

Fires, flash fires, deflagrations, and explosions often occur from excessive dust accumulation in areas external to equipment due to poor housekeeping. Beyond the routine clean-up of settled dust(s), one important and often overlooked factor contributing to situations with excessive dust accumulations outside of equipment and within a building compartment is poor process containment (e.g., fugitive dust emissions and leaks).

Preventing or minimizing the escape of dust into the work environment is a critical component to preventing hazardous accumulations of dust. Housekeeping considerations can be performed in conjunction with *Combustible Dust Equipment Considerations* and *Electrical (Hazard) Class II Considerations*. When performed together, CSHOs should review each of these sections before beginning, to ensure that all aspects of these inspections are adequately covered.

Recognition of Housekeeping Hazards

Small quantities of combustible dusts may not constitute a housekeeping hazard except when the dusts are addressed in *OSHA Standards Regarding Combustible Dusts*. NFPA standards provide guidance regarding what constitutes excessive dust loading for various combustible dusts not addressed in OSHA standards.

If a combustible dust housekeeping hazard is suspected, CSHOs should first review the *NEP*.

Asking questions and reviewing documents during the inspection also provide CSHOs with valuable information needed to recognize the hazards. *Appendix C, Common Inspection Questions*, can help CSHOs in this regard and can be used throughout the inspection. Safety data sheets (SDSs), an employer's explosibility and combustibility analysis results, and other data can also provide evidence of the possible hazards.

The criteria for a dust hazard is typically based on an evaluation of dust accumulations in areas of the facility. The combustible dust accumulation level that would support a fire and/or explosion, if there was an ignition source present, depends on numerous factors, including but not limited to:

- Layer depth of the dust in the area (LD). *Note: When the depth varies, several measurements should be taken and averaged.*
- Total floor area of the enclosed space or room (A_f).
- Dusted area in the enclosed space or room (A_d). This should include all surfaces with dust accumulations.
- Room volume (V).

- Bulk density (BD). *Bulk density published values can be used in most cases. However, in some cases it may be required to send a sample to the SLTC Lab for analysis.*[49]
- Other measurements as required based on the applicable industry standard(s).

For some dusts, accumulation limits are specified. For other dusts, accumulation limits can be calculated. The following standards set dust threshold accumulation limits:

- NFPA 61-2017—Agricultural and food processing facilities: Establishes an accumulation limit of 1/8 inch over 5% of the foot print area.
- NFPA 85-2019—Combustible coal dust: Accumulation limits are not specifically set but include housekeeping provisions to keep dust deposits "less than the minimum required to create an explosion hazard." These provisions direct the employer to NFPA 654 for the use of calculation methods described in NFPA 654. [*Note: The binding OSHA requirement on combustible coal dust in the operation and maintenance of electric power generation, control, transformation, transmission, and distribution lines and equipment is 29 CFR 1910.269(v)(11)(xii).*]
- NFPA 484-2019—Combustible metals: Typically, accumulations should minimally not be allowed to accumulate to a level that obscures the color of the surface beneath it, and could be stricter based on the material and the dust hazard analysis. Before conducting site visits, refer to the considerations specific to the particular metal or metal alloy.
- NFPA 654-2017—Particulate solid dusts: Provides calculation methods for determining the hazards of many particulate solid dust accumulations based on the factors listed earlier in this section.[50]
- NFPA 655-2017—Sulfur: Provides calculation methods for determining the hazards of sulfur accumulations.
- NFPA 664-2017—Wood: Provides information and calculation methods for characterizing wood dust accumulations. Establishes an accumulation limit of 1/8 inch over the foot print area for smaller areas and as an average of 1/8 inch of accumulation on upward facing surfaces for larger building compartments.
- OSHA's *Grain Handling Facilities* standard 29 CFR 1910.272 has requirements for limiting dust accumulations in grain handling facilities.
    - 29 CFR1910.272(j)(2)(ii): "The employer shall immediately remove any fugitive grain dust accumulations whenever they exceed 1/8 inch (0.32 cm) at priority housekeeping areas, pursuant to the housekeeping program, or shall demonstrate and assure, through the development and implementation of the housekeeping program, that equivalent protection is provided."

[49] See OSHA memorandum dated April 21, 2015, *Evaluating Hazardous Levels of Accumulation Depth for Combustible Dusts*. "CSHOs should send samples to SLTC for bulk density determination only if the material is light (such as paper dust or fabric fibers) and the levels of accumulations are greater than ¼ inch extending over 5% of the floor area of a room or a building, or 1000 ft^2, whichever is less."

[50] See also OSHA memorandum dated April 21, 2015, *Evaluating Hazardous Levels of Accumulation Depth for Combustible Dusts*.

- 29 CFR 1910.272(j)(1): “The employer shall develop and implement a written housekeeping program that establishes the frequency and method(s) determined best to reduce accumulations of fugitive grain dust on ledges, floors, equipment, and other exposed surfaces.”

[*Note: The summaries above are not all inclusive. Exceptions and additional criteria often apply. Therefore, CSHOs should review the applicable NFPA standard(s) to ensure that the criteria for the dust hazards are understood, rather than simply relying on the above summaries. If an OSHA standard specifically refers to or incorporates an older version of an industry standard, the older version applies*.]

If there is a question about the provisions or use of these standards, contact your supervisor. The SLTC laboratory, or the HRT, is also available to assist as needed.

Evaluation of Housekeeping Hazards

Dust may accumulate on almost any surface, including angled or vertical surfaces, depending on the particle size or charge. Accumulations may also occur on surfaces that are not visible without looking beyond the ground level. The exterior and immediate area surrounding process equipment that generates dust, collects dust, and/or transfers materials containing dust (e.g., crushers, grinders, mixers, dryers, ductwork, pipes, belt conveyors, bucket elevators, screw conveyors, or connectors) are also especially prone to dust accumulation.

Places where dust accumulations are most likely include:

- Floors, railings, structural surfaces, and processing equipment surfaces.
- Overhead structural supports and components, ductwork, pipes, trays, conduit, and pipe racks.
- Open control rooms, storage rooms, and other areas built inside or adjacent to larger production areas where dust has accumulated.
- Above ceilings (e.g., hidden surfaces behind false ceilings, ceiling tiles, or ceiling plenum areas), behind walls, behind wall coverings, and inside ventilation ducts. [*Note: This is particularly true in cases where suspended ceilings and visible structural members are observed in production areas with combustible dust.*]

Documentation of the condition is essential. CSHOs should ask for a copy of a site plan drawing and then observe processing areas for dust in the air and for dust deposits, particularly at high elevations and on or around potential ignition sources. Locations of dust accumulation can then be marked on the site plan drawing. Measurements, notes, sketches, drawings, and/or photographs should also be used to document findings.

In most cases, measurements should be taken in order to determine if the dust accumulations present hazards. Rulers, tape measures, machinist scales, and mechanic’s rulers are commonly used to measure dust thicknesses. In addition, common items such as paper clips, and coins, can be used to provide a relative accumulation thickness, but should not be used for obtaining documented dust-depth measurements. Footprints in the dust layer, and dust thicknesses that obscure the color of the respective surfaces below, are also indications that dust accumulations may be hazardous. In such cases, thickness measurements should be taken.

When taking measurements, important considerations should include:

- An initial evaluation of the space and the dust accumulations. [*Note: If dust accumulations are obviously less than 5% of the floor area, measurements may not be needed.*]
- Measurements should not include spillage from openings in equipment where the spillage does not meet the definition of a fugitive combustible dust.
- Measurements should include the length, width, and height of rooms or building enclosures in which combustible dusts are present.
- Measurements should also include the length, width, and depth of dust accumulations in each of these areas. [*Note: Depths of the dust may vary, in which cases, a few depth measurements should be taken so that an average depth can be determined.*]
- When dust is not present throughout the room or building enclosure, the size of each of the dust accumulation areas should be measured. [*Note: Small, isolated piles need not be included in the measurements. These dimensions will help determine if greater than 5 percent of the floor area is covered by dust accumulations.*]

Once measurements have been taken (and other appropriate documentation made), CSHOs should select locations and collect a representative sample in the location(s). In most instances, only one 1-liter sample will be required. However, CSHOs should recognize that multiple samples may be required if dusts are sampled from different locations in the facility, the dusts could be different, and/or there are potential hazards that make multiple sampling of value.[51]

[*Note: Where measurements of elevated surfaces are not feasible and accumulations are visibly excessive, well documented photographs should be taken strategically throughout the room to document any visually excessive overhead accumulations of dust*.]

Samples should be collected as early as possible. Proper sampling procedures are delineated in *Appendix G, Procedure for Safe Sampling of Most Combustible Dusts*, *Appendix H, Procedures for Safe Sampling of Low-MIE Combustible Dusts*, *and* *Appendix I, Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*. **CSHO safety during sampling is paramount.**

[51] For example, if the facility has locations where different combustible dusts are present, due to the processes at the facility, and the locations contain combustible dusts that could present deflagration and/or explosion hazards, a sample of the contents at each location may be advisable.

The use of improper cleaning methods by employers can create fire, deflagration, and/or explosion hazards. NFPA documents delineate proper cleaning methods and protections that should be followed by employers. Cleanup equipment and methods that may introduce hazards during cleaning include:

- Use of non-rated vacuum cleaning systems in hazardous (classified) locations. These systems include electrical parts that may not be appropriate for Class II locations.
- Use of compressed air, which often disperses combustible dust into the air.
- Use of high pressure water sprays, which can also disperse combustible dust into the air.
- Aggressive sweeping that may produce dust clouds.

If there is a question about the requirements or methods for measuring accumulations, taking samples, or evaluating cleaning equipment, contact your supervisor. The SLTC laboratory, or the HRT, is also available to assist as needed.

IX. Combustible Dust Equipment Considerations

Dust fires, deflagrations, and explosions often occur within dust collection systems and, to a lesser extent, within processing equipment. Deflagrations and explosions that may occur in areas outside of equipment are covered in *Housekeeping Considerations*.

Combustible Dust Equipment Considerations can be performed in conjunction with *Housekeeping Considerations* and *Electrical (Hazard) Class II Considerations*. When performed together, CSHOs should review each of these sections before beginning, to ensure that all aspects of these inspections are adequately covered.

Recognition of Dust Equipment Hazards

Dust fire, deflagration, and explosion hazards associated with equipment are usually associated with poor or inadequate design, installation, operation, and/or maintenance of the equipment. CSHOs should develop a basic understanding of the industrial processes at the facility and of the associated dust equipment.

Equipment manufacturers often identify provisions for proper installation, operation, and maintenance of their equipment. Manufacturers also usually specify design and operating limits of their equipment. In other cases, industry consensus standards have been developed for equipment and should be reviewed by CSHOs. Additionally, OSHA standards have some specific requirements regarding what constitutes adequate design, installation, operation, and maintenance of dust equipment. Information on common dust equipment is found in the following appendices:

- *Appendix L, Typical Combustible Dust Generation Systems and Equipment*
- *Appendix M, Typical Combustible Dust Collection Systems and Equipment*

Information on common dust deflagration and explosion control equipment is found in the following appendices:

- *Appendix N, Typical Combustible Dust Explosion Prevention and Protection Technologies*
- *Appendix O, Typical Combustible Dust Deflagration Propagation Protection (Isolation) Technologies*
- *Appendix P, Typical Other Prevention and Protection Technologies*

Asking questions early in the inspection and reviewing process-related documents can be helpful. *Appendix C, Common Inspection Questions*, can assist CSHOs and be used throughout the inspection. Piping and instrumentation diagrams (P&IDs), process flow diagrams, process narratives, equipment description manuals, operating procedures, manufacturer documentation, and maintenance records can also be helpful to review as part of the equipment inspections.

If there is a question about the requirements or use of the above standards, or of the processes, contact your supervisor. The SLTC laboratory, or the HRT, is also available to assist as needed.

Evaluation of Dust Equipment Hazards

Many of the hazards found during OSHA combustible dust inspections are associated with dust collection systems. Whenever dust collection, or deflagration/explosion prevention or protection equipment is installed on site, the equipment should be inspected. Inspection of these systems should include evaluating whether the dust collection systems are installed as designed (such as with proper sizing and configuration, adequate conveying velocities, and proper discharge location).[52] *Appendix D, Inspection Questions for Dust Collection, and for Deflagration/Explosion Prevention and Protection Equipment* may be a helpful guide in this regard.

Additionally, CSHOs should look at processing equipment and vessels upstream of the dust collection systems in order to document possible ignition sources for a dust collector deflagration, explosion, or fire and to evaluate whether or not the equipment itself may also present a deflagration, explosion, or fire hazard on its own.

CSHOs should also review key design, installation, operation, and maintenance records and documents associated with the equipment that the CSHO has identified as being a concern (e.g., as determined through experience, consultation with the manufacturer, or identified in industry consensus standards) or has been involved in or contributed to a documented deflagration, explosion, or fire event. *Appendix C, Common Inspection Questions*, includes useful questions and document requests. CSHOs should obtain information about:

- Manufacturer name, model number, and date of installation
- Equipment specifications
- Changes to dust equipment since original installation
- Management of change (MOC) records for dust equipment

CSHOs should also obtain the following documents:

- Dust equipment manufacturer manuals for key pieces of equipment. Key pieces of equipment may include dust collection equipment and/or dust equipment involved in or associated with incidents at the facility.
- Operating procedures for key pieces of equipment.
- Preventive maintenance, breakdown, and turn-around maintenance work records for key pieces of equipment, include records for the past several years (up to five years of records in some cases). This should include work performed by contractors as well as plant personnel.

[52] Many ventilation standards are available, including ACGIH's Industrial Ventilation Manual that has some general information on conveying velocities and dust control equipment.

- Incident records for incidents involving dust equipment at the facility.
- Inspection and test records for specific equipment (include bonding and grounding/continuity inspections and tests).

Walk-arounds provide visual indication as to the condition of the equipment, and whether it has been designed, installed, operated, and maintained in accordance with the manufacturer documents, and OSHA standards.

Before going on a walk-around it is most effective to ask the following questions about the current operation status:

- What products are being manufactured that day?
- What production equipment is in service and out of service?
- Are they operating at full or partial production rates?
- What dust producing equipment is in service and out of service?
- What dust handling equipment is in service and out of service?
- What dust control equipment is in service and out of service?
- What deflagration protection equipment and/or controls are installed?
- What deflagration prevention equipment and/or controls are installed?
- What fire protection equipment and systems are installed?

Representative dust samples should be taken for each piece of equipment that could present a deflagration/explosion/fire hazard. Representative samples can normally be taken from locations that contain material(s) representative of the conditions occurring inside of the equipment that may present a combustible dust deflagration/explosion/fire hazard. These locations may include upstream locations or downstream locations. These locations can vary depending on the type of equipment and other process considerations.

Obtaining samples directly from the interior of potentially hazardous equipment (i.e., reaching into or physically entering equipment with mechanical or atmospheric hazards) is normally not necessary and should be avoided unless representative samples cannot be obtained from alternative locations.

If determined necessary, obtaining samples from the interior of equipment that contains hazardous energy sources or are permit-required confined spaces (PRCS) must only be done in coordination between the Area Office, Regional Office (including HRT if necessary) and in compliance with OSHA's SHMS chapters on lockout/tagout (LOTO) and PRCS as applicable. It is also important, in this scenario, to ensure that any employer representatives/employees assisting the CSHO (e.g., opening of equipment for a CSHO to obtain a sample) also be protected under the provisions of 29 CFR 1910.147, *The Control of Hazardous Energy – Lockout/Tagout* and 1910.146, *Permit-Required Confined Spaces*, as applicable.

If there are any question(s) as to where it is best to take a representative sample for a given piece of equipment, contact your Regional Office for guidance.

CSHOs should recognize that multiple samples may be required if dusts are at different equipment locations in the facility, the dusts are not the same, and/or there are potential hazards that make multiple samples of value.[53] Representative samples should be obtained for each piece of equipment for which the CSHO is alleging a combustible dust deflagration, explosion, or fire hazard.

Samples should be collected as early as possible. Proper sampling procedures are discussed in *Appendix G, Procedure for Safe Sampling of Most Combustible Dusts*, *Appendix H, Procedures for Safe Sampling of Low-MIE Combustible Dusts, and Appendix I, Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*. **CSHO safety during sampling is paramount.**

If there is a question about requirements for dust collectors, controls, or sampling procedures, contact your supervisor. The SLTC laboratory and the HRT are also available to assist as needed.

[53] For example, if there is more than one dust collector at the site and each dust collector contains combustible dusts that could present deflagration and/or explosion hazards, a sample of the contents of each dust collector may be advisable.

X. Electrical (Hazard) Class II Considerations

CSHOs should perform evaluations of electrical equipment where the locations in which they are located might be hazardous (classified) locations. Examples include locations:

- Where dust clouds are normally present.
- Where dust clouds are not normally present but could become present due to abnormal conditions or infrequent malfunctioning of handling or processing equipment.
- Where dust accumulations may be sufficient to interfere with the safe dissipation of heat from electrical equipment.
- Where dust accumulations may be ignitable by abnormal operation or failure of electric equipment.

Ignition sources at facilities can include electrical equipment located in areas where fire or explosion hazards potentially exist due to combustible dust. 29 CFR 1910.307, *Hazardous (Classified) Locations*, paragraph (c) requires that electrical equipment installed in these locations be intrinsically safe, approved, or safe for the locations. The definition of Class II locations is set forth in 29 CFR 1910.399.

Evaluation of Electrical Equipment Hazards

Before proceeding with the combustible dust electrical equipment inspection, CSHOs should request information from the employer regarding the electrically classified locations at the facility. Hazardous (classified) locations must be properly documented in accordance with 29 CFR 1910.307(b).

After reviewing provided electrical classification information, CSHOs should inspect the classified locations in the facility to ensure these locations are properly classified and that boundary distances have been adequately defined (see *Appendix Q, Combustible Dust Electrical Classification and Control* for more information). If combustible dust fire or explosion hazards are discovered in areas not classified during this inspection, during the *Combustible Dust Equipment Considerations*, or during the *Housekeeping Considerations*, CSHOs may refer to *Appendix Q, Combustible Dust Electrical Classification and Control*, for added guidance.

Once classified locations in the facility have been identified, CSHOs should ensure that electrical equipment (including electrical switches, outlets, lighting, wiring, conduit, and motors), located in these areas are intrinsically safe, approved, or safe for the locations as required by 29 CFR 1910.307(c). Review of equipment labels and manuals, and/or contacting the manufacturer of the electrical equipment are recommended approaches for determining if electrical equipment is either intrinsically safe, approved for the location, or safe for the location.

Evaluation of Powered Industrial Truck Hazards

Where hazardous (classified) locations (i.e. Class II locations) have been documented, CSHOs should also assess that the powered industrial trucks used in those hazardous (classified) locations are appropriate (i.e., in accordance with 29 CFR 1910.178, *Powered Industrial Trucks*.

If there is a question about the OSHA requirements for electrical classifications and equipment, or for powered industrial truck certifications, contact your supervisor. The SLTC laboratory and the HRT are also available to assist as needed.

XI. Determining Tests to Request from the SLTC Laboratory

Collect a full 1-liter bottle of sample whenever possible. If a full 1-liter bottle cannot be collected, collect as much representative sample as possible. Do not mix samples. If the dust has a low bulk density (such as tissue paper), more than one 1-liter sample may be required. Contact the lab if there is a question about the amount of sample needed.

A K_{st} test (IMIS code M102) is the appropriate SLTC test (see *Appendix J, SLTC Laboratory Tests*, for a discussion of the K_{st} test) for documenting either:

- that the material in a dust collector or other process vessel/equipment is a combustible dust (i.e., fuel for an equipment-related deflagration/explosion hazard); or
- that accumulations of settled particulate in a room or building compartment is a combustible dust (i.e., fuel for a housekeeping-related deflagration/explosion hazard).

A Class II test (IMIS code E101) is the appropriate SLTC test for documenting that electrical equipment is not appropriate for a hazardous (classified) location (see *Appendix J, SLTC Laboratory Tests*, for a discussion of the Class II test). A Class II test should NOT be used to document a housekeeping hazard or an equipment deflagration/explosion hazard.

In most cases, one test (either Kst or Class II) will be sufficient to identify a hazard. However, in cases where more than one test is required, CSHOs should collect, if possible, an additional sample for each additional test to be performed by the SLTC laboratory.

XII. Packaging and Shipping Samples to the SLTC

Some samples will be considered "hazardous materials" or "dangerous goods" and will require special packaging, handling, and shipping procedures in accordance with the applicable shipping standards.

For packaging and shipping of hazardous materials or dangerous goods, follow:[54]

- For ground shipments, Department of Transportation (DOT) hazardous shipping regulations (available at 49 CFR *171*, *172*, and *173*);
- For air shipments, applicable *International Air Transport Association (IATA) Dangerous Goods Regulations* (the HRT maintains a current copy of the IATA regulations and can be contacted with questions); and/or
- When shipping with UPS by ground or by air, also follow UPS shipping requirements (available at *UPS Chemical Table*).

Note: The OSHA intranet *Hazardous Materials Shipping Page* has instructions about shipping many of the common *Combustible Dust* samples. Look to this resource first, before searching through the above regulations and standards, which can be complicated.

For other shipping questions, please contact the HRT for guidance.

[54] DOT = Department of Transportation. DOT regulations apply when transporting samples by ground. IATA = International Air Transport Association. IATA standards apply when transporting samples by air both nationally and internationally. OSHA's current shipping contractor is UPS. UPS requirements are often more restrictive than DOT and IATA. Therefore, UPS requirements must also be reviewed to ensure that they will accept the samples for shipping.

XIII. Combustible Dust Hazard Analyses

NFPA standards include provisions for performance of a dust hazard analysis (DHA) when there is a potential combustible dust at a facility. These analyses are helpful to employers in making informed decisions regarding housekeeping procedures, administrative controls, engineering controls, personal protective equipment specifications, employee training needs, and other safety related issues.

Employers should recognize that a competent professional, experienced in the identification, evaluation, abatement, and control of combustible dust hazards, is crucial to conducting an effective DHA.

Remember: OSHA is concerned with the presence of hazards and hazardous conditions, not if the employer has performed a DHA.

A sample DHA is available in NFPA 652-2019, Annex B.

XIV. References and Standards

OSHA Standards

- 29 CFR 1910.22, *Walking-Working Surfaces General Requirements*
- 29 CFR 1910.94, *Ventilation*
- 29 CFR 1910.107, *Spray Finishing Using Flammable and Combustible Materials*
- 29 CFR 1910.109, *Explosives and Blasting Agents*
- 29 CFR 1910.132, *PPE General Requirements*
- 29 CFR 1910.176, *Handling Materials – General*
- 29 CFR 1910.178, *Powered Industrial Trucks*
- 29 CFR 1910.261, *Pulp, Paper, and Paperboard Mills*
- 29 CFR 1910.263, *Bakery Equipment*
- 29 CFR 1910.265, *Sawmills*
- 29 CFR 1910.269, *Electric Power Generation, Transmission, and Distribution*
- 29 CFR 1910.272, *Grain Handling Facilities*
- 29 CFR 1910.307, *Hazardous (Classified) Locations*
- 29 CFR 1910, Subpart Q, *Welding, Cutting and Brazing*
- 29 CFR 1910.1200, *Hazard Communication*

OSHA Resources

- *Combustible Dust National Emphasis Program*
- *Field Operations Manual*, Directive Number CPL 02-00-160. August 2, 2016
- *Hazardous Materials Shipping Page*
- *Fact Sheet: Protecting Workers from Combustible Dust Explosion Hazards*
- *Firefighting Precautions at Facilities with Combustible Dust*
- *Hazard Communication Guidance for Combustible Dusts*
- *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions*
- *Combustible Dust: An Explosion Hazard – Safety and Health Topics Page*
- *Hazard Alert: Combustible Dust Explosions*
- *SHIB: Dust Explosion Hazard in Certain Textile Processes*
- *Report: Combustible Dust Expert Forum*
- *Transporting Hazardous Materials*

U.S. Chemical Safety Board (CSB) Resources

- *CSB AL Solutions Fatal Dust Explosion*
- *CSB CTA Acoustics Dust Explosion and Fire*
- *CSB Hayes Lemmerz Dust Explosions and Fire*
- *CSB Imperial Sugar Company Dust Explosion and Fire*
- *CSB West Pharmaceutical Services Dust Explosion and Fire*

NFPA Standards

[Note: For the latest NFPA standards CSHOs should go to the IHS Website. Many of the most recent as well as earlier revisions are also available on OSHA's global network.]

- NFPA 1-2018, Fire Code
- NFPA 33-2018: Standard for Spray Application Using Flammable or Combustible Materials
- NFPA 61-2017: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
- NFPA 68-2018: Standard on Explosion Prevention by Deflagration Venting
- NFPA 69-2019: Standard on Explosion Prevention Systems
- NFPA 70-2017: National Electrical Code
- NFPA 77-2019: Recommended Practice on Static Electricity
- NFPA 85-2019: Boiler and Combustion Systems Hazards Code
- NFPA 86-2019, Standard for Ovens and Furnaces
- NFPA 91-2015: Standard for Exhaust for Air Conveying of Vapors, Gases, Mists, and Particulate Solids
- NFPA 101-2018: Life Safety Code
- NFPA 400-2019: Hazardous Materials Code
- NFPA 484-2019: Standard for Combustible Metals
- NFPA 496-2017: Standard for Purged and Pressurized Enclosures for Electrical Equipment
- NFPA 499-2017: Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- NFPA 505-2018: Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations
- NFPA 652-2019: Standard on the Fundamentals of Combustible Dust
- NFPA 654-2017: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
- NFPA 655-2017: Standard for Prevention of Sulfur Fires and Explosions
- NFPA 664-2017: Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
- NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations
- NFPA 921-2017: Guide for Fire and Explosion Investigations
- NFPA 2112-2018: Standard on Flame-Resistant Garments for Protection of Industrial Personnel against Flash Fire
- NFPA 2113-2015: Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel against Flash Fire
- NFPA 5000-2018: Building Construction and Safety Code
- NFPA Guide to Combustible Dusts, 2012

- NFPA Fire Protection Handbook, 20th Edition, 2008

CCPS Resources

- Guidelines for Safe Handling of Powders and Bulk Solids, November 2004
- Guidelines for Combustible Dust Hazard Analysis, May 2017
- Understanding Explosions, July 2003
- Deflagration and Detonation Flame Arresters, May 2002

FM Global Resources

- FM Global 5-1, Electrical Equipment in Hazardous (Classified) Locations
- FM Global 5-8, Static Electricity
- FM Global 6-2, Pulverized Coal-Fired Boilers
- FM Global 6-9, Industrial Ovens and Dryers
- FM Global 6-13, Waste Fuel-Fired Boilers
- FM Global 6-17, Rotary Kilns and Dryers
- FM Global 7-10, Wood Processing and Woodworking Facilities
- FM Global 7-11, Conveyors
- FM Global 7-17, Explosion Protection Systems
- FM Global 7-27, Spray Application of Ignitable and Combustible Materials
- FM Global 7-36, Pharmaceutical Operations
- FM Global 7-57, Pulp and Paper Mills
- FM Global 7-73, Dust Collectors and Collection Systems
- FM Global 7-75, Grain Storage and Milling
- FM Global 7-76, Prevention and Mitigation of Combustible Dust Explosion and Fire
- FM Global 8-10, Coal and Charcoal Storage
- FM Global 8-27, Storage of Wood Chips

U.S. Bureau of Mines Reports

- 6516 Explosibility of Metal Powders
- 7208 Explosibility of Miscellaneous Dusts
- 5753 Explosibility of Agricultural Dusts
- 5971 Explosibility of Dusts Used in the Plastics Industry
- 6597 Explosibility of Carbonaceous Dusts
- 7132 Explosibility of Chemicals, Drugs, Dyes, and Pesticides

Other References

- ASTM International, American Society for Testing and Materials (See *Appendix K: ASTM Test Methods*)
- Dust Explosions in the Process Industries, Eckhoff, Rolf K. (2003)

- Explosibility of Agricultural Dusts, report of investigations 5753 United States Department of the Interior, Bureau of Mines (1961)
- Explosibility of Dusts Used in the Plastics Industry, report of investigations 5971 United States Department of the Interior, Bureau of Mines (1962)
- Explosibility of Metal Powders, report of investigations 6516 United States Department of the Interior, Bureau of Mines (1964)
- Explosibility of Carbonaceous Dusts, report of investigations 6597 United States Department of the Interior, Bureau of Mines (1965)
- Explosibility of Chemicals, Drugs, Dyes, and Pesticides, report of investigations 7132 United States Department of the Interior, Bureau of Mines (1968)
- *Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA) GESTIS-Dust Database*
- 49 CFR 171, 172, and 173, DOT Hazardous Material Standards
- *UPS Chemical Table*, for shipping hazardous materials
- Classification of Combustible Dusts in Accordance with the National Electric Code. National Materials Advisory Board, NMAB 353-3-80

Appendix A
Combustible Dust Case Studies and Lessons Learned

Polyethylene Dust Explosion at West Pharmaceutical Services, Kinston, North Carolina, January 29, 2003[55]

Figure I-1: Response to West Pharmaceuticals explosion and fire on January 29, 2003. (Source: CSB)

A powerful explosion and fire ripped through the West Pharmaceutical Services rubber manufacturing plant in Kinston, North Carolina, taking the lives of six employees, and injuring 38 others including two firefighters who responded to the accident (Figure I-1). The blast occurred without warning at 1:28 p.m. during a routine workday and was heard 25 miles from the plant. A student at a school more than half a mile away was injured by shattered glass. Flaming debris set woods on fire as far as two miles away.

This plant used large quantities of very fine talc-like polyethylene powder mixed with water to process medical quality rubber. Polyethylene dust became airborne in the process when rubber parts were dried. The polyethylene dust settled on surfaces and particularly over an acoustic tile ceiling installed above the rubber production area. Above that ceiling (visible only to maintenance workers) the dust gradually built up to a thickness of 6 to 13 mm (1/4 – 1/2 inch) on

[55] See CCPS, Incidents that Define Process Safety. Pg 143.

ceiling tiles, beams, conduits, and light fixtures. As much as a ton of combustible powder could have accumulated in the area above the ceiling.

A first explosion (not identified because of the later destruction) dispersed other dust accumulations into the air around the production area and ignited them, causing a devastating cascade of fires and explosions.

Although the plant had the material safety datasheets (MSDSs) warning of the explosive properties of polyethylene powder, employees had not received any significant training about combustible dust hazards. Had maintenance workers been aware of the catastrophic nature of this hazard, they could have alerted management to the presence of dangerously large dust accumulations above the acoustic ceiling. The initial explosion and ignition source were not identified, but it is important to note that electrical fixtures and wiring in the production area were general purpose and not rated for use around combustible dust.

The CSB issued the following recommendations in their final report:

- Modify the material safety data sheet for manufactured polyethylene anti-tack agents to include hazards posed by the end-use of the product.
- Revise policies and procedures for new material safety reviews. In particular:
  - use the most recent versions of material safety data sheets (MSDSs) and other technical hazard information;
  - fully identify the hazardous characteristics of new materials, including relevant physical and chemical properties, to ensure that those characteristics are incorporated into safety practices, as appropriate; and
  - include an engineering element that identifies and addresses the potential safety implications of new materials on manufacturing processes.
- Develop and implement policies and procedures for safety reviews of engineering projects. In particular:
  - address the hazards of individual materials and equipment and their effect on entire processes and facilities;
  - consider hazards during the conceptual design phase, as well as during engineering and construction phases;
  - cover all phases of the project, including engineering and construction performed by outside firms; and
  - identify and consider applicable codes and standards in the design.
- Identify West manufacturing facilities that use combustible dusts. Ensure that they incorporate applicable safety precautions described in NFPA 654, Standard for the Prevention of Fire and Dust Explosions From the Manufacturing, Processing, and Handling of Combustible Particulate Solids. In particular:
  - ensure that penetrations of partitions, floors, walls, and ceilings are sealed dust-tight; and
  - ensure that spaces inaccessible to housekeeping are sealed to prevent dust accumulation.
- Improve hazard communication programs so that the hazards of combustible dust are clearly identified and communicated to the workforce. In particular, ensure that the most

current MSDSs are in use and that employees receive training on the revised/updated information.

Phenolic Resin Dust Explosion at CTA Acoustics, Inc., CortJin, Kentucky, February 20, 2003[56]

Figure I-2: Results of a dust explosion at CTA Acoustics, Inc., on February 20, 2003. (Source: CSB)

A dust explosion killed seven and injured 37 workers at a plant that produced acoustic and thermal insulation products from fiberglass and phenolic resin powder for industrial and automotive clients (Figure I-2). This incident caused extensive damage to the production area of the plant, and disturbed production at customer facilities, including the temporary shutdown of four Ford assembly plants. The CSB determined that combustible phenolic resin dust that had accumulated throughout the facility fueled the explosions and subsequent fire.

Substantial quantities of phenolic resins, often several hundred thousand pounds per month, were used by multiple production lines located in the same building. Just prior to the explosion, workers cleared a blockage in a production line and combustible material was dumped down a vertical pipe into a box on the floor. Dust was generated as the material landed in the box. A

[56] See CCPS, Incidents that Define Process Safety. Pg 158.

room fan directed the combustible dust toward an oven where it likely ignited. The most probable initiating event was therefore a combustible dust explosion at the oven.

The fireball generated by this initial explosion ignited dispersed combustible dust, which caused a secondary explosion in the relatively confined area – above a blend room. The force of this explosion damaged firewalls, metal wall panels, and ceilings. The pressure wave and fireball produced by that secondary dust explosion propagated west along the ceiling toward other lines injuring or killing workers. An additional secondary dust explosion occurred in the southeast corner of the blend room, nearly 100m (300 ft) away from the first explosion. The first explosion dispersed other dust accumulations into the air around the production area and ignited them, causing a devastating cascade of fires and explosions.

The CSB issued the following recommendations in their final report:

- Develop procedures to maintain safety during non-routine operating conditions, such as the loss of oven temperature control.
- Revise the incident investigation program to ensure that the underlying causes of incidents such as fires are identified and corrective actions implemented.
- Develop a combustible dust safety program using good practice guidelines, such as NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids. At a minimum:
    - Minimize surfaces where combustible dust could accumulate in the design or modification of the plant.
    - Ensure phenolic resin-handling facilities are designed to prevent the spread of fires or explosions involving combustible dust. Options include measures such as the use of firewalls and blast-resistant construction.
    - Prevent the unsafe accumulation and dispersion of combustible dust by frequently cleaning process areas, including locations above production lines.
    - Minimize the dispersion of combustible dust by using appropriate dust-cleaning methods and tools.
    - Address the dangers of combustible dust and the prevention of dust explosions in the hazard communication training program.

Hayes Lemmerz Dust Explosions and Fires, Huntington, IN, October 29, 2003[57]

An aluminum dust explosion and fire on October 29, 2003 (Figure I-3) at the Hayes Lemmerz International−Huntington, Inc. (Hayes) facility, Huntington, Indiana, killed one employee and burned two other employees, one critically. Three other Hayes employees and one contractor received minor injuries.

[57] See www.csb.gov/hayes-lemmerz-dust-explosions-and-fire/

Figure I-3: Fires and explosions at Hayes Lemmerz on October 29, 2003. (Source: CSB)

The facility manufactured cast aluminum alloy wheels. The CSB determined that the dust that exploded originated in a scrap re-melting system. The explosion completely destroyed the dust collection equipment outside the building and damaged equipment inside the building. The explosion also lifted a portion of the building roof above one furnace and ignited a fire that burned for several hours.

The CSB issued the following recommendations in their final report:

- Develop and implement a means of handling and processing aluminum chips that minimizes the risk of dust explosions.
- Implement a program to provide regular training for all facility employees on the fire and explosion hazards of aluminum dust.
- Develop and implement written operating procedures for chip processing and train all affected employees. Ensure that procedures address maintenance and housekeeping.

Sugar Dust Explosion and Fire at Imperial Sugar Company, Port Wentworth, GA, February 7, 2008[58]

[58] See www.csb.gov/imperial-sugar-company-dust-explosion-and-fire.

Figure I-4: Results of explosions and fires at Imperial Sugar Company on February 7, 2008. (Source: CSB)

On February 7, 2008, a series of explosions and fires occurred at the Imperial Sugar refinery northwest of Savannah, Georgia, causing 14 deaths and injuring 38 others, including 14 with serious and life-threatening burns (Figure I-4). The explosion was fueled by massive accumulations of combustible sugar dust throughout the packaging building. The explosions and subsequent fires destroyed the sugar packing buildings, palletizer room, and silos, and severely damaged the bulk train car loading area and parts of the sugar refining process areas.

The Imperial Sugar manufacturing facility housed a refinery that converted raw cane sugar into granulated sugar. A system of screw and belt conveyors, and bucket elevators transported granulated sugar from the refinery to three, 105-foot tall sugar storage silos. It was then transported through conveyors and bucket elevators to specialty sugar processing areas and granulated sugar packaging machines. Sugar products were packaged in four-story packing buildings that surrounded the silos, or loaded into railcars and tanker trucks in the bulk sugar loading area.

The CSB determined that the first dust explosion initiated in the enclosed steel belt conveyor located below the sugar silos. The recently installed steel cover panels on the belt conveyor allowed explosive concentrations of sugar dust to accumulate inside the enclosure. An unknown source ignited the sugar dust, causing a violent explosion. The explosion lofted sugar dust that had accumulated on the floors and elevated horizontal surfaces, propagating more dust explosions throughout the buildings. Secondary dust explosions occurred throughout the packing buildings, parts of the refinery, and the bulk sugar loading buildings. The pressure waves from the explosions heaved thick concrete floors and collapsed brick walls, blocking stairwells and other exit routes. The resulting fires destroyed the packing buildings, silos, palletizer building, and heavily damaged parts of the refinery and bulk sugar loading area.

The CSB issued the following recommendations in their final report:

- Apply the following standards to the design and operation of the new Port Wentworth facility:
  - NFPA 61: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
  - NFPA 499: Recommended Practice for the Classification of Combustible Dusts and Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
  - NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
  - NFPA Handbook, Electrical Installations in Hazardous Locations
  - NFPA 70 Article 500: Hazardous (Classified) Locations
- Conduct a comprehensive review of all existing Imperial Sugar Company sugar manufacturing facilities against the standards listed in recommendations and implement identified corrective actions.
- Implement a corporate-wide comprehensive housekeeping program to control combustible dust accumulation that will ensure sugar dust, cornstarch dust, or other combustible dust does not accumulate to hazardous quantities on overhead horizontal surfaces, packing equipment, and floors.
- Develop training materials that address combustible dust hazards and train all employees and contractors at all Imperial Sugar Company facilities. Require periodic (e.g., annual) refresher training for all employees and contractors.
- Improve the emergency evacuation policies and procedures at the Port Wentworth facility; specifically:
  - install an emergency alert (alarm) system in the facility, and
  - require routine emergency evacuation drills and critiques.

Metal Dust Explosion and Fire at AL Solutions, New Cumberland, West Virginia, December 9, 2010[59]

[59] See www.csb.gov/al-solutions-fatal-dust-explosion.

Figure I-5: Response to an explosion and fire at AL Solutions on December 9, 2010. (Source: CSB)

On December 9, 2010, a metal dust explosion and fire took the lives of three workers in a production (blender/press) room at the facility and injured one other working in a nearby location (Figure I-5).

Two operators were running presses that were making titanium and zirconium compact "pucks" (3-inch diameter that looked like hockey pucks) from blended dusts, while a third operator was mixing a batch of zirconium dust at the blender.

A noise (like metallic parts hitting each other or hitting the ground) was heard first, followed by a whoosh and a boom. Orange sparkling flames were seen coming from the room after the explosion.

Two operators in the blending and press room died at the scene, and the zirconium press operator died three days following the incident from severe burn injuries. The explosion and subsequent fire caused minor blast damage to doors, walls, and interior windows as well as more substantial thermal damage throughout the production area. Equipment damage included a lift truck, the blender, and the press feed conveyor. The explosion propelled papers, desks, and lockers from the office into the parking lot outside of the production building.

The AL Solutions safety manual listed several requirements for safe storage and handling of titanium and zirconium. However, the CSB found that management did not enforce these requirements. AL Solutions and the previous owner designed and installed production equipment with enclosures intended to limit the accumulation of combustible metals on external surfaces. The blender and the press conveyor had metal lids, and the plan was to leave the lids closed whenever possible to isolate the equipment and prevent dispersion of dust. Management did not enforce this practice at the facility, and the blender, conveyor belt lid, and storage drums were regularly left open during operation. In addition, to limit the quantity of flammable metal in the blending area, only metal currently in production was to be allowed in the production area. All other material was to be kept in a separate warehouse or in outside storage. However, AL Solutions employees commonly left barrels of titanium and zirconium dusts in the production building, even if they were not in use.

The CSB issued the following recommendations in their final report:

- For all new and existing equipment and operations at AL Solutions facilities that process combustible dusts or powders, apply the following chapters of NFPA 484-2012, Standard for Combustible Metals:
  - Chapter 12, Titanium
  - Chapter 13, Zirconium
  - Chapter 15, Fire Prevention, Fire Protection, and Emergency Response
  - Chapter 16, Combustible Metal Recycling Facilities
- Develop training materials that address combustible dust hazards and plant-specific metal dust hazards and then train all employees and contractors. Require periodic (e.g., annual) refresher training for all employees and contractors.
- Prohibit the use of sprinkler systems and water deluge systems in all buildings that process or store combustible metals.
- Conduct a process hazard analysis as defined in NFPA 484-2012, Section 12.2.5, and submit a copy to the local fire department or the enforcing authority for the fire code.

Appendix B
Combustible Dust Inspection Common Structure and Guidance

The following table describes a common structure for combustible dust inspections that can provide guidance to CSHOs. Combustible dust inspections are seldom identical, often requiring changes in this structure, and requiring judgement specific to the processes, equipment, and conditions found during the inspection. As a result, CSHOs should not consider this structure and guidance to be a step-by-step checklist, rather a tool to assist during the inspection.

Before Travelling to the Site			
1. Have you received the required training to perform a combustible dust inspection?	See the *NEP* for training requirements. If not trained, contact your supervisor for assistance from a CSHO having the required combustible dust training. Another CSHO with the required training may need to be assigned to the case.	☐Yes	☐**No – STOP. Contact Supervisor.**
2. Have you reviewed the current NEP?	CSHOs must be familiar with the requirements of the *NEP* before performing a combustible dust inspection.	☐Yes	☐**No – STOP and review.**
3. Do you have the PPE and sampling supplies needed for inspection?	PPE must include a hard hat, safety glasses, and FRC. Supplies must include 1-liter sample bottles, an aluminum scoop, a natural bristle brush, a measuring tool, pen and paper, and a camera. Additional PPE and sampling supplies are necessary when low-MIE combustible dusts are present (see *Appendix H, Procedures for Safe Sampling of Low-MIE Combustible Dusts*).	☐Yes	☐**No – Obtain the PPE and sampling supplies before proceeding**.
4. Consider the hazards and characteristics of the combustible dust(s) expected at the site.	See *Combustible Dust Hazards* and *Combustible Dust Characteristics* sections of this chapter.		☐Done

5. Determine and be familiar with the applicable OSHA standards.	See the *Scope and Applicability of OSHA Standards Regarding Combustible Dusts* section of this chapter.	☐Done
6. Review *Appendix C, Common Inspection Questions* section of this chapter.	Many of these questions can be asked of the employer before or while performing walk-arounds. Then, observations can be made and documented during the walk-arounds.	☐Done
While at the Site		
7. Confirm information about the hazards and characteristics of the combustible dust(s).	See *Combustible Dust Hazards* and *Combustible Dust Characteristics* sections of this chapter. For safety, CSHOs must understand the hazards and characteristics of the particular dust(s) at the site before proceeding. Seek assistance as needed.	☐Done
8. Ask the employer for drawings and other applicable documents to assist in walk-arounds.	See the *NEP*, as well as the *Housekeeping*, *Equipment*, and *Class II* Consideration sections of this chapter.	☐Done
9. Discuss the on-site combustible dust generating processes and associated equipment with the employer.	Discuss all processes and equipment that make, use, handle, convey/transport, and/or create combustible dusts. See Appendices XII through XVI for information about these types of equipment.	☐Done
10. Discuss PPE and area entry requirements with the employer.	See *On-Site Inspection Initial Considerations* section of this chapter.	☐Done
11. Wear the proper PPE into the field.	PPE must include a hard hat, safety glasses, and FRC. Respirators may also be required, but only if the CSHO is medically approved and fit-tested for respirator use. Additional PPE may be necessary when low-MIE combustible dusts are encountered (see *Appendix H, Procedures for Safe Sampling of Low-MIE Combustible Dusts*).	☐Done

12. Document conditions in the field during the initial walk-around.	See *Housekeeping Considerations*, *Combustible Dust Equipment Considerations*, and *Electrical (Hazard) Class II Considerations* sections of this chapter. Determine where samples should be taken.	☐Done
13. Take dust accumulation measurements.	See *Housekeeping Considerations* section of this chapter for guidance.	☐Done
14. Collect adequate quantities of combustible dust samples and perform additional walk-arounds as needed.	See *Determining Tests to Request from the SLTC Laboratory* as well as appendices G through I of this chapter, *Procedure for Safe Sampling of Most Combustible Dusts*, *Procedures for Safe Sampling of Low-MIE Combustible Dusts*, and *Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*.	☐Done
After the Site Visit(s)		
15. Confirm dust tests to request from the SLTC Lab.	See *Determining Tests to Request from the SLTC Laboratory* section of this chapter.	☐Done
16. Safely handle and ship samples to the SLTC Lab.	See *Packaging and Shipping Samples to the SLTC* section of this chapter.	☐Done
17. Review information collected.	Determine if more information (such as documents) are needed. If so, collect them at this time.	☐Done
18. Obtain a better understanding of industry, process, and equipment hazards (if necessary).	Investigate industry-wide loss history concerning combustible dust fires, deflagrations, and explosions. Refer to sources such as: *CSB Reports*, *CCPS Guidelines for Safe Handling of Powders and Bulk Solids*, Eckhoff, *Dust Explosions in the Process Industries,* as well as other sources of information. See the *References and Standards* section of this chapter.	☐Done

	Research how specific combustible dust processing, transport, handling, storage, and collection equipment functions. [See CCPS, *Guidelines for Safe Handling of Powders and Bulk Solids* (Appendix B).] Research the combustible dust fire, deflagration, and explosion risks associated with combustible dust related processing, transport, storage, handling, and collection equipment. Research possible ignition sources for the equipment/process(es). [See CCPS, *Guidelines for Safe Handling of Powders and Bulk Solids* (Chapter 5).] Research feasible abatement strategies and technologies for specific equipment. [See *CCPS Guidelines for Safe Handling of Powders and Bulk Solids* (Chapter 5) and the *References and Standards* section of this chapter.]	☐Done ☐Done ☐Done ☐Done
19. Review applicable OSHA standard requirements and/or industry recognition of hazards and methods of abatement.	Identify and review applicable OSHA promulgated standards. See the *Scope and Applicability of OSHA Standards Regarding Combustible Dusts* section of this chapter. In the absence of an applicable OSHA promulgated standard, identify and review the applicable sections of industry standards including, but not limited to, NFPA combustible dust consensus standards. Unincorporated NFPA standards, although not binding, may provide evidence of industry recognition of hazards and the existence of feasible abatement measures. See the *Scope and Applicability of Notable Industry Combustible Dust Standards and Guidance* section of this chapter.	☐Done
23. Communicate any documented hazards to the employer	Consider the most appropriate and applicable approach(es) for the given hazard, or situation, such as: • OSHA standard; • Section 5(a)(1) - general duty clause; and • Hazard Alert Letter.	☐Done

Appendix C
Common Inspection Questions

The following questions may be helpful for CSHOs to ask during the course of a combustible dust inspection. These questions are not all-inclusive or a step-by-step checklist, but can be used as a tool to assist CSHOs during the inspection.

Once the types of combustible dusts and equipment are known (e.g., agricultural or food dusts, or metal dusts), CSHOs should refer to the appropriate OSHA, NFPA, and/or other standards to develop their own questions.

[*Note: Negative responses to these questions should be addressed by the CSHO with a focus on the resulting hazardous conditions. Suggested findings and recommendations must be consistent with OSHA standards and the general duty clause*.]

	Question	Comments
☐Done	1. Are you aware of the hazards of the combustible dust(s) at your facility? [Ask managers and employees.]	If they are not aware of the hazards, you could ask them if they have reviewed SDS's, NFPA standards, or other documents that list hazards or combustion characteristics (e.g., K_{st} values) of the particular dust(s). Ask if they are members of an industry group. There may be information published by these groups that identifies hazards.
☐Done	2. Have you determined the hazards of all potentially combustible dusts at your facility? [Ask managers for a copy of the identified dust hazards.]	NFPA standards[60] describe how owners/operators of a facility can determine the combustibility and explosibility of the dust(s).
☐Done	3. Are employees aware of the hazards of the combustible dust(s) at your facility? How have they been made aware? [Ask managers and employees for a copy of the training records.]	29 CFR 1910.1200(h) requires that owners/operators provide effective information and training to their employees.

[60] See NFPA 652-2019, Chapter 5. Other NFPA standards specific to the type of dust should also be reviewed.

	Question	Comments
☐Done	4. Have there been any previous incidents of fires or explosions? [Ask managers and employees for a copy of the incident reports.]	Previous fires and/or explosions provide evidence that the employer is aware of the hazards. Also see question 19 below.
☐Done	5. Have there been any injuries or fatalities caused by fires or explosions? [Ask managers and employees for a copy of the OSHA 300 forms and/or other reports.]	29 CFR 1904.39, *Reporting Fatalities, Hospitalizations, Amputations, and Losses of an Eye as a Result of Work-Related Incidents to OSHA*, requires timely reporting of fatalities and certain injuries.
☐Done	6. Do you have written procedures and work practices in place to prevent or mitigate fires, deflagrations, and explosions from combustible dusts? [Ask managers and employees for a copy of the procedures and work practices.]	See NFPA 652-2019, Chapter 8, for guidance regarding written procedures and work practices. 29 CFR 1910, Subpart L provides fire protection requirements.
☐Done	7. Do you have a written procedure(s) for housekeeping with regular cleaning frequencies and methods established (including for cleaning of high areas such as above beams, ducts, and piping)? [Ask managers and employees for a copy of the procedure (s).]	OSHA standards require control of combustible dust hazards posed by excessive accumulations of combustible dust. Use of existing OSHA housekeeping standards can be supported with applicable NFPA standard guidance. Housekeeping procedures vary depending on the type of dust. The applicable standards should be reviewed to determine if acceptable housekeeping methods and procedures are in place for the dust(s) at the facility.
☐Done	8. Is housekeeping in the facility routinely inspected and documented? [Ask managers and employees for a copy of the documents.]	NFPA 652-2019, section 8.4, describes how housekeeping effectiveness can be assessed and cleanliness documented.
☐Done	9. Is a hot work program in place and implemented for any hot work occurring in areas containing, or	When hot work includes welding, cutting, or brazing, the requirements of 29 CFR

	Question	Comments
	potentially containing, combustible dusts? [Ask managers and employees for a copy of the hot work procedure.]	1910, Subpart Q, *Welding, Cutting, and Brazing*, must be followed.
☐Done	10. Has your PPE hazard assessment evaluated the need for FRC in areas where flash fire hazards could exist? [Ask managers and employees for a copy of the PPE hazard assessment.]	See 29 CFR 1910.132 requirements. All PPE requirements should be reviewed for compliance with 29 CFR 1910, Subpart I, *Personal Protective Equipment*.
☐Done	11. Are combustible dust-handling and dust-related equipment and systems designed and installed in accordance with industry standards? What specific industry standards are applied? [Ask managers and engineers for a copy of pertinent design standards, design drawings, and manuals.] As a follow-up, CSHOs should ask pertinent questions to better understand how these were designed and how they operate (see *CCPS Guidelines for Safe Handling of Powders and Bulk Solids,* Appendix B).	This is the first question to ask in a series of questions to help CSHOs evaluate if the combustible dust handling equipment and systems are properly designed, installed, operated, and maintained. For each specific type of equipment, CSHOs should also understand: • potential fire and explosion risks, • potential mechanism(s) for the generation of ignition sources, and • potential methods of fire and explosion prevention and protection. [*Many of the questions in this regard should be asked while observing the equipment and systems in the fiel*d.] [*See Appendices XII through XVI of this chapter for examples of many different combustible-dust-handling equipment and systems*.]
☐Done	12. Are combustible dust-handling and dust-related equipment and systems inspected, tested, and maintained in accordance with industry standards? [Ask managers, engineers, and	NFPA standards provide guidance based on the dust type. Review the manufacturer's manuals as they have guidance on necessary preventive maintenance and inspections.

	Question	Comments
	maintenance workers for a copy of maintenance records.]	
☐Done	13. Does the facility have an ignition control program? [Ask managers and employees for a copy of the program.]	See *29 CFR 1910.178* and *29 CFR 1910.307*, Controls should include: • Electrical equipment and devices must be intrinsically safe, approved for, or safe for the Class II locations; • Areas where smoking is prohibited must be posted with "No Smoking" signs; • The facility must have a hot work permit program if hot work is done; • The facility must utilize grounding and bonding, and other methods, for dissipating any electrostatic charge that could be generated; and • The facility must select and use powered industrial trucks that are approved for the combustible dust locations. NFPA 652-2019, and other dust specific standards include guidance from industry in this regard.
☐Done	14. Are personnel who perform manual emptying or filling of containers or vessels grounded during these operations? [Ask managers and employees.]	Guidance suggests that this be done for dusts with an MIE less than or equal to 30 mJ. (See NFPA 652-2019, section 9.4.7.3.)
☐Done	15. Are combustible dust handling equipment and systems constructed of non-combustible materials? [Ask managers and engineers for a copy of the bill of materials.]	NFPA 652-2019, section 9.3.4.4, and sections of the dust-specific NFPA standards provide guidance on when non-combustible materials may be used.
☐Done	16. Are facilities, equipment, and systems operated to prevent fires, deflagrations, and explosions? [Ask managers and employees for a copy	NFPA 652-2019, section 8.3, and applicable sections of the dust-type NFPA standards provide additional guidance.

	Question	Comments
	of the written procedures and safe work practices.]	
☐Done	17. Are contractors with the requisite skills selected and trained to perform work on combustible dust facilities, equipment, and systems? [Ask managers and contractors for a copy of the contractor records.]	NFPA 652-2019, sections 8.8 and 8.9, as well as other dust-specific NFPA standards provide guidance on the use of qualified contractors, training on the potential hazards, safe work practices and policies, and emergency response and evacuation plans.
☐Done	18. Does the facility have a written emergency response plan? [Ask managers and employees for a copy of the written plan.] • Does it include an evacuation plan/route/map? • Are employees familiar with evacuation and fire drill protocols/procedures?	1910.38, 1910.39 and certain paragraphs of 1910.120 may or may not apply based on the conditions at the worksite and the scope of these standards. Refer to the scope of these standards and associated OSHA directives for guidance. NFPA 652-2019, section 8.10, and other dust-specific NFPA standards provide guidance when the above OSHA standards do not apply.
☐Done	19. Are dust fire, deflagration, and explosion incidents investigated and documented? [Ask managers and employees for a copy of the applicable incident reports.]	NFPA 652-2019, section 8.11, and other dust-specific NFPA standards provide guidance for investigation of incidents in a timely manner, with suggested documentation.
☐Done	20. Are any of the equipment locations designated as electrically (hazardous) classified locations? [Ask managers and employees for a copy of the electrical classification drawings and/or documents.]	Locations where hazardous levels of combustible dusts exist should be appropriately classified. (See 29 CFR 1910.399 for the definitions of Class II locations.)
☐Done	21. Have there been changes in the dust hazards or characteristics since the initial equipment or process design and installation that could create new dust hazards? If so, were appropriate changes made to prevent or mitigate any new hazards? [Ask managers,	NFPA 652-2019, section 8.12, and other dust specific standards contain provisions for changes to be made through a management of change process. Some facilities can create, handle, and/or process a number of different materials, which can change based on contract changes, demand for products, etc. When changes in

	Question	Comments
	employees, and engineers for a description of changes in dust hazards or characteristics. Ask if the employer has a management of change procedure (MOC). If so, request a copy of MOCs associated with these changes.]	materials and dust-types occur, existing equipment and systems may not be properly designed to handle the changes.

<u>Appendix D</u>
<u>Inspection Questions for Dust Collection, and for Deflagration/Explosion Prevention and Protection Equipment</u>

The following data sheet can be used as a guide for inspecting dust collection systems, and for inspecting associated deflagration/explosion prevention and protection equipment systems. [*Note: This table can also be used for air-material separators (AMSs) other than dust collectors, such as cyclones or filters used for process material sizing and/or separation.*] This is not an all-inclusive list, and should be used in conjunction with applicable standards.

Air-Material Separator (AMS) Field Data Sheet [*and guidance*]	
Manufacturer Info: *(Make, model, serial no.)*	*Who is the manufacturer of the equipment?* *What is the model?* *What is the serial number?* *[Identify markings, and obtain/review the manual]*
Employer Info: *(Equipment ID, asset no., terminology)*	*What does the employer call the AMS? How does the employer identify the AMS?* *[Identify markings, and ask questions]*
Category: *(Cartridge media dust collector, bag filter media dust collector, enclosure-less collector, cyclone, wet collector)*	*What specific type of AMS (dust collection) system is this? How does it work?* *[Ask questions, and obtain/review the manual(s)]*
Year Installed:	*When did the employer put the AMS into service or what year did the employer significantly alter the AMS?* *[Ask questions, and obtain/review purchase and installation documentation]*
General Application: *(Dust collection, or other air-material separation for a production purpose/step)*	*Does the AMS remove and collect fugitive dust from upstream equipment (i.e. dust collection), or does the AMS provide size separation for a process requirement? – describe* *[Ask questions, and review the associated process]*

Location: *(Indoor/out-door, or near exterior wall) & (Site references)*	*Where is the AMS located at the facility (outdoors / indoors)?* *If outdoors, is the AMS near any entry/exit doors, loading areas, pathways, or vents? – measure* *If indoors, is the AMS near any work stations, pathways, or exit routes? – measure* *If indoors, is the AMS near an exterior wall? – measure* *[Review AMS, and obtain/review diagrams]*
Service: *(Collecting what from where)*	*What is the process that the AMS services? What materials are being collected? What is the purpose of the AMS? Where does the collected dust go / how is it used?* *[Review upstream equipment, ask questions, and obtain/review diagrams]*
Upstream equipment: *(Equipment categories feeding the system)*	*What upstream equipment feeds into the AMS? – describe (including type, make/model, and number)* *[Review upstream equipment, ask questions, identify markings, and obtain/review manuals]*
Filter Description: *(Type, mfg., material, or NA)*	*What category of filter mechanism is utilized in the AMS (e.g., bag/sock, or cartridge)?* *What is make/model of the filter?* *What is the filter made of?* *What is the filter's supporting structure made of?* *[Review replacement filters in stock, ask questions, and identify markings.]*
Filter Cleaning Mechanism: *(Pneumatic pulse, automatic shaker, manual shaker, reverse air, or NA)*	*What is the mechanism used to periodically remove the dust cake layer from the filters?* *[Ask questions, and obtain/review the manual.]*
Approx. Dimensions: *(Total) & (Dirty side)*	*What is the total interior volume of the AMS?* *What is the volume of the dirty side of the AMS (i.e. area below the plenum that includes the dirty air inlet, filters, material discharge hopper)?* *Is the unit exempt from explosion protection requirements?*

	[Measure, obtain/review the manual, contact the manufacturer, and review applicable NFPA standards]
Material Hopper Discharge Set-up: *(Open w/ no slide gate, open w/ slide gate, rotary airlock)*	*How does the filtered material leave the bottom of the AMS?* *What is the connection between the material hopper and the discharge container?* *[Review AMS design and field installation.]*
Rotary Valve/Airlock Info: *(Make, model, Serial no., or NA)*	*If a rotary valve is utilized at the material hopper discharge opening, what are the details for the unit?* *Is the unit designed, tested, and rated for use as a deflagration propagation protection (isolation) device?* *[Review AMS design and field installation, identify markings, contact the manufacturer, and review applicable NFPA standards]*
Material Discharge Container: *(Metal container, FIBC, fiberboard drum or box)*	*Where does the filtered material discharge to?* *If there is a discharge container, what is it and what material is it made from?* *If there is no discharge container, where is the material transported and how is it transported?* *[Review AMS design and field installation.]*
Fan/Blower Location: *(Fan on clean side, blower on dirty side)*	*Where is the fan package located relative to the AMS?* *[Review AMS design and field installation.]*
Exhaust Termination: *(outside permanent, recycled inside permanent, optional/ seasonal)*	*Where does the filtered air discharge to (e.g., permanently outdoor, permanently indoors, or seasonal dependent?)* *If outdoors, where specifically?* *If directly indoors, where specifically?* *If returned indoors (from the outside), where specifically?* *If seasonal dependent, what months is it returned indoors?* *[Ask questions, and review AMS design and field installation.]*
Explosion Protection: *(Venting, chemical suppression, or none)*	*Does the AMS contain any recognized methods of explosion protection?* *If so, what are the details (type, manufacturer, model, and year of installation.)?* *If so, was the system installed by a competent party?* *If so, was the system designed for the specific properties of the materials being collected at this facility?*

	If so, is the system being properly maintained (inspected and tested)? *[Ask questions, review AMS design and field installation, identify markings, obtain/review installation documentation, review applicable NFPA standards, and obtain/review manufacturer's information.]*
Isolation Devices: *(Active system description, passive system description, or none)*	*Does the AMS contain any recognized methods of active or passive isolation to prevent deflagration propagation out of all AMS openings (such as the dirty air inlet, clean air exhaust outlet, and material discharge hopper)?* *If so, what are the details (type, manufacturer, model, and year of installation.)?* *If so, is each system being properly maintained (inspected and tested)?* *If there is no isolation device on the clean air exhaust outlet, does the ducting terminate at a safe, outdoor location away from employees and any air inlets?* *[Ask questions, review AMS design and field installation, identify markings, obtain/review installation documentation, review applicable NFPA standards, and obtain/review manufacturer's information.]* *Note: High-speed abort gates are not deflagration propagation isolation devices. They are for temporarily aborting air to a safe location during a fire condition to protect employees from the hazardous byproducts of a fire (e.g., smoke, toxic gases, embers, fire). They do not react quickly enough in normal installations to adequately prevent propagating flame front transmission, and they are not recognize by NFPA as deflagration propagation isolation devices.*
Other fire controls: *(Spark/ember detection and suppression, abort, or none)*	*Specific to exhaust air:* *If the exhaust air terminates indoors, does the AMS have recognized methods of detecting a fire condition and mitigating the hazard?* *If so, what are the details (type, manufacturer, model, and year of installation.)?* *If so, is the system being maintained (inspected and tested) per the manufacturer's recommendations?* *In general:* *Are there any upstream controls in place to detect a fire condition and provide a response?* *If so, describe the system.*

	[Ask questions, review AMS design and field installation, identify markings, obtain/review installation documentation, and obtain/review manufacturer's information.]
Evidence of prior damage: *(Explosion, deflagration, fire damage, or none)*	*Has the dust collection system (ducting, AMS, fan package) been involved in a fire, deflagration, or explosion event at this location?* *If so, what are the details?* *[Ask questions, review employer incidents, review AMS for signs of incidents/damage, and review fire department reports.]*
Sample(s) Collection and Testing Results Descriptions: *(SLTC sample information and test results, and employer testing results)*	*Where were OSHA samples taken, what SLTC tests were run, and what were the results?* *Does the employer have any explosibility parameter data for the materials being collected?* *If so, where were the samples taken from?* *If so, what tests were run and what were the results?* *[Safely obtain samples, review SLTC reports, ask questions, and review employer explosibility reports.]*
Other Notes:	

Following is a clean copy of this data sheet for use by CSHOs in the field (if desired).

Air-Material Separator Field Data Sheet	
ADD PHOTOS HERE	
Manufacturer Info: ***(make, model, serial no.)***	
Employer Info: ***(employer ID, asset no., terminology)***	
Category: ***(cartridge media dust collector, bag filter media dust collector, enclosureless collector, cyclone, wet collector)***	
Year Installed:	
General Application:	

(dust collection, air/material separation for a production purpose/step)	
Location: ***(indoor/outdoor, or near exterior wall) & (site references)***	
Service: ***(collecting what*** ***from where?)***	
Upstream equipment: ***(equipment categories feeding system)***	
Filter Description: ***(type, mfg., material, or NA)***	
Filter Cleaning Mechanism: ***(pneumatic pulse, automatic shaker, manual***	

shaker, reverse air, or NA)	
Approx. Dimensions: ***(total) & (dirty side)***	
Material Hopper Discharge Set-up: ***(open w/ no slide gate, open w/ slide gate, rotary airlock)***	
Rotary Valve/Airlock Info: ***(make, model, Serial no., or NA)***	
Material Discharge Container: ***(metal container, FIBC, or box)***	

Fan/Blower Location: ***(fan on clean side, blower on dirty side)***	
Exhaust Termination: ***(outside permanent, recycled inside permanent, optional/seasonal)***	
Explosion Protection: ***(venting, chemical suppression, or NONE)***	
Isolation Devices: ***(active system description, passive system description, or NONE)***	
Other fire controls: ***(spark/ember detection and suppression/abort or NONE)***	

Evidence of prior damage: ***(explosion / deflagration / fire damage, or NA)***	
Sample(s) Collection **and Testing Results Descriptions:** ***(SLTC sample information and test results, and employer testing results)***	
Other Notes:	

Appendix E
Low-MIE Combustible Dusts[61]

Low-MIE combustible dusts are dusts with an MIE of 30 mJ or less. Examples of low-MIE dusts are listed below for dusts tested at the particle sizes noted. The same dusts may not be low-MIE dusts when the particles are larger in size.

This is not an all-inclusive list. When CSHOs suspect that the dusts to be sampled may have MIEs at or below 30 mJ, CSHOs should either collect the samples as low-MIE dusts or contact their supervisor for direction. The RO, NO, or HRT also have experts who can assist when questions arise.

[Note 1: For size reference – white granulated sugar is 450 - 600 µm; table salt is >100 µm; beach sand is > 50 µm; soft-white wheat flour is > 45 µm; talcum powder is ~ 10 µm.]

[Note 2: If a dust does not meet the criteria in the categories below but it is observed to be an extremely fine powder (i.e. the size of common soft-white wheat flour or smaller), then CSHOs should strongly consider anticipating that the material may have a low MIE.]

Metals

- Aluminum, atomized & flake, fines (less than 75 µm)
- Magnesium (less than 75 µm)
- Aluminum-magnesium alloy, milled (less than 150 µm)
- Titanium (less than 105 µm)
- Zirconium (less than 50 µm)
- Iron, carbonyl 99% Fe (less than 54 µm)
- Tin, atomized (less than 54 µm)
- Niobium (less than 80 µm)
- Tantalum (less than 100 µm)

Food, Feedstuffs, Natural Products

- Wood flour (less than 75 µm)
- Milk sugar (less than 75 µm)
- Wheat starch (less than 75 µm)

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[61] Appendix references: Dust Explosions in the Process Industries Eckhoff, Rolf K. (2003); Explosibility of Agricultural Dusts, report of investigations 5753 United States Department of the Interior, Bureau of Mines (1961); Explosibility of Dusts Used in the Plastics Industry, report of investigations 5971 United States Department of the Interior, Bureau of Mines (1962); Explosibility of Metal Powders, report of investigations 6516 United States Department of the Interior, Bureau of Mines (1964); Explosibility of Carbonaceous Dusts, report of investigations 6597 United States Department of the Interior, Bureau of Mines (1965); Explosibility of Chemicals, Drugs, Dyes, and Pesticides, report of investigations 7132 United States Department of the Interior, Bureau of Mines (1968); NFPA 652 "Standard on the Fundamentals of Combustible Dust" (2019 edition): Tables A.5.2.2(a),(h),(i) and (j).

- Potato starch (less than 75 µm)
- Cocoa bean shell (less than 75 µm)

Other Inorganic Products

- Sulfur (less than 75 µm)

Plastics, Resins, Rubber

- Acetal, linear (less than 75 µm)
- Methyl methacrylate polymer and copolymers (less than 75 µm)
- Acrylonitrile polymer and copolymers (less than 75 µm)
- Cellulose acetate (less than 75 µm)
- Nylon (less than 75 µm)
- Polycarbonate (less than 75 µm)
- Polyethylene (less than 75 µm)
- Polypropylene (less than 75 µm)
- Polyvinyl butyral (less than 75 µm)
- Polyester, dust from grinding and polish (less than 20 µm)
- Epoxy (less than 75 µm)
- Phenol furfural (less than 75 µm)
- Phenol formaldehyde (less than 75 µm)
- Polyurethane foam with isocyanate (less than 75 µm)
- Coumarone-indene (less than 75 µm)
- Cashew oil phenolic (less than 75 µm)
- Gum (less than 75 µm)
- Lignin, hydrolyzed-wood-type (less than 75 µm)
- Rosin (less than 75 µm)
- Shellac (less than 75 µm)
- Lacquer, stripped from gas cylinders (less than 75 µm)
- Isophthalic acid (less than 75 µm)
- Salicylic acid (less than 75 µm)
- Terephthalic acid (less than 75 µm)
- Rubber dust, from grinding (less than 135 µm)

Pesticides

- 'Ferbam' (less than 75 µm)
- 'Sevin' (less than 75 µm)

Chemical Compounds, Intermediate Products, Auxiliary Materials

- Toner dust (less than 75 µm)
- Benzoic acid (less than 75 µm)

- Stearic acid (less than 75 µm)
- Methionine (less than 20 µm)
- Dehydroacetic acid (less than 75 µm)
- Diphenyl (less than 75 µm)
- Isatoic anhydride (less than 75 µm)
- Sorbic acid (less than 75 µm)
- Aspirin (less than 75 µm)
- Methyl cellulose (less than 75 µm)
- Ethyl cellulose (less than 75 µm)
- Dimethyl terephtalate (less than 32 µm)
- Ferrocene (less than 125 µm)
- Naphthalene (less than 500 µm)
- Naphthalic acid anhydride (less than 63µm)
- 2-Naphtol (less than 71 µm)
- Pentaerythrite (less than 500 µm)
- Lead stearate (less than 75 µm)
- Calcium stearate (less than 500 µm)
- Zinc stearate (less than 75 µm)

Carbonaceous Materials

- Charcoal, hardwood mixture (less than 75 µm)
- Gilsonite (less than 75 µm)
- Pitch, coal tar & petroleum (less than 75 µm)
- Asphalt, brown petroleum resin (less than 75 µm)

Nanoparticles/Nanomaterials/Nanometals and Extremely Fine Powders

Nanoparticles (including nanomaterials and nanometals) can behave in a highly reactive manner due to their extremely fine particulate size, which increases the ignition potential and the combustion rate. There are similar concerns for extremely fine powders of all categories of combustible dusts. A hazardous process that utilizes/generates nanometals includes 3D printing operations utilizing combustible metals. A process that generates extremely fine particulate metal powder is abrasive blasting operations utilizing steel shot. Sampling during these processes should be handled with extreme care.

[Note 1: Combustible dust associated with abrasive blasting utilizing steel shot should be considered as a low MIE dust unless determined otherwise.]

Note 2: Combustible dusts associated with 3D printing operations utilizing metal powders should be sampled only after consultation with your Region and HRT as they can be extremely hazardous.

Appendix F
Combustible Dusts with Other Hazards

Other hazards are sometimes associated with combustible dusts. The following are examples of combustible dusts with other hazards.

[*Note: This is not an all-inclusive list. When CSHOs suspect that the dusts to be sampled may have other hazards, CSHOs should contact their supervisor for direction. The RO, NO, and HRT also have experts who can assist when questions arise*.]

Toxic Dusts

- Many pharmaceutical drug dusts
- Aluminum ferrosilicon powder
- Aluminum phosphide
- Arsenic powder
- Barium azide
- Beryllium powder
- Calcium phosphide
- Decaborane
- Dinitrophenol
- Ferrosilicon
- Ferrous arsenate
- Lead dusts
- Potassium phosphide
- Stannic phosphides
- Zinc phosphide

Self-Heating and Self-Reactive Dusts

Self-heating and self-reactive dusts do not have to be dispersed in the air to ignite.

- Activated carbon
- Calcium hydrosulfite
- Cyclooctadiene phosphines
- Some ferrous metals
- Hafnium powder
- Magnesium powder
- Metal catalysts
- Potassium sulfide
- Thiourea dioxide
- Titanium powder
- Xanthates
- Zinc powder

- Zirconium powder

Dangerous-When-Wet Dusts

Dangerous-when-wet dusts react with water/moisture to release hydrogen gas. These dusts do not have to be dispersed in air to ignite.

- Alkali metal and alkali metal alloys (e.g., Lithium, Sodium, Potassium, Rubidium, Cesium, Francium)
- Aluminum carbide
- Aluminum ferrosilicon powder
- Aluminum hydride
- Uncoated aluminum powder
- Aluminum smelting products
- Barium
- Cesium
- Calcium
- Calcium carbide
- Calcium cyanamide
- Calcium phosphide
- Cerium
- Chlorosilanes
- Some cosmetic dusts
- Ferrosilicon
- Magnesium powder
- Phosphorous pentasulfide
- Potassium phosphide
- Stannic phosphides
- Titanium powder
- Zinc
- Zirconium

Corrosive Dusts

- Alkali metal and metal alloys

Radioactive Dusts

- Cesium and alloys
- Uranium and alloys
- Plutonium and alloys

Appendix G
Procedure for Safe Sampling of Most Combustible Dusts

Most combustible dust samples can be collected safely by wearing PPE described in the *NEP* and by following this procedure.

Safely Collecting Samples Using Approved Equipment and Methods

- **Do not use this procedure for collecting samples of low-MIE dusts**. See *Appendix E, Low-MIE Combustible Dusts*. Follow *Appendix H, Procedures for Safe Sampling of Low-MIE Dusts* for sampling these dusts.
- **Do not use this procedure for collecting samples of metal dusts**. Follow *Appendix I, Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*.
- **Do not collect samples of combustible dust hybrid mixtures** (e.g., combustible dust present with flammable gas, vapor, or liquid present), **or dusts that have other hazardous characteristics without the approval of your area office, in consultation with other offices and teams as necessary**. See *Appendix F, Combustible Dusts with Other Hazards*
- **Never sample when dust is suspended in the air, and take care not to generate suspended dust while sampling.**

General Safety Considerations

- Wear the proper PPE including a hard hat, safety glasses, and flame-resistant clothing (FRC).
- Utilize a 1-liter plastic sampling container, an aluminum, non-sparking scoop, and a natural bristle brush (Figure VII-1).

Figure VII-1: Sampling Kit: 1 Liter Sample Collection Bottles, Metal (Aluminum) Scoop, and a Natural Fiber Brush. (Source: OSHA SLTC)

- Avoid generating dust clouds during sampling. Avoid aggressive motions and techniques. Also, do not collect samples overhead where you do not have a clear line of site as dust clouds may be formed over your head.
- Avoid leaning over/into drums when sampling out of collection containers.
- If accumulations on overhead structural supports cannot be safely accessed, consider obtaining samples from other elevated locations such as from railings, building structural components, or equipment surfaces accessible from mezzanines, staircases, or other work platforms that contain compliant guardrail systems. If no alternatives exist contact your Area Office and Regional Office for guidance.
- Avoid collecting samples from inside of equipment that may require LOTO and/or PRCS procedures to safely obtain. Representative samples can normally be taken from upstream and downstream locations.

Other Technical Considerations

- For area samples - when a 1-liter sample cannot be attained from the highest locations, start collecting dust from the highest safely-accessible levels in the same area and work your way down (if necessary) in that same area in order to fill the 1-liter bottle. Each sample collected must be representative of the sampling location or area.
- For equipment representative samples – Representative samples should be taken for each piece of equipment anticipated of being an explosion hazard and having the potential for being involved in a citation due to recognized unsafe condition.
- Do not collect dusts from multiple locations to develop an aggregate sample if the sample will not be representative of the area.
- Collect as much of the sample as possible up to one liter. More than one liter may be required for dusts with very low bulk densities. In some cases where less than one liter is all that can be collected, contact the SLTC Lab for guidance.
- If multiple tests are being requested of the SLTC Lab (e.g., K_{st}, Class II, and Bulk Density), additional samples may be required.[62] Except on rare occasion, either K_{st} or Class II testing is required but not both. In almost all cases, the bulk density test is a stand-alone test. CSHOs should take separate samples for each test that they need performed.
- Samples shall not be collected in plastic bags because they cannot be sealed tightly enough to prevent sample leakage or moisture loss. In addition, these bags have a bellows effect which can make the dust airborne when collecting, closing, opening, or emptying the samples.

Handling, Documenting, Labelling, and Preserving Sample Integrity

- OSHA 21 seals must be accurate and legible to match the OSHA 91A form, and must be properly affixed with the seal contacting both the lid and the container.

[62] Low bulk density dusts may actually require more than one liter. Contact the lab when needed. Some dust bulk densities are available in NFPA 61, 484, 652, and 664 as well as on line, for example, at: https://www.binmaster.com/_resources/dyn/files/75343622z9caf67af/_fn/Bulk+Density.pdf.

- OSHA 91A forms must be accurate and legible, and should indicate the test requested (e.g., IMIS code M102 for K_{st}, or IMIS code E101 for Class II) as well as other useful information such as a sample description, sampling location, and brief process description. Information critical to lab personnel safety and health when handling and processing the samples is imperative.
- If an SDS is available, include a copy with the sample.
- Keep samples out of the sun.
- Store samples:
  - in a dry location,
  - clear of other combustible materials,
  - away from sources of heat,
  - away from work areas, and
  - protected from tampering.

Appendix H
Procedures for Safe Sampling of Low-MIE Combustible Dusts

The purpose of the procedures in this section are to establish the minimum requirements necessary to ensure CSHO safety when taking bulk samples of combustible dusts, which may be sensitive to ignition from human electrostatic discharge when suspended in air (see *Appendix E, Low-MIE Combustible Dusts*).

Do not follow the procedures in this section if the combustible dusts:

- **Are hybrid mixtures (e.g., combustible dusts present with flammable gases, vapors, or liquids present)**. Contact your AO and/or other offices within OSHA as needed to get approval to sample. For assistance with sampling hybrid mixtures contact the HRT. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]
- **Have other hazardous characteristics (e.g., toxic, pyrophoric, corrosive, or radioactive).** See *Appendix F* for examples of combustible dusts with other hazardous characteristics. For sampling combustible dusts with other hazardous characteristics, contact your AO and/or other offices within OSHA as needed to get approval to sample. For assistance with sampling these mixtures contact the HRT. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]

For combustible metal dusts - in addition to this section of Low-MIE combustible dusts, be sure to follow the additional guidance found in *Appendix I, Procedures for Safe Sampling of Combustible Metal Dusts (Beyond Low-MIE)*.

When there are serious concerns about safely sampling dust(s):

- **Call the AO and discuss the concerns with your assistant area director (AAD) and/or area director (AD).**
- **If the determination after discussion is that it is too dangerous for you to sample, consult with the RO to determine how to proceed. The region can escalate concerns to the HRT or to DEP, Office of Chemical Process Safety and Enforcement Initiatives (OCPSEI) as appropriate.**
- **If an imminent hazard exists, an imminent hazard notice may be appropriate in accordance with the FOM.**

In most cases CSHOs should be collecting their own samples. However, in some cases when dealing with low-MIE combustible dusts, facility personnel (only those who are familiar with the hazards and handling procedures for the dust) could be used to take the samples while the CSHO observes. This should be a rare occurrence.

The procedures CSHOs should follow when sampling low-MIE dusts are described below.

- *Introduction*
- *Low-MIE Hazard Awareness*

- *Required PPE for Sampling Low-MIE Dusts*
- *Required Sampling Tools for Sampling Low-MIE Dusts*
- *Sampling Low-MIE Dusts from Metal Collection Drums*
- *Sampling Low-MIE Dusts from Horizontal or Vertical Surfaces*
- *Sampling Low-MIE Dusts from Inside Equipment Such as Dust Collectors, Ductwork, and Size-Reducing Equipment*
- *Sampling Low-MIE Dusts from Non-Metallic or Non-Conductive Containers Such as Plastic and Fiberboard Drums*
- *Sampling Low-MIE Dusts from Other Containers or Equipment Not Covered Above*

a. Introduction

As discussed in the *Combustible Dust Characteristics* section, the MIE is the lowest spark energy capable of igniting the most ignition-sensitive concentration of a combustible dust in cloud form. Some dusts can be ignited with very little energy (i.e. MIE less than or equal to (≤) 30 milli-joules, mJ).

Static electric discharges from the human body can reach between 10 and 30 mJ. An MIE of 30 mJ, is therefore, commonly listed as a threshold below which personnel bonding and grounding is considered a preventive measure.

Dusts with MIEs ≤ 30 mJ are referred to as 'low MIE' dusts within this chapter. These dusts include, but are not limited to, most non-ferrous metal dusts, and extremely fine particulates (powders) of other materials including foods, feedstuffs, natural products, plastics, resins, rubbers, and other chemical compounds (see the *Low-MIE Combustible Dusts* appendix for examples).

Several NFPA standards, such as NFPA 652-2019 and NFPA 484-2019, require personnel grounding when manually filling or emptying particulate containers or vessels for particulates (e.g., dusts) with MIEs of 30 mJ or less due to concerns with the formation of ignitable dust clouds. In addition, NFPA 652-2019 requires that dust samples be collected "in a safe manner without introducing an ignition source, dispersing dust, or increasing the risk of injury to workers."

Dust sampling activities such as scooping, sweeping, and transferring dusts have the potential to form a dust cloud (e.g., aggressive motions, dropped scoop, dust clinging to the interior sides of a collection drum and suddenly loosening, process vessel above the collection drum releasing dust, or spilling dust while transferring).

When manually handling low MIE dusts, CSHOs must consider the potential for a dust cloud occurring, must ensure the use of controls for potential electrostatic ignition sources, and must don appropriate PPE. These precautions include the following controls (in order of hierarchy):

1. Avoid the formation of a dust cloud during the sampling activity,
2. Utilize bonding and grounding procedures,

3. Wear PPE including hard hat, safety glasses, and FR clothing.

b. Low-MIE Hazard Awareness

As discussed above, CSHOs should be aware of combustible dusts that have the potential for having MIEs ≤ 30 mJ. However, MIEs are not a universal property of any given dust. The actual MIE for a material will vary based on several factors, such as particle size and moisture content. CSHOs should also recognize that material degradation is an inherent function of dust processing, handling, and conveying processes, so that the size of dust particles at the beginning stage of a process will generally be larger than the size in the dust collection system, in downstream processing equipment, and/or in the work environment (as fugitive emissions). *Appendix E, Low-MIE Combustible Dusts* contains notations for the size fraction of the dust tested, and the MIEs listed are only for the dusts of that size. CSHOs should exercise caution in determining whether a published MIE adequately represents the actual MIE of a given dust.

When there is a question, CSHOs should obtain additional information regarding combustible dust MIEs prior to sampling. Other potential sources of information may include any chemical manufacturer explosibility data listed on the SDSs, and/or the results of any employer-commissioned explosibility parameter testing (e.g., results of MIE of a Dust Cloud in Air via the ASTM E2019 test method).

CSHOs should consider a dust to be sampled as hazardous under this protocol if any chemical manufacturer data, employer commissioned MIE testing results, or published data show that the MIE of a material either is ≤ 30 mJ or is likely to be ≤ 30 mJ in the form to be sampled. In these cases, CSHOs should obtain samples necessary to support an enforcement action in a safe manner using procedures in this protocol, and in coordination with their supervisor. In addition, if the dust does not meet the criteria above, but is observed to be an extremely fine powder (i.e. the size of common flour or smaller), CSHOs should strongly consider using the guidelines in this protocol for sampling.

In cases of hybrid mixtures (e.g., combustible dust present with flammable gas, vapor, or liquid present), or combustible dusts with other hazards, or where MIE is excessively low (i.e., ≤ 1 mJ), do not collect a sample without AO and RO approval. The OSHA HRT may be consulted if there are questions as to how to safely take these samples. The Regional Office should be notified in cases where HRT assistance, beyond simple consultation, may be necessary.

c. Required PPE for Sampling Low-MIE Dusts[63]

CSHOs taking bulk samples of low-MIE combustible dust shall wear:

[63] NFPA 2112 compliant flame-resistant clothing is available from the OSHA Cincinnati Technical Center's (CTC) Agency Expendable Supplies Program (AESP).

- FRC for flash fire protection which complies with the requirements of NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel against Short-Duration Thermal Exposures from Fire*. Such clothing shall have a certification label attached to the garment stating: "**THIS GARMENT MEETS THE REQUIREMENTS OF NFPA 2112. NFPA 2113 REQUIRES UPPER AND LOWER BODY COVERAGE.**"
- FRC worn and cared for in accordance with the requirements of NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel against Short-Duration Thermal Exposures from Fire*. Guidance on use, includes, but is not limited to the following:
    - Fully button and close collars,
    - Fold down and secure sleeves and cuffs,
    - Wear FRC as the outermost garment, and
    - Wear heat-tolerant undergarments that resist melting (e.g., cotton, aramid, wool). [*Note: An incidental amount of elastic on non-melting fabric underwear and socks is permitted.]*
- Safety glasses to protect the eyes. *[Note: There are no known commercially available face shields rated for flash-fire protection, so face shields are not required.]*
- NFPA 2112 compliant balaclavas or hoods to protect the face and neck (encouraged, not required).
- Hard hats to protect the head.

Gloves should <u>not</u> be worn to ensure continuity with non-sparking, aluminum scoops. If gloves are necessary due to a hazard scenario, gloves should be conductive or antistatic.

d. <u>Required Sampling Tools for Sampling Low-MIE Dusts</u>[64]

The following sampling tools shall be available to CSHOs when performing low-MIE combustible dust inspections:

- 1-liter plastic sampling containers
- Aluminum, conductive, non-sparking scoops
- Natural bristle brushes
- Sample seals (Form OSHA-21)
- Bonding and grounding equipment:
    - One (1) bonding cable with hand-activated ground clamps on each end having sharp, hardened stainless steel contact points [Referred to hereafter as the "**double hand clamp bonding wire"** (Figure VIII-1)]

[64] All of the listed sampling equipment is available from the OSHA Cincinnati Technical Center's (CTC) Agency Expendable Supplies Program (AESP).

Figure VIII-1: Double hand clamp bonding wire. (Source: OSHA HRT)

- One (1) bonding cable with one end hand-activated ground clamp with a sharp, hardened stainless steel contact point, and the other end having a c-clamp with thumb screw opposite a sharp, hardened stainless steel contact point [Referred to hereafter as the **"scoop bonding wire"** (Figure VIII-2)]

Figure VIII-2: Scoop bonding wire. (Source: OSHA HRT)

- Two (2) heel grounders (Figure VIII-3), which should be used only while the low-MIE combustible dust sample is being taken.[65]

[65] For the purposes of OSHA inspections, static dissipative footwear will not reliably provide adequate personnel grounding. This is because when an employer relies on static-dissipative footwear alone for ignition source control, the floor resistance to ground needs to be maintained between 10^6 and 10^8 ohms (and even higher resistivity for low MIE dusts). Floor deposits, residues, and coatings can limit floor conductivity and limit the effectiveness of such footwear. Furthermore, OSHA does not have control over employers' floors and does not have quick, reliable methods of determining floor resistance. Finally, static dissipative footwear presents additional hazards where a

Figure VIII-3: Heel grounders.
(Source: OSHA HRT)

e. <u>Sampling Low-MIE Dusts from Metal Collection Drums</u>

1. Don the heel grounders prior to sampling.
2. Bond the metal collection drum to the metal frame of the dust collector, hopper, beam or other grounded metal surface using the **double hand clamp bonding wire**.
   a. It is imperative that CSHOs make a specific effort to penetrate any paint or coating that may be on the surface of the metal used to establish a reliable ground path.
   b. CSHOs shall visually verify that the grounding clamps contact clean metal surfaces.
   c. CSHOs shall also verify a grounding path based on observation of the connection of the metal frame of the dust collector, hopper, beam or other metal surface and ground (e.g., there should be no vibration isolators beneath equipment feet, or no insulating washers used on anchor bolts).
3. Clamp the hand activated clamp end of the **scoop bonding wire** to the metal collection drum.
4. Attach the thumb screw end of the **scoop bonding wire** to the handle of the aluminum, conductive hand scoop.
5. Check that all systems are visually bonded (Figure VIII-4):
   a. Metal drum to the dust collector, hopper frame, or ground rod via the **double hand clamp bonding wire**.
   b. Aluminum, conductive hand scoop to the metal drum via the **scoop bonding wire**.
   c. CSHO to the metal drum and dust collector or hopper frame via the grasping of the aluminum, conductive hand scoop with a bare hand.

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possibility of electrocution by line voltages exists. <u>This procedure therefore recommends the temporary wearing of heel grounders as a secondary precautionary measure and does not solely rely on heel grounders to achieve the grounding of personnel.</u>

6. CSHOs shall ensure that the dust collection and hopper transfer systems are adequately controlled by the employer prior to performing the sampling. This is to ensure that a dust cloud is not formed external to the collection drum (from the release of dust from the discharge outlet of the collector or hopper) during the sampling event. This could include the manual activation of a slide gate on the discharge outlet of the collector or hopper, the immediate replacement of the removed drum with an alternate drum, or taking the sample when the dust collection system is off-line.
7. Carefully scoop the combustible dust from the collection drum with the aluminum, conductive hand scoop.
   a. **<u>Be cautious to avoid generating a dust cloud during sampling</u>.**
   b. If possible, avoid leaning into the drum with the upper torso and face during sampling.
8. Transfer the contents of the scoop into a 1-liter sampling container.
9. Repeat until the 1-liter sampling container is nearly full. Close the lid tightly and wipe off excess dust that may be clinging to the bottle.
10. Apply the sample seal.
11. Remove the heel grounders and bonding wires.
12. Notify the employer that sampling is complete.

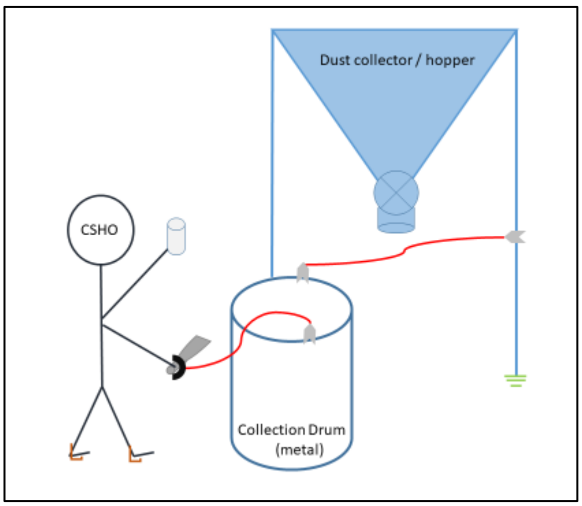


Figure VIII-4: Sampling low-MIE dusts from metal collection drums. (Source: OSHA R5)

f. <u>Sampling Low-MIE Dusts from Horizontal or Vertical Surfaces</u>

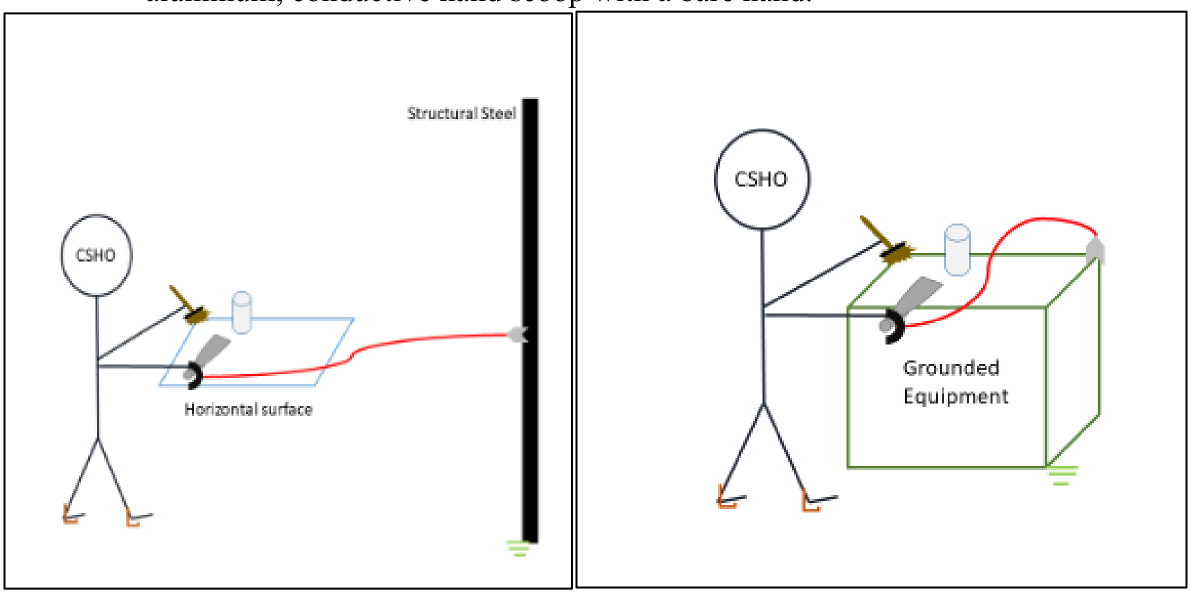
1. Don the heel grounders prior to sampling.
2. Connect the hand activated clamp end of the **scoop bonding wire** to a nearby grounded metal surface (e.g., structural steel beam or metal frame of equipment bolted directly to the floor).[66] *[Note: It is imperative that CSHOs make a specific*

[66] See footnote 79 if there is not a grounded metal surface to bond to.

effort to penetrate any paint or coating that may be on the surface of the metal used to establish a reliable ground path.]

a. CSHOs shall visually verify that the grounding clamps contact clean metal surfaces.
b. CSHOs shall also verify grounding path based on observation of the structural steel or metal equipment, and ground. (e.g., there should be no vibration isolators beneath equipment feet or no insulating washers used on anchor bolts).

3. Attach the thumb screw end of the **scoop bonding wire** to the handle of the aluminum, conductive hand scoop.
4. Check that all systems are visually bonded (Figures VIII-5 and VIII-6):
   a. Grounded structural steel or grounded equipment to the aluminum conductive scoop via the **scoop bonding wire**.
   b. CSHO to grounded structural steel or grounded equipment via the grasping of the aluminum, conductive hand scoop with a bare hand.



Figures VIII-5 and VIII-6: Sampling low-MIE dusts from horizontal or vertical surfaces. (Source: OSHA R5)

5. Utilize a natural bristle brush or your clean hand to gently sweep the dust into the aluminum, conductive hand scoop.
6. **Be cautious and avoid the use of excessive force or speed across the surface upon which the dust has accumulated.**
7. **Avoid generating a dust cloud.**
8. Transfer the contents of the scoop into a 1-liter sampling container.
9. Repeat until the 1-liter sampling container is nearly full. Close the lid tightly and wipe off excess dust that may be clinging to the bottle.
10. Apply the sample seal.
11. Remove the heel grounders and bonding wires.
12. Notify the employer that sampling at that location has been completed.

g. Sampling Low-MIE Dusts from Inside Equipment such as Dust Collectors, Ductwork, and Size-Reducing Equipment

Sampling combustible dusts from directly inside of hazardous equipment should be performed **only if a representative sample cannot be obtained from outside the equipment** and must be done in coordination between the Area Office, Regional Office (including HRT) if necessary and OSHA's SHMS chapters on LOTO and PRCS as applicable**.** See *Combustible Dust Equipment Considerations*, Evaluation of Dust Equipment Hazards, for more discussion on this topic.

If the sampling of combustible dusts from directly inside of hazardous equipment (1) has been determined to be necessary, and (2) all applicable precautions have been taken to protect the CSHO and any assisting employer representatives/ employees (e.g., compliance with OSHA's SHMS chapters on LOTO and PRCS, and compliance with 29 CFR 1910.147 and 1910.146), then sampling of Low-MIE dusts from inside equipment may be permitted. The basic elements of a sampling procedure for this scenario are provided below; however, CSHOs and Area Offices are encouraged to work with their Regional Office and HRT to ensure that this procedure is adequate for the specific scenario at hand (e.g., work environment, equipment, and dust characteristics).

Important: This basic outline of a potential sampling procedure is contingent on being able to first – obtain approval from your AO and RO, second – develop plans to ensure compliance with OSHA's SHMS chapters and 29 CFR 1910.147 and 1910.146 as applicable, and third – execute the procedure and ensure compliance with applicable standards.

[*Note 1: In addition, if the space is a permit-required confined space, no OSHA personnel are to break the plane of the space with any portion of their body*.]

[*Note 2: If access doors or other openings need to be removed in order to collect the sample, request this be done by plant personnel under the protection of 29 CFR 1910.147 and 1910.146 as applicable*.]

Elemental Secondary Steps to Consider for a Sampling Procedure (beyond preparing the space for safe access)

1. Allow any suspended dusts inside the equipment to settle before sampling.
2. Don the heel grounders prior to sampling.
3. CSHOs shall verify a grounding path based on observation of the connection of the dust collector, hopper, ductwork, or other equipment and the concrete floor/ground (e.g., there should be no vibration isolators beneath equipment feet or no insulating washers used on anchor bolts).
4. Clamp the hand activated clamp end of the **scoop bonding wire** to the metal equipment. *[Note: It is imperative that CSHOs make a specific effort to penetrate any paint or coating that may be on the surface of the metal used to establish a reliable ground path.]*

5. Attach the thumb screw end of the **scoop bonding wire** to the handle of a **non-sparking, conductive extension scoop assembly**[67] (Figure VIII-7).

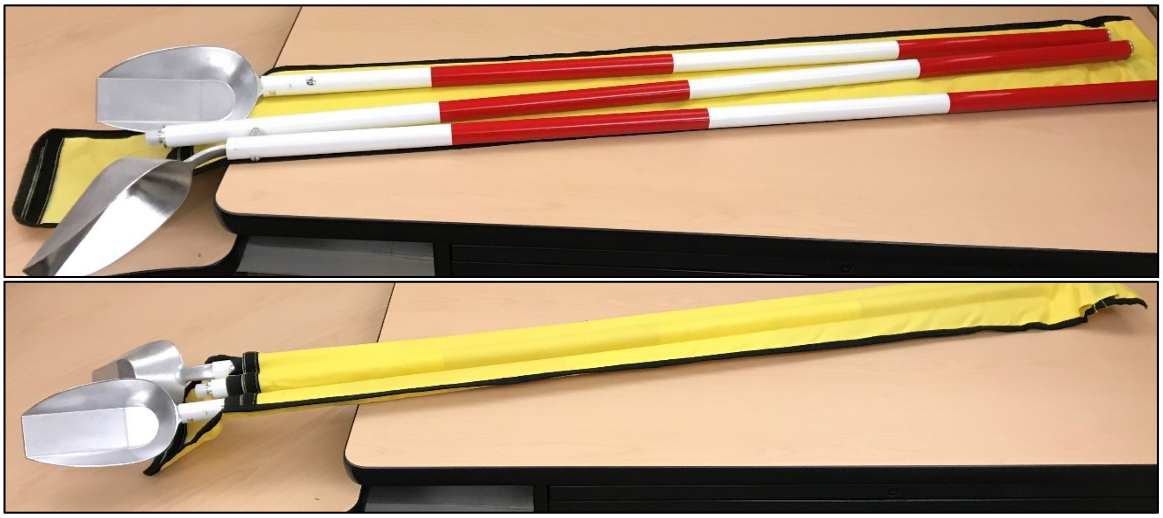


Figure VIII-7: Non-sparking, aluminum extension scoop assembly. (Source: OSHA HRT)

6. Check that all systems are visually bonded (Figure VIII-8):
   a. Non-sparking, conductive extension scoop assembly to the metal equipment via the **scoop bonding wire**.
   b. Equipment to ground.
   c. CSHO to the metal equipment via the grasping of the aluminum, conductive hand scoop with a bare hand.
7. Carefully scoop the combustible dust from the equipment with the non-sparking, conductive extension scoop.
   a. <u>Be cautious to avoid generating a dust cloud during sampling</u>.
8. Transfer the contents of the scoop into a 1-liter sampling container.
9. Repeat until the 1-liter sampling container is nearly full.
10. Close the lid tightly and wipe off excess dust that may be clinging to the bottle.
11. Remove the heel grounders and bonding wires.
12. Notify the employer that sampling at that location is complete.

[67] This is an assembly with two, 4' aluminum screw-together extension rods and an aluminum scoop. The aluminum scoop must be tightly taped to the rod so that metal-to-metal contact is assured. This assembly is available from the HRT upon request.

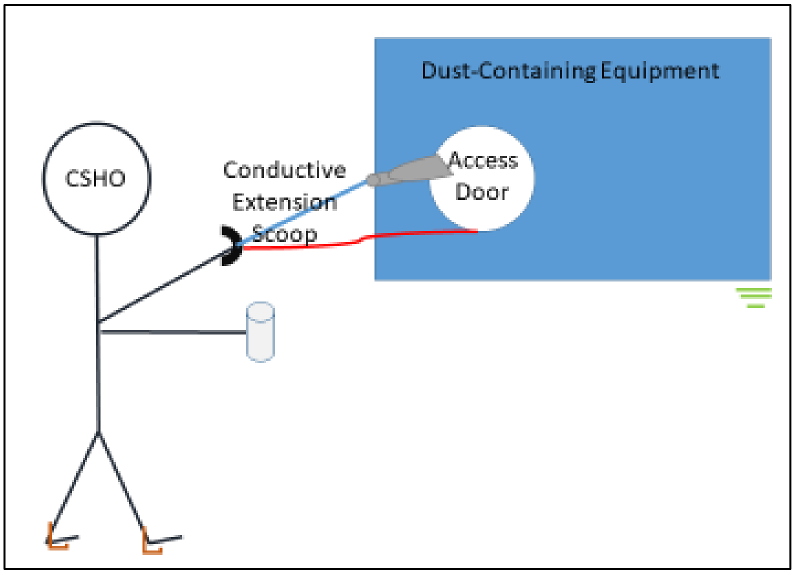


Figure VIII-8: Sampling low-MIE dusts from inside equipment. LOTO by employer with no confined space entry required. This should be a rare occurrence. (Source: OSHA HRT)

h. <u>Sampling Low-MIE Dusts from Non-Metallic or Non-Conductive Containers such as Plastic Drums or Fiberboard Drums</u>

Conductive dusts are restricted from storage in non-metallic or non-conductive containers except under very strict conditions (see for example NFPA 77-2019, paragraph 11.1.2.4, NFPA 484-2019, sections 16.4.1 and 16.4.2, and NFPA 652-2019, section 9.4.7). **Samples of conductive dusts (whether low-MIE or not) should not be taken from non-conductive containers**.

If a sample is needed, determine if the sample can be collected from another location or container. If a sample of a conductive dust is required from a non-metallic or non-conductive container, then HRT assistance is likely necessary. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]

When there are serious concerns about safely sampling dust(s):

- **Call the AO** and discuss the concerns with your AAD and AD.
- **If the determination after discussion is that it is too dangerous for you to sample, consult with your RO to determine how to proceed**. The region can escalate the concerns to the HRT or DEP/OCPSEI as appropriate.
- If an imminent hazard exists, **an imminent hazard notice may be appropriate** in accordance with the FOM.

i. <u>Sampling Low-MIE Dusts from Other Containers or Equipment Not Covered Above</u>

When samples of low-MIE combustible dusts must be collected from containers or equipment that do not fall in the categories covered above, sampling should not be done until approved by the AO and RO. In some cases, a specific procedure may have to be developed or sampling may have to be performed by the HRT, or by other professionals familiar with bonding, grounding, and sampling methods. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]

Appendix I
Procedures for Safe Sampling of Combustible Metal Dusts
(Beyond Low-MIE)

Combustible metals dusts have specific characteristics, and the associated hazards cannot always be grouped with other combustible dusts. The conditions in NFPA 484 are also, in some cases, somewhat different than for other dusts. As a result, safe sampling of combustible metal dusts is covered specifically in this section.

Hazards Specific to Combustible Metal Dusts

Many metal dust particulates present a fire, deflagration, and explosion hazard and may include metal powders, dusts, fines, turnings, sponge, and swarf.

- Many metal dusts react with moisture to release hydrogen gas. Examples include alkali metals (lithium, sodium, potassium, rubidium, and cesium); uncoated aluminum powder and aluminum smelting by-products; calcium powder; magnesium powder; zinc powder; and zirconium powder.
- Many metal dusts burn at very high temperatures (>3000ºF) when ignited. High temperature "thermite" reactions (used in some industries) can occur when metal powders are burned with metal oxides such as aluminum burning with iron oxide.
- A hybrid mixture can be present (e.g., combustible dusts with flammable gases, vapors, or liquids present) when handling some metals in a combustible form, due to hydrogen generation through moisture reaction or by the presence of oils or solvents during milling operations. Even when the metal has an MIE greater than 30 mJ, the MIE of the hybrid mixture can be less than 30 mJ.

Procedures for Safe Sampling of Combustible Metal Dusts

When you have serious concerns about safely sampling dust(s):

- **Call the AO** and discuss the concerns with your AAD and AD.
- **If the determination after discussion is that it is too dangerous for you to sample, consult with your RO to determine how to proceed.** The region can escalate the concerns to the HRT or DEP/OCPSEI as appropriate.
- If an imminent hazard exists, **an imminent hazard notice may be appropriate** in accordance with the FOM.

If CSHOs are taking the sample and the employer has a procedure (or procedures) that can be used for sampling:

- Review their procedure(s) and follow their procedure(s) if they are in agreement with the safety provisions in the NEP and in this chapter.
- If not totally in agreement, review and incorporate portions of their procedure(s) that are of value into your sampling procedure.

If the employer does <u>not</u> have a procedure (or procedures) that can be used for sampling then proceed as follows:

- Prior to sampling, always ensure that open areas inside of containers and equipment of combustible metal dusts are well ventilated. Hydrogen gas and other possible gases need to be dissipated from the area before sampling and are quickly removed from areas when the areas are well ventilated. *[Note: Although some metal dusts may not generate hydrogen or other flammable gases, this is a good procedure to follow for all metal dust sampling to be sure that no flammable gases are present.]*
- Almost all metal dusts are conductive. Therefore, **do not sample metal dusts that are in non-metallic or non-conductive containers**. See *Sampling Low-MIE Dusts from Non-Metallic or Non-Conductive Containers*.
- If the metal dust does not have a low-MIE (see examples in *Appendix E: Low-MIE Combustible Dusts*), follow the *Procedure for Safe Sampling of Most Combustible Dusts*.
- If sampling low-MIE metal dusts from, or on, conductive containers or surfaces, follow the procedure for *Sampling Low-MIE Dusts from Metal Collection Drums*, or *Sampling Low-MIE Dusts from Horizontal or Vertical Surfaces*.
- If sampling low-MIE metal dusts from inside equipment, follow the procedure for *Sampling Low-MIE Dusts from Inside Equipment*.
- When samples of metal dusts must be collected from containers or equipment that do not fall in the categories covered above, **sampling should not be done until approved by the AO and RO**. In some cases, a specific procedure may have to be developed, or sampling may have to be performed by the HRT, or by other professionals familiar with the metals, and the bonding, grounding, and sampling methods. [*Note: Use of the HRT for site visits to perform sampling or other activities must be approved by the RO.*]

Appendix J
SLTC Laboratory Tests

The tests described in this appendix are commonly performed at the SLTC laboratory. Other combustible dust tests are available, but not performed at the SLTC lab. When other tests are necessary, CSHOs can contact the SLTC Lab or HRT for assistance in finding accredited labs that can perform the needed tests. *[Note: See* *Appendix K, ASTM Test Methods**, for a compilation of combustible dust test methods from the American Society for Testing and Materials (ASTM).]*

Screen Analysis

All received samples have a screening analysis performed to determine the percentages of the different sizes of material in the samples. This analysis consists of the following steps:

1. An aliquot of sample is placed on top of a sieve stack.
2. The sample is sieved through a 20 mesh (850µm), a 40 mesh (425µm), and a 200 mesh (75µm) screen.
3. The material passing through each screen is weighed and recorded.
4. Weights are summed up from the top screen to the bottom screen.
5. The percent passing each screen is calculated as:

(>20 Mesh Weight / Total Weight) x 100
(>20 Mesh Weight + >40 Mesh Weight / Total Weight) x 100
(>20 Mesh Weight + >40 Mesh Weight + >200 Mesh Weight / Total Weight) X 100
(< 200 Mesh Weight / Total Weight) X 100

Percent Moisture Content

Moisture content is a factor which may affect dust explosibility, and is the initial determination made on an aliquot of all dust samples that are received at the SLTC Laboratory. Moisture in dust particles raises the ignition temperature.

Dusts with more than 5% moisture are dried prior to performing explosibility tests. Drying sample materials to (or less than) the 5% moisture content level is a standardized test protocol. The moisture content is determined by measuring the weight loss after drying. This test method must be modified when the materials being tested degrade at 75ºC. Percent moisture content of as-received material is determined as follows:

1. Weigh crucible.
2. Weigh aliquot of sample in crucible.
3. Dry for a minimum of 12 hours in a drying oven set at 75ºC.
4. Reweigh the crucible and aliquot.
5. Subtract weight of crucible.
6. Calculate the moisture content as:

[(Initial Wet Weight – Dry Weight) / (Initial Wet Weight)] x 100

Percent Combustible Material

Percent combustible material is the percent of the less than 40 mesh fraction of the sample that will burn. Percent combustible material is determined as follows:

1. Weigh crucible.
2. Weigh aliquots of non-dried (as-received) material which passed through a 40 mesh sieve.
3. Heat for one hour, uncovered, at 600ºC in a muffle furnace.
4. Reweigh the ash residue.
5. Calculate the combustible material as:

[(Initial Wet Weight – Ash Weight) / (Initial Wet Weight)] x 100

Percent Combustible Dust

Percent combustible dust is the product of the percent of material which went through a 40 mesh sieve and the percent combustible material. This produces the percent of the total sample that is a combustible dust, and is calculated as:

(% through 40 mesh)(% combustible material) / 100

[Note: Be aware of the distinction between combustible material and combustible dust as discussed in the Percent Combustible Material section above.]

Maximum Normalized Rate of Pressure Rise (dP/dt) – K_{st} Test

In this test, the dust sample is suspended in a 20-liter explosibility testing chamber (shown in Figure XI-1) and is ignited using a chemical igniter. The 20-liter explosibility testing chamber determines the maximum pressure and rate of pressure rise of the sample. These parameters are used to determine the maximum normalized rate of pressure rise (K_{st}). K_{st} is calculated as:

$$K_{st} = (dP/dt)_{max} \ V^{1/3}$$

Where:

$(dP/dt)_{max}$ = the maximum rate of pressure rise.
V = the volume of the testing chamber.

The K_{st} test involves the following steps:

1. The dust is tested "as received" (except drying).
2. If the moisture content is greater than 5%, the dust is dried following the Percent Moisture Content test procedure above.

3. The dust sample is suspended in a 20-liter explosion chamber which uses 2500 J Sobbe igniters (Figure X-1).
4. Test at three to five dust concentrations, from 500 g/m^3 to about 2500 g/m^3. Plot the maximum normalized dP/dt values versus dust concentration, and report the highest value from the plateau of the plot.

*[Note: CSHOs should be aware that SLTC's 20 L chamber explosibility tests differ from the ASTM E1226 protocols used by private industry, due to testing of the material in the "as received" condition (and also partially due to a lower ignition energy and a low turbulence chamber). The K_{st} values provided by SLTC are lower than the K_{st} values from most outside commercial labs. CSHOs should therefore caution employers that the K_{st} values determined at SLTC **cannot** be used for the design of protective systems for equipment handling combustible dusts. They are intended to conservatively establish whether a dust explosion hazard exists, not for use in equipment design.*]

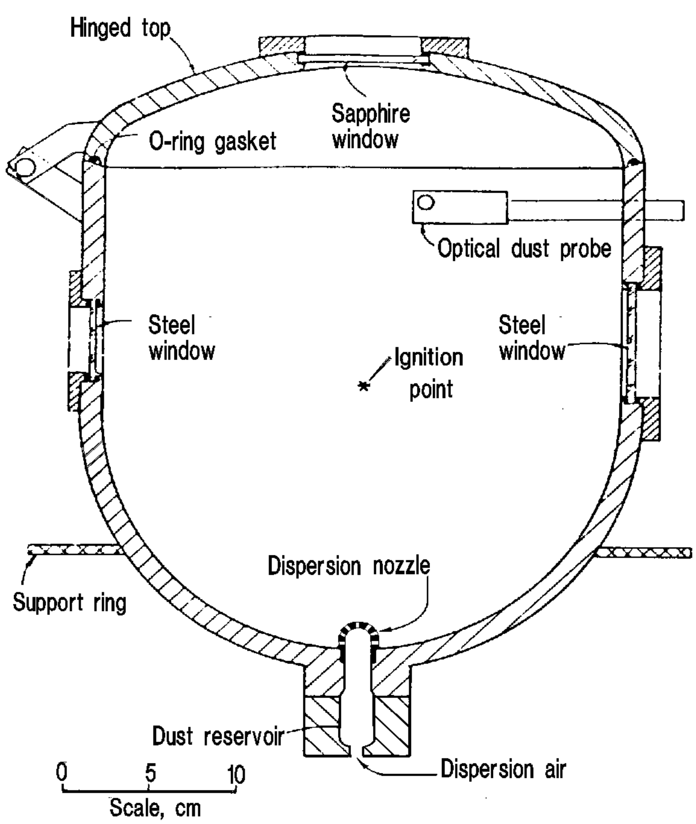


Figure X-1: Bureau of Mine 20-Liter Explosibility Test Chamber. (Source: BOM. Also used in the current NEP and in the OSHA test procedure for K_{st})

Class II Test

National Materials Advisory Board (NMAB) 353-3-80, *Classification of Combustible Dusts in Accordance with the National Electrical Code*, defines dusts having Ignition Sensitivity (IS) greater than or equal to 0.2, or Explosion Severity (ES) greater than or equal to 0.5, as requiring electrical equipment suitable for Class II locations.[68] Dusts whose explosibility parameters fall below these limits are generally considered to be weak explosion hazards and need only non-classified electrical equipment.

SLTC only characterizes a sample sufficiently to prove (or disprove) that the sample meets the definition for Class II dusts, based on results of the ES test.

Explosion Severity (ES)

Explosion severity tests are made to prove (or disprove) that the sample meets the definition for Class II dusts, as follows:

1. The 200 mesh (75µm) screen sample is suspended in a Hartmann stainless steel 1.2 liter explosion chamber and is ignited with an electrical spark.
2. If the sample explodes, the maximum pressure and rate of pressure rise developed by the explosion are recorded.
3. ES is calculated as the product of the maximum explosion pressure (P_{max}) and the maximum rate of pressure rise (K_{st}), normalized to Pittsburgh coal dust. Mathematically it is defined as:

$$(P \text{ x } R)_{sample} / (P \text{ x } R)_{pittsburgh\ coal}$$

Where:

P = Maximum Explosion Pressure (P_{max})
R = Maximum Rate of Pressure Rise (K_{st})

If ES is greater than or equal to 0.5, further tests are suspended and the sample is reported to be a Class II dust. If no explosion occurs in the Hartmann Class II chamber, the sample is tested in the 20-liter explosibility testing chamber to determine if the sample is explosive (see the *Maximum Normalized Rate of Pressure Rise (dP/dt) – K_{st} Test* procedure above).

Bulk Density

Before taking this sample:[69]

1. An area is marked out to be sampled, this area is measured and recorded in field notes.
2. Depth measurements are taken in the area in order to get an average depth of the area to be sampled and recorded in field notes.
3. All the material in the marked area is collected in a 1-liter sample bottle.
4. The sample bottle, along with the depth and area measurements, are sent to the lab.

[68] National Materials Advisory Board (NMAB) 353-3-80 is listed as a reference document in Appendix A to Subpart S of 29 CFR 1910.
[69] See OSHA memorandum dated April 21, 2015, *Evaluating Hazardous Levels of Accumulation Depth for Combustible Dusts*.

After receiving the sample at the SLTC lab:

1. The sample is dried for 24 hours in a drying oven set at 167º F or 75° C.
2. The sample is weighed.
3. The bulk density (lbs/ft^3 or kg/m^3) is determined based on the volume and weight of the sample as:

Dry Weight / Initial Volume

Appendix K
ASTM Test Methods

ASTM International, formerly known as the American Society for Testing and Materials, is an international standards organization that develops and publishes standards for a wide range of materials, products, systems, and services. There are more than 12,500 ASTM standards, including many test methods for the characterization of combustible dusts.

This appendix includes some of the most used ASTM test methods for the testing of combustible dusts. ASTM standards referenced in NFPA, CCPS, and FM Global combustible dust standards are also included.

ASTM Test Methods for Testing Combustible Dusts (Not all Inclusive)

Most Commonly Used Test Methods

<u>ASTM E1226 Rev A</u>, *Standard Test Method for Explosibility of Dust Clouds*.
<u>ASTM E1515</u>, *Standard Test Method for Minimum Explosive Concentration of Combustible Dusts*.
<u>ASTM E2019</u>, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

Less Commonly Used Test Methods

<u>ASTM E2931</u>, *Standard Test Method for Limiting Oxygen Concentration of Combustible Dust Clouds*.
<u>ASTM E1491</u>, *Standard Test Method for Minimum Auto-ignition Temperature of Dust Clouds.*
<u>ASTM E2021</u>, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*.
<u>ASTM C136/136M</u>, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*.
<u>ASTM MNL32</u>, *Manual on Test Sieving Methods*.
<u>ASTM C559, D6111, D5057, Etc</u>. Standard test methods for determining bulk density of different dusts. Many different test methods exist for determining bulk density.

Other ASTM Test Methods Referenced in Combustible Dust Standards

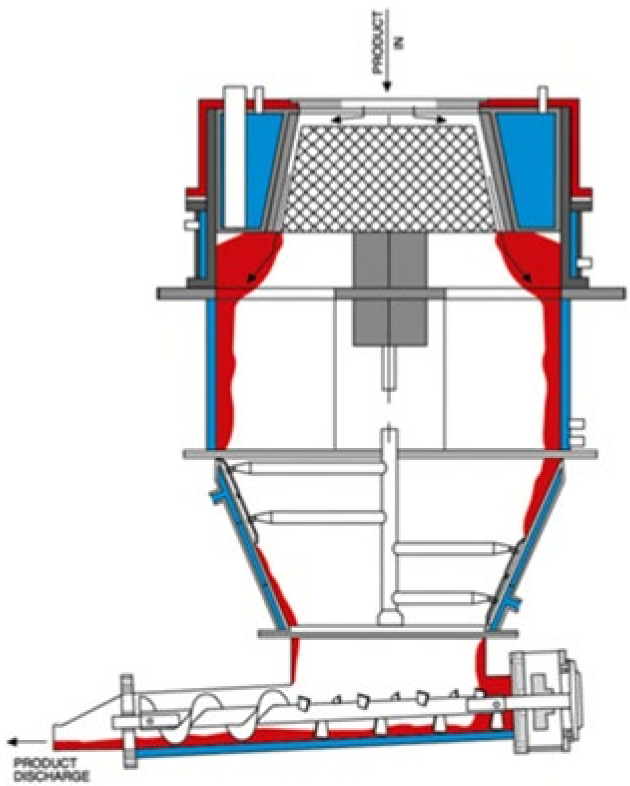
<u>ASTM D257</u>, *Standard Test Method for DC Resistance or Conductance of Insulating Materials*.
<u>ASTM D3175</u>, *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*.
<u>ASTM D5680</u>, *Standard Test Method for Sampling Unconsolidated Solids in Drums or Similar Containers*.
<u>ASTM E119</u>, *Standard Test Method for Fire Tests of Building Construction and Materials.*
<u>ASTM E136</u>, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 C*.
<u>ASTM E582</u>, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures*.

Appendix L
Typical Combustible Dust Generation Systems and Equipment[70]

Mills (size reduction)	
Common Types	Hammer, roller, pin disk, turbine, gap
Concerns	Fire and explosion
Potential ignition source mechanism(s)	Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal or stones) Frictional heating and/or sparking from mechanical components (e.g., internal components or bearings rubbing or striking the mill housing due to misalignment / mechanical failure) Frictional heating of internal material due to improper feed rates, plugging, or material degradation. Electrostatic build-up/discharge
Potential dust cloud formation mechanism(s)	Grinding
Potential control considerations	Tramp metal protection, external bearings, bonding/grounding, optimal feed rates, vibration monitoring, high amperage monitoring, high temperature monitoring, plugged condition monitoring, shear pins, overload detection, routine maintenance (e.g., lubrication, proper clearances, or blade sharpening/ replacement), deflagration suppression, pressure containment, and inerting

[70] Sources: Center for Chemical Process Safety (CCPS) Guidelines for Safe Handling of Powders and Bulk Solids, American Institute of Chemical Engineers (2004), and FM Global Property Loss Prevention Data Sheet 7-76 "Prevention and Mitigation of Combustible Dust Explosion and Fire".

Hammer Mill (Source: OTI) **Hammer Mill – Lump Breaker** (Source: R5)



Gap Mill (Source: http://www.chocolatemixer.in/gapmill.html)

Mixers (blending)	
Common Types	Ribbon, paddle, single rotor, twin rotor, tumbler (double cone, v-type), muller (heavy weight), drum
Categories	Batch or continuous
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Frictional heating and/or sparking from mechanical components or bearings (e.g., internal components rubbing or striking the

	trough wall due to misalignment / mechanical failure / trough wall denting) Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal or stones) Frictional heating of internal material Electrostatic build-up/discharge
Potential dust cloud formation mechanism(s)	Loading, mixing, unloading, cleaning
Potential control considerations	Tramp metal protection, external bearings, bonding/grounding, reduced speeds during loading, filling levels, shear pins, overload detection, routine maintenance (e.g., lubrication, proper clearances, or paddle replacement), deflagration venting, deflagration suppression, and inerting

Plough Mixer (Source: R5)

Single Rotor Paddle Mixer (Source: R5)

Single Rotor Ribbon Mixer (Source: R5)

Twin Roller Ribbon Mixer (Source: http://www.bpdm.com/industrial-mixers.aspx)

Bucket Elevators (vertical conveying)	
Common Types	Centrifugal discharge, continuous discharge, internal discharge
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Frictional heating and/or sparking from mechanical components (e.g., belt slippage or bearings) Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal or stones) Frictional heating of internal material Electrostatic build-up/discharge
Potential dust cloud formation mechanism(s)	Loading and unloading in head and boot sections, turbulence from operation. Even where bulk commodities (e.g., granular materials) are handled, fines can occur and become suspended, often resulting in dense dust cloud formation.
Potential control considerations	Tramp metal protection, external drives, external bearings, bonding/grounding, belt speed sensors, belt alignment sensors, bearing temperature sensors, bearing vibration sensors, conductive belts, fire/oil resistant belts, routine maintenance (e.g., lubrication, proper clearances, belt replacement, or bucket

	replacement), deflagration venting, deflagration suppression, and inerting

Bucket inside an elevator housing (Source: OTI)

Dryers (heating and blending)	
Common Types	Spray, fluid bed, vacuum, belt, rotary, flash, batch compartment, screw conveyor, and agitated paddle/disk
Categories	Direct fired or indirect fired
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Exposure to heat and flame from direct fired dryers Autoignition of internal material or overheating of internal material from improper operation Hybrid mixtures (flammable vapor ignition) Frictional heating and/or sparking from mechanical components or bearings (e.g., internal components rubbing or striking) Frictional heating of internal material Electrostatic build-up/discharge
Potential dust cloud formation mechanism(s)	Varies by type (e.g., gravity, rotation, or fluid bed suspension)
Potential control considerations	Varies by type – appropriate selection based on properties of the material is key Maintaining optimal conditions (e.g., temperatures, or feed rates), bonding/grounding, fire detection/suppression,

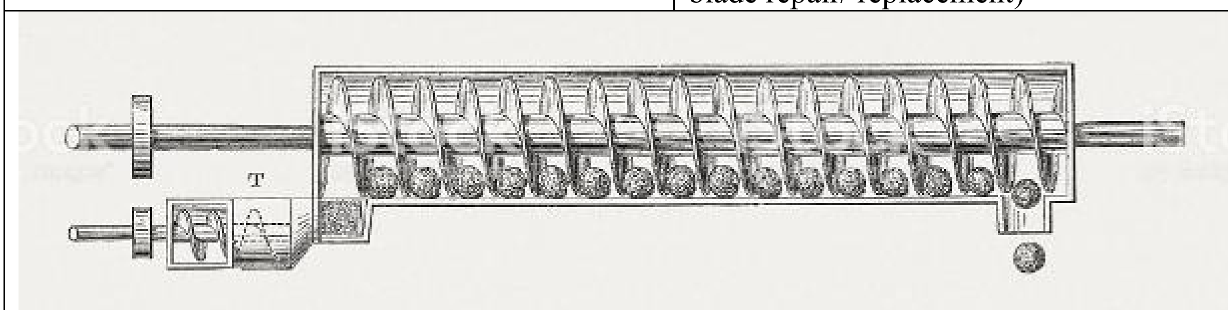
	routine maintenance of heating components, deflagration venting, deflagration suppression, pressure containment, and inerting

Rotary Dryers (Source: www.barr-rosin.com/products/rotary-dryer.asp)

Bins / Hoppers / Silos (storage)	
Common Types	Silos and bins are generally larger for longer term storage, hoppers are typically smaller and used for shorter term storage
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Electrostatic build-up/discharge Upstream operations generating heat, sparks, embers, or fire. Spontaneous heating
Potential dust cloud formation mechanism(s)	Loading (filling), cleaning of filters on integrated AMS/dust collectors, breaking up bridging conditions. Even where bulk commodities (e.g., granular materials) are loaded, fines can occur and become suspended, often result in dense dust cloud formation.
Potential control considerations	Upstream size separation to reduce fines, tramp metal protection, bonding/grounding, spark/ember detection, deflagration venting, deflagration suppression, pressure containment, and inerting

Screw Conveyors (horizontal, inclined, or vertical conveying)

Common Types	Single flight, double flight, single flight with mixing elements, and ribbon
Main concern	Fire (explosion possible, but less likely)
Potential ignition source mechanism(s)	Frictional heating and/or sparking from mechanical components or bearings (e.g., flights rubbing or striking trough wall) Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal, or stones) Frictional heating of internal material Electrostatic build-up/discharge
Potential control considerations	Tramp metal protection, bonding/grounding, temperature sensors, flow sensors, shear pins, overload detection, and routine maintenance (e.g., lubrication, proper clearances, or screw blade repair/ replacement)



Screw Conveyor (Source: istockphoto.com)

Other Horizontal Conveyors (horizontal conveying)	
Common Types	Belt, drag, en-masse, apron, and scraper
Main concern	Fire and explosion, varies by type
Potential ignition source mechanism(s)	Frictional heating and/or sparking from mechanical components or bearings (e.g., belt misalignment, or seized rollers) Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal, or stones) Frictional heating of internal material

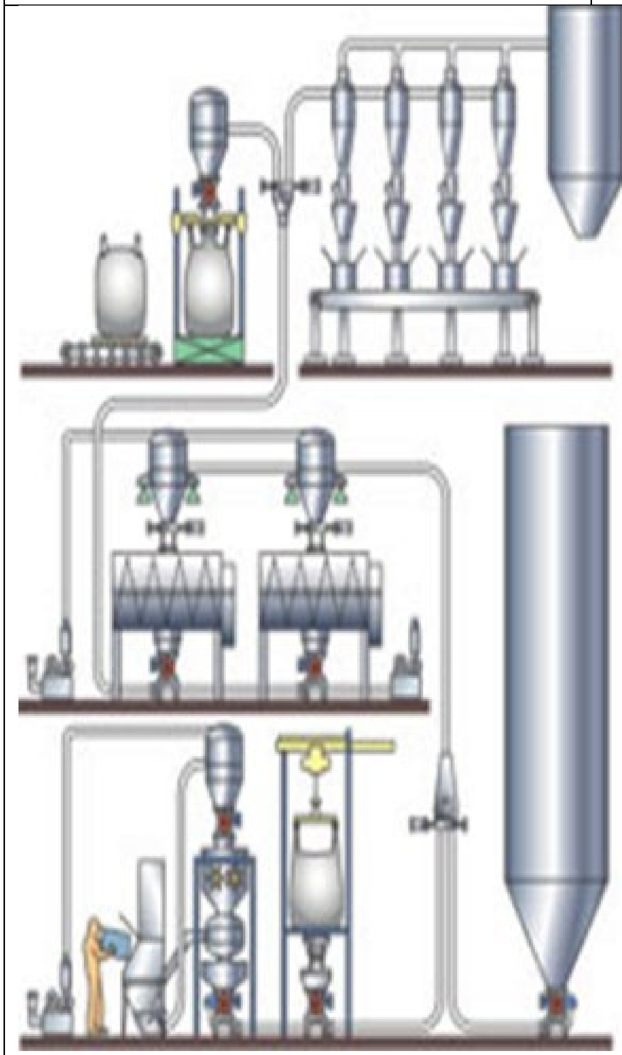
	Electrostatic build-up/discharge
Potential dust cloud formation mechanism(s)	Loading, unloading, conveying (if covered)
Potential control considerations	Tramp metal protection, bonding/grounding, fire resistant belts, anti-static belts, fire detection/suppression, bearing temperature sensors, plug sensors, alignment sensors, slippage sensors, routine maintenance (e.g., lubrication, proper clearances, or parts repair/ replacement), deflagration venting, deflagration suppression, and inerting
 **Horizontal Drag Chain Conveyor** (Source: R5)	
Spouts, Hoses, and Boots (flexible connections)	
Common Types	Spouts, chutes, flexible hose, and flexible boots
Main concern	Fire (explosion possible, but less likely)
Potential ignition source mechanism(s)	Electrostatic build-up/discharge
Potential control considerations	Conductive or static dissipative construction and bonding/grounding of internal helical support wire for flexible hose. Bonding/grounding for loading spouts. Conductive or static dissipative construction and bonding/grounding for boots. In addition, routine maintenance (e.g., inspections and spout/hose/boot replacements) and routine system checks and verification.

Flexible Elbow (with bonding wire)
(Source: OSHA HRT)

4" Flexible Hose
(Source: OSHA HRT)

Pneumatic Conveying (product transfer)	
Common types	Positive pressure, negative pressure, or combination
Categories	Dilute or dense phase
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Electrostatic build-up/discharge Upstream operations generating heat, sparks, embers, or fire Connected air-material separators Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal, or stones) Frictional heating and/or sparking from fan/blower impeller misalignment
Potential dust cloud formation mechanism(s)	Unloading points, dilute phase transfer
Potential control considerations	Varies by type – appropriate selection based on properties of the material is key Maintaining optimal conditions (e.g., feed rates, flow rates, and pressures), tramp metal protection, bonding/grounding, fire detection/suppression, routine maintenance or fans and blowers, deflagration venting,

	deflagration suppression, pressure containment, and inerting



Pneumatic Conveying System (Source: www.flexicon.com)

Pellet Mills (size enlargement)	
Common Types	Roller press, or die press
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Electrostatic build-up/discharge Frictional heating and/or sparking from mechanical components (e.g., bearings) Frictional heating and/or sparking from introduction of foreign materials (e.g., tramp metal or stones)

	Overheating of internal material from improper operation
Potential dust cloud formation mechanism(s)	Rotation, fine materials fed to press
Potential control considerations	Tramp metal protection, external bearings, bonding/grounding, routine maintenance, deflagration suppression, deflagration venting, and inerting

Appendix M
Typical Combustible Dust Collection Systems and Equipment[71]

See also NFPA 484, Annex A, for diagrams of typical dust collection systems and equipment.

Baghouse (dry-type, fabric filter media dust collector)	
Primary Use	Separate and collect particulate matter from the air stream using a dust cake layer on a media filter - fugitive dust collection
Common Types	Filter bag or cartridge filter
Categories	Pneumatic pulse, mechanical shaker, or reverse flow
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Upstream operations generating heat, sparks, embers, or fire Electrostatic build-up/discharge via any isolated conductors (e.g., metal filter clamps, collars, cages, support frames, or wires) Filter failure and subsequent introduction of particulate into fan Sparking from introduction of foreign materials (e.g., tramp metal, or stones)
Potential dust cloud formation mechanism(s)	Filter cleaning suspends dust and often forms dense clouds
Potential control considerations	Bonding/grounding, fire detection and suppression/abort systems, routine maintenance (e.g., to fans/blowers, filter replacement), deflagration venting, deflagration suppression, deflagration isolation systems, and location

[71] Sources: Center for Chemical Process Safety (CCPS) Guidelines for Safe Handling of Powders and Bulk Solids, American Institute of Chemical Engineers (2004). FM Global Property Loss Prevention Data Sheet 7-73 "Dust Collectors and Collection Systems". FM Global Property Loss Prevention Data Sheet 7-76 "Prevention and Mitigation of Combustible Dust Explosion and Fire".

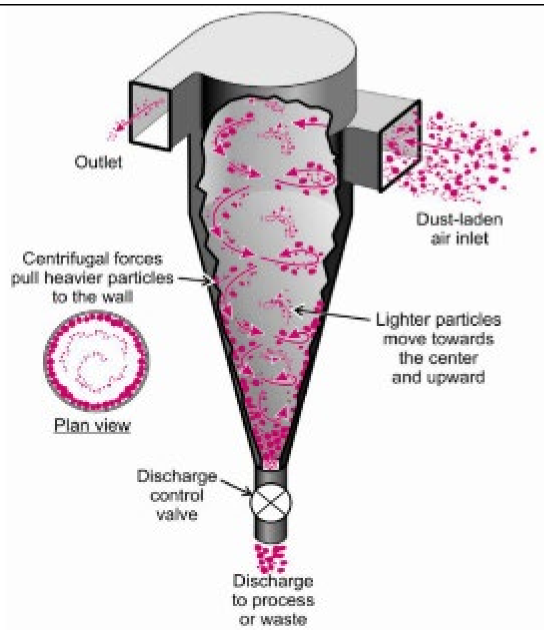
Enclosed Baghouse (Source: OTI)

Enclosed Baghouse (Source: R5)

Cartridge and Envelop Baghouse (Source: Donaldson Co.)

Cyclone (dry-type, inertia dust collector)	
Primary Use	Separate and collect particulate matter from the air stream using centrifugal force - fugitive

	dust collection (often used as an initial separator in a multi-stage system)
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Upstream operations generating heat, sparks, embers, or fire Electrostatic build-up/discharge Sparking from introduction of foreign materials (e.g., tramp metal or stones)
Potential dust cloud formation mechanism(s)	Internal zone of dense dust concentration near walls during separation
Potential control considerations	Bonding/grounding, fire detection and suppression/abort systems, routine maintenance (e.g., inspection and repair or replacement of eroded parts), deflagration venting, deflagration suppression, deflagration isolation systems, and location



Cyclone Operation (Source: https://www.researchgate.net/figure/Typical-design-of-a-cyclone-dust-collector_fig12_318967816)

Cyclone Dust Collector (Source: OTI)

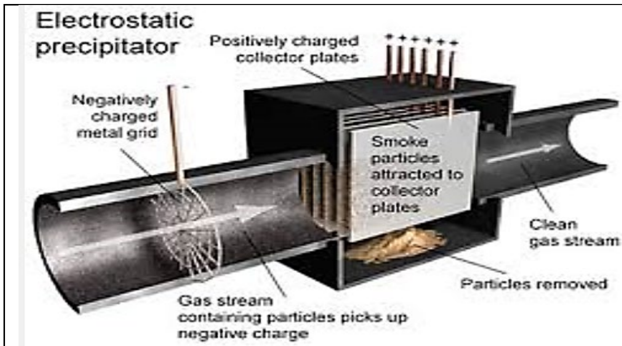
Enclosureless Collector (dry-type, filter collectors without vessel containment)	
Primary Use	Separate and collect particulate matter from the air stream - fugitive dust collection (normally used for smaller, single equipment operations)
Main concern	Fire (deflagration possible, but less likely)
Potential ignition source mechanism(s)	Upstream operations generating heat, sparks, embers, or fire Frictional heating and/or sparking from upstream blower (air-moving device) components Frictional heating of internal material due to moving material through upstream blower (air-moving device) Sparking from introduction of foreign materials (e.g., tramp metal or stones) Ignition sources external to the bags from bag failures or fine dusts filtering through the bags)
Potential control considerations	Bonding/grounding, spark-resistant fan construction, fire detection and suppression, maintenance (e.g., frequent emptying of bags and bag replacements), location, and limited use scenarios

Enclosureless Collector (Source: OTI)

Wet Collector (wet-type collector)	
Primary Use	Separate and collect particulate matter from the air stream - fugitive dust collection (normally used for collection of metal particulate)
Concerns	Fire and/or explosion
Potential ignition source mechanism(s)	Hydrogen accumulation from sludge where metals collect Metal reactions (e.g., thermite reaction from collection of incompatible metals) Ignition of moist residue accumulation in the exhaust outlet Spontaneous ignition of dust accumulated in the base

	Upstream operations generating heat, sparks, embers, or fire (e.g., water filter mechanism that is not serviced / maintained and becomes ineffective)
Potential dust cloud formation mechanism(s)	Internal dust cloud formation is possible if the water filter mechanism is not serviced / maintained and becomes ineffective
Potential control considerations	Bonding/grounding, hydrogen venting, rigorous maintenance, frequent sludge removal, liquid level sensor, water tank/supply capacity interlock, and equipment operation interlocks

Electrostatic Precipitators (electric charge separation)	
Primary Use	Separate and collect particulate matter from the air stream by giving the particulate an electrical charge and collecting them on an electrode - fugitive dust collection (sometimes used for collection of fines dusts where high collection efficiency is required)
Main concern	Fire (explosion possible, but less likely)
Potential ignition source mechanism(s)	Internal arcing may ignite inlet dust concentrations if they exceed the MEC and/or internal arcing may ignite internal dust concentrations if a dry cleaning system is utilized Upstream operations generating heat, sparks, embers, or fire Lint or oil residue accumulation on electrodes
Potential dust cloud formation mechanism(s)	Internal dust cloud formation is possible if the system uses a mechanical, dry cleaning system rather than a wet cleaning system or if the concentration of dust in the upstream inlet ducting is above the MEC
Potential control considerations	Bonding/grounding, fire detection and suppression, maintenance (e.g., electrode/ collector plate charge), and limited use scenarios

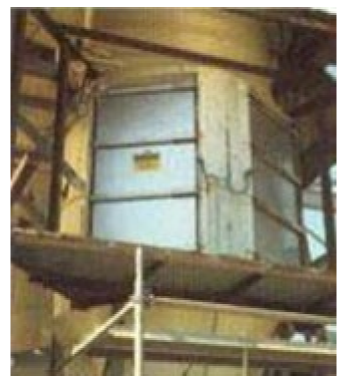


Electrostatic Precipitator (Source: https://sway.office.com/s/PRN1nHk7ojS9ekxL/embed?accessible=true)

Appendix N
Typical Combustible Dust Explosion Prevention and Protection Technologies[72]

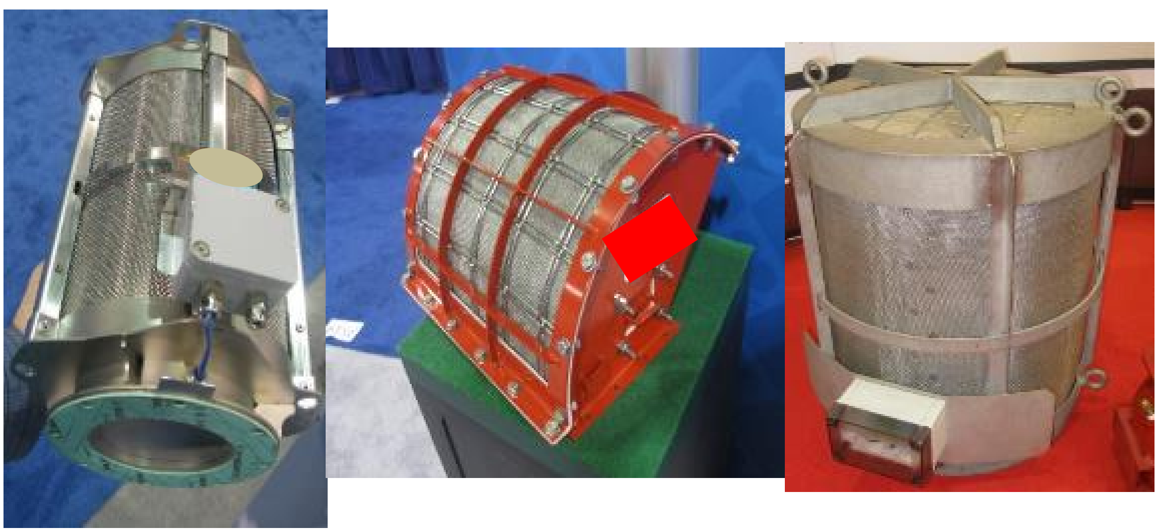
Deflagration Venting (aka Explosion Venting)	
Theory of operation	Vent panel(s) are manufactured, designed, selected, and installed to open at low internal pressures when an internal deflagration occurs. The opening of the vent panel(s) limits the pressure experienced inside of the vessel so that it is below the value for the strength of the vessel. Effective venting ensures that catastrophic failure of the vessel does not occur. It is essentially a prescribed, controlled, safer explosion event.
Category	Protective measure – allows for a deflagration to occur and a controlled relief event, but not a catastrophic vessel explosion
NFPA Reference	NFPA 68
General considerations	For outdoor applications, the vent panel(s) should be oriented so that they vent away from locations occupied by or potentially occupied by personnel, the building structure, and air intakes. Fireball dimensions can be calculated per NFPA 68 guidance and additional engineering and administrative controls implemented to ensure employee safety where employee exposure may be possible. For indoor applications, venting to a safe outdoor location can be achieved if the collector is near an exterior wall and a ducting system can be designed and accounted per NFPA 68 guidance. Otherwise, indoor deflagration venting through a listed and flame-arresting and dust-retention device may be necessary. Venting

[72] Sources: FM Global Property Loss Prevention Data Sheet 7-73 "Dust Collectors and Collection Systems"; FM Global Property Loss Prevention Data Sheet 7-76 "Prevention and Mitigation of Combustible Dust Explosion and Fire"; NFPA 68 "Standard on Explosion Protection by Deflagration Venting"; NFPA 69 "Standard on Explosion Prevention Systems"; Dust Explosion Prevention and Protection: A Practical Guide. Barton, J (ed.) (2002).

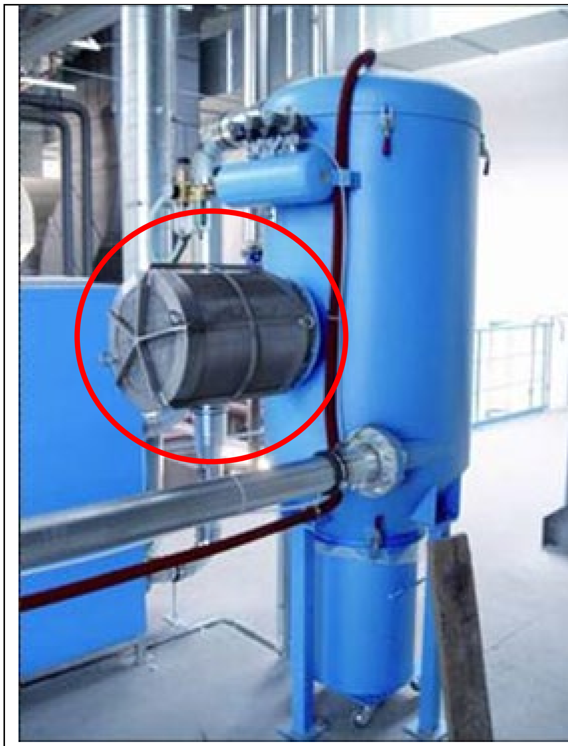
	indoors with standard vent panels is considered hazardous. Venting systems need to be designed, installed, and maintained using the manufacturer's recommendations. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. Among others, several particular parameters that must be determined are the maximum pressure in a contained deflagration (P_{max}) and the deflagration index (K_{St}).
 **Explosion Panel and Vents** (Source: R5)	 **Explosion Door** (Source: OTI)

Deflagration Venting with a Flame-Arresting and Dust Retention Device (aka Flameless Venting)	
Theory of operation	A device mounted over a deflagration vent panel to stop flame propagation during a vented deflagration. Captures any expelled unburned dust clouds that would normally escape the vessel and pose a secondary explosion hazard. The device utilizes a flame-arresting and particulate retention mesh mounted on a retaining frame surrounding the vent panel opening. The result is that flame propagation stops, combustion gases are cooled, unburned particulate is trapped, and resulting pressures are minimized. Intended for indoor venting applications.

Category	Protective measure – allows for a deflagration to occur and a controlled relief event, but not a catastrophic vessel explosion
NFPA Reference	NFPA 68
General considerations	Underlying venting systems need to be designed with the flame-arresting and dust retention device taken into consideration. Venting systems need to be designed, installed, and maintained using the manufacturer's recommendations. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. Among others, several particular parameters that must be determined are the maximum pressure in a contained deflagration (P_{max}) and the deflagration index (K_{St}).



Flameless Vents/Arrestors (Source: R5)

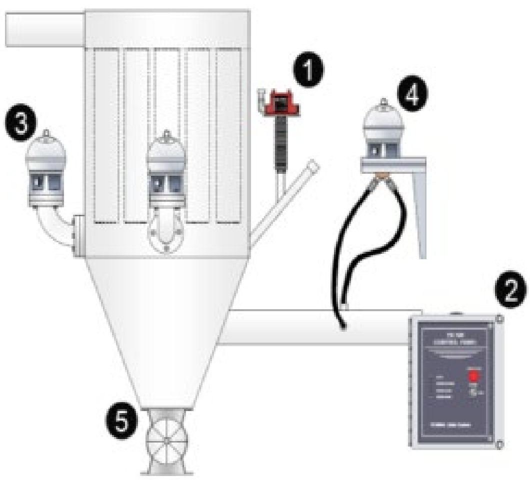


Flameless Vent on Equipment (Source: Fenwal)

Deflagration Suppression Systems (aka Chemical Suppression Systems or Explosion Suppression Systems)	
Theory of operation	System that includes pressure sensors, a control pane, and pressurized chemical suppressant bottles. The system utilizes strategically located pressure sensors to detect incipient stage deflagrations soon after ignition and subsequently triggers a high-rate discharge of chemical suppressant to extinguish the expanding deflagration. The internal deflagration is extinguished early and before the generated pressure can exceed the strength of the vessel.
Category	Protective measure – allows for a small deflagration to occur inside of the vessel prior to extinguishment and avoidance of pressures that exceed the strength of the vessel
NFPA Reference	NFPA 69
General considerations	Deflagration suppression systems need to be designed, installed, and maintained using the manufacturer's recommendations and NFPA guidance. The design of the system should be

based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. Some particular parameters that must be determined are the maximum pressure in a contained deflagration (P_{max}) and the deflagration index (K_{St}).

Servicing and maintenance on these systems or on vessels protected by these systems requires hazardous energy control and/or isolation depending on the hazard scenario (e.g., 1910.147)



Chemical Suppression System (Source: Fenwal)

Chemical Suppression (Source: R5)

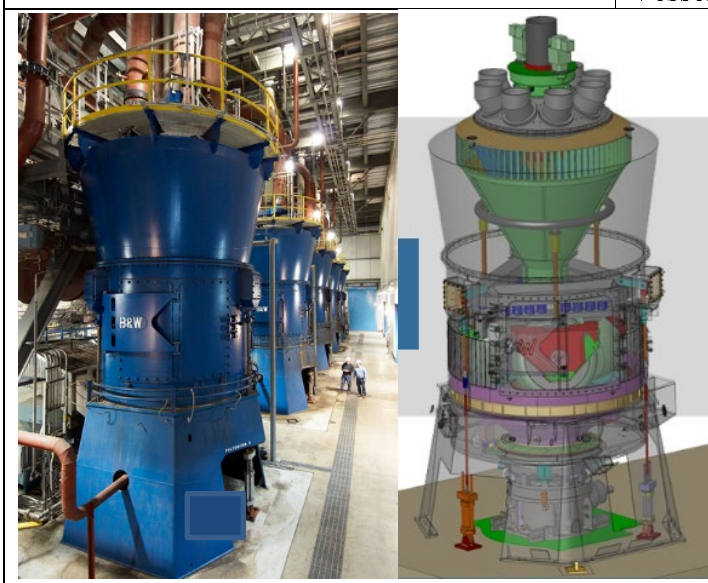
Oxidant Concentration Reduction via Inert Gas (aka Inerting)

Theory of operation	A system in which inert gases are introduced into the enclosed space or system to reduce the concentration of oxygen (or other oxidant) below the concentration required for ignition to occur
Category	Preventative measure – removes oxygen from the explosion pentagon to prohibit ignition
NFPA Reference	NFPA 69
General considerations	Inerting systems need to be designed, installed, and maintained using NFPA guidance. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. One parameter that must be determined is the limiting oxidant concentration (LOC) of the material. The LOC is the concentration of oxidant in a fuel-oxidant-diluent mixture below which a deflagration cannot occur under specified conditions. NFPA provisions include installation of instrumentation/alarm/interlock systems to ensure the desired oxidant concentration reduction within the system. The employer, in order to protect employees working around these systems or employees that may be required to perform servicing and maintenance on or within these systems, must account for the oxygen deficient atmospheres created by these systems.

Nitrogen System (Source: OSHA HRT)

Carbon Dioxide System (Source: OSHA HRT)

Deflagration Pressure Containment (aka Explosion Containment)	
Theory of operation	Vessels are constructed so that their design strength is suitable enough to resist the maximum pressure experienced during a deflagration/explosion to prevent vessel rupture.
Category	Preventative measure – removes fuel from the explosion pentagon to prohibit ignition
NFPA Reference	NFPA 69
General considerations	Deflagration pressure containment systems should be designed, installed, and maintained to prevent vessel rupture. NFPA 69 should be used for guidance. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. One parameter that must be determined is the maximum pressure in a contained deflagration (P_{max}). NFPA provisions include that enclosures protected by design for deflagration pressure containment be designed and constructed according to the ASME Boiler and Pressure Vessel Code.



Coal Pulverizer (Source: OSHA HRT)

Appendix O
Typical Combustible Dust Deflagration Propagation Protection (Isolation) Technologies[73]

Flow-Actuated Flap Valve (aka Passive Flap Valve)	
Theory of operation	A mechanical flap valve within a housing designed to be installed in the ducting upstream of a vessel protected by deflagration venting and to automatically shut from the resulting reduced pressure wave preceding the flame front (i.e., a check valve).
Category	Passive isolation device
NFPA Reference	NFPA 69
General considerations	Flow-actuated flap valves should be designed, installed, and maintained in accordance with the manufacturer's recommendations (CSHOSs should consult NFPA 69 for guidance). The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. Flow-actuated flap valves are normally designed to be used upstream of dust collectors protected by deflagration venting. The reasons for this are (1) the design strengths of these systems cannot normally withstand the maximum pressure (P_{max}) in a contained deflagration (e.g., unvented vessel), and (2) the upstream (dirty air inlet) ducting's normal direction of airflow will not force close the flap whereas the normal direction of air flow on the exhaust air outlet (downstream) ducting of a dust collector may interfere with the flap valve. NFPA design provisions for flow-actuated flap valves include characteristics such as: pressure resistance; locking mechanism to keep the flap sealed in the event of closure;

[73] Sources: NFPA 69 "Standard on Explosion Prevention Systems".

	inspection doors; dust layer sensor; and system interlock
 **Flap Valves** (Source: R5)	

Flow-Actuated Float Valve (aka Passive Float Valve)	
Theory of operation	A valve with a float (plug) in the interior that moves axially and closes automatically due to the pressure of the preceding flame front. These valves are designed to be installed in ducting connected to a vessel protected by deflagration venting. These valves can function in both directions and are more likely to be installed on the exhaust air outlet (downstream) side of a dust collector.
Category	Passive isolation device
NFPA Reference	NFPA 69
General considerations	Flow-actuated float valves need to be designed, installed, and maintained using the manufacturer's recommendations. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. NFPA design provisions for flow-actuated float valves include characteristics such as: pressure resistance; locking mechanism to keep the float sealed in the event of closure; and signal to indicate the closed position

Float Valve (Source: R5)

Flame Front Diverter (aka Passive Diverter)	
Theory of operation	A device installed in ducting that generates a significant change in direction of process flow (e.g., 180 degrees). In the event of a deflagration in an attached vessel, the exiting flame front cannot easily make the turn and exits straight up and out of the device through

	a hinged closure (explosion door) or a rupture disc.
Category	Passive isolation device
NFPA Reference	NFPA 69
General considerations	Flame front diverters should be designed, installed, and maintained using the manufacturer's recommendations and NFPA guidance. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. NFPA guidance prohibits the use of flame front diverters as the only means of isolation where the design intent is to completely stop flame propagation. It is noted by NFPA that, although severity of the events were reduced, some flame front diverters have been unable to demonstrate complete deflagration isolation in testing. NFPA design provisions for flame front diverters include characteristics such as: pressure resistance and discharging to a safe, unrestricted, unobstructed, and outdoor location
 **Flame Front Diverter** (Source: J.O.A.)	

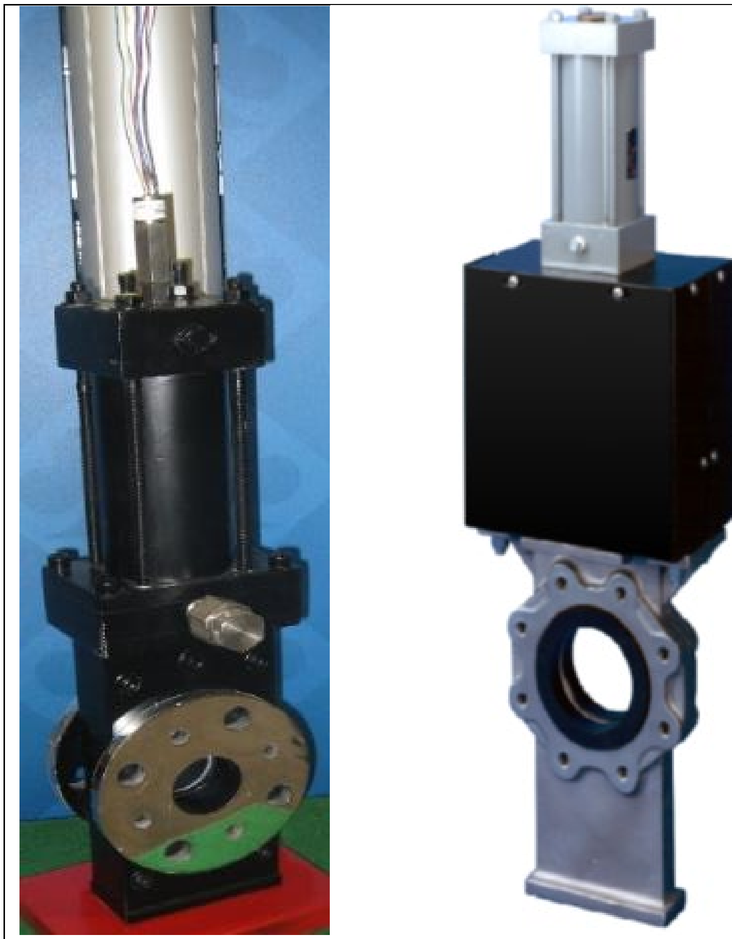
Rotary Valve (aka Passive Material Choke)	
Theory of operation	A specialized rotary air valve installed on the material discharge hopper of a vessel to protect against flame propagation from the vessel's hopper outlet. One approach is to use a close-clearance valve to provide deflagration isolation by flame quenching. Another approach is to use a valve and sensor system to provide deflagration isolation by material blocking through the maintenance of a product layer above the rotary valve.
Category	Passive isolation device
NFPA Reference	NFPA 69
General considerations	Rotary valves need to be designed, installed, and maintained using the manufacturer's recommendations. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process. NFPA design provisions for isolation rotary valves in general include characteristics such as: pressure resistance; at least six diametrically opposed vanes; minimum clearance; normally metal vanes; external bearings; and interlocks. For material blocking applications, additional provisions include a level control switch and interlock to maintain a minimum material layer above the valve of at least 1 ft.


Rotary Airlock Assembly (Source: eBay)

Chemical Barrier (aka Active Chemical Suppression System)	
Theory of operation	A system that utilizes strategically located pressure sensors to detect incipient stage deflagrations soon after ignition and to subsequently trigger a high-rate discharge of chemical suppressant to extinguish the expanding deflagration prior to the arrival of the flame front.
Category	Active isolation system
NFPA Reference	NFPA 69
General considerations	Chemical suppression systems need to be designed, installed, and maintained using the manufacturer's recommendations and NFPA guidance. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility's process.

Chemical Suppression Assembly (Source: R5)

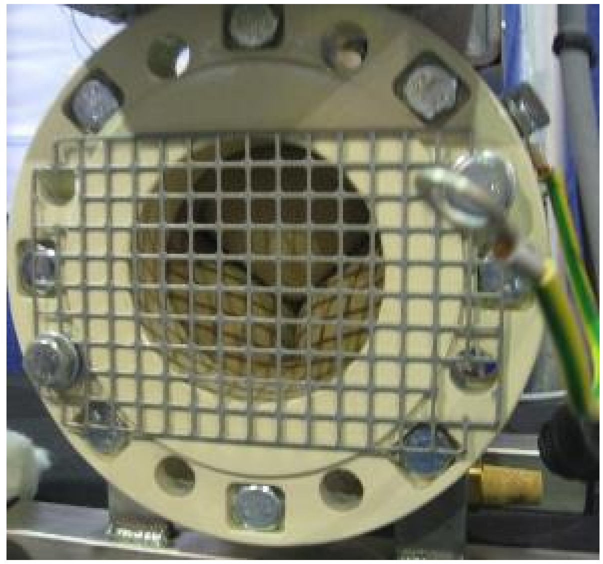
Fast-Acting Mechanical Valve (aka Active Gate Valve)	
Theory of operation	A device that is installed in ducting to prevent flame propagation by providing a positive mechanical seal. Some systems utilize sensors to detect the deflagration and provide a signal to the device which then activates the release of a pressurize propellant to drive a valve gate into the closed position via a pneumatic actuator. Other systems utilize sensors to detect the deflagration and provide a signal to a gas generating system to rapidly close the valve gate in a similar fashion.
Category	Active isolation system
NFPA Reference	NFPA 69
General considerations	Fast-acting mechanical valves need to be designed, installed, and maintained using the manufacturer’s recommendations. The design of the system should be based on the worst case scenario properties of the particulate representative within the vessel at the facility’s process.



Fast Acting Gates Valves (Source: Fenwal)

Actuated Pinch Valve (aka Active Air Pinch Valve)

Theory of operation	A device that is installed in ducting to prevent flame propagation by providing a seal via an elastomeric pinch. These systems utilize sensors to detect the deflagration and provide a signal to an actuator powered by a connected pressurized cylinder. The sealing action is provided by the elastomeric pinch which is formed by rapidly filling the bladders with gas (typically an inert gas).
Category	Active isolation system
NFPA Reference	NFPA 69
General considerations	Actuated pinch valves need to be designed, installed, and maintained using the manufacturer’s recommendations. The design of the system should be based on the worst

	case scenario properties of the particulate representative within the vessel at the facility’s process.
 **Pinch Valves** (Source: R5)	

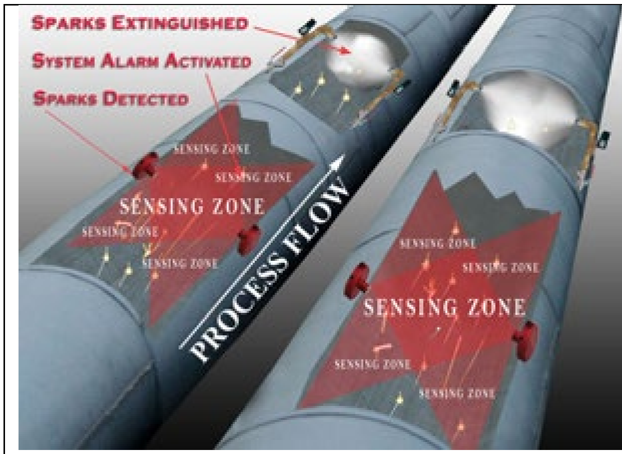
Appendix P
Typical Other Prevention and Protection Technologies[74]

High-Speed Abort Gate (aka Abort Gate)	
Theory of operation	A temporary electronically actuated diversion gate. Optical sensors are used to detect sparks and glowing embers and subsequently trigger the temporary diversion of air flow to a safe outdoor location. This type of device can be installed upstream of a dust collector to provide ignition source control for sparks or embers generated by upstream processes. In such an application, the device will send the air containing the ember or sparks to atmosphere to avoid sending it to the downstream dust collector. This type of device can also be installed downstream of a dust collector for the intent of protecting building occupants from the hazardous byproducts of a dust collector fire (e.g., smoke, toxic gases, and fire) where exhaust air is returned to the building. In such an application, the building occupants must also be protected from the hazards of deflagration propagation with an approved deflagration propagation protection (isolation) device.
Category	Ignition source control, fire protection
General considerations	High speed abort gates are NOT downstream deflagration propagation protection (isolation) devices. High speed abort gates do not react in sufficient time to provide effective deflagration propagation protection (isolation). They are intended for ignition source control and/or general fire protection.

[74] Sources: NFPA Guide to Combustible Dusts (2012).

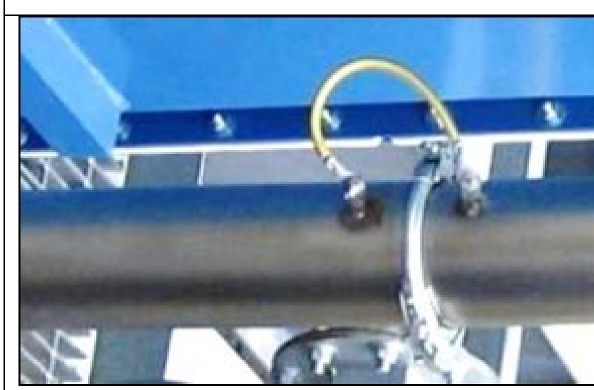
Abort Gate (Source: Imperial Systems)

Spark Detection and Extinguishment System	
Theory of operation	Optical sensors are used to detect sparks and glowing embers in ducting upstream of a vessel and subsequently trigger a liquid suppressant at an extinguishing valve/nozzle to extinguish the ignition source prior to it entering the downstream vessel. Some applications may utilize carbon monoxide (CO) gas sensors instead of optical sensors to detect thermal decomposition products. An example is the use of CO detection and suppression systems as part of spray dryer safety systems in the dairy industry.
Category	Ignition source control
General considerations	These systems are generally installed where upstream processes are frequently capable of producing sparks or embers. The suppression liquid is typically water but may be changed based on the specific hazards of the dust (e.g., water reactive materials).



Spark Detection and Extinguishing System (Source: BS&B)

Bonding and Grounding	
Theory of operation	Bonding is the practice of controlling static electrical hazards by connecting conductive objects via conductors so that those objects are at the same electrical potential. Grounding is the practice of bonding conductive objects to ground so that all objects are at zero electrical potential.
Category	Ignition source control
General considerations	Relies heavily on the use of conductive components. See NFPA 77 for detailed guidance. Personnel bonding and grounding is generally not necessary when flammable gases, vapors, and hybrid mixtures are not present and where the MIE of the dust cloud is greater than 30 mJ.



Static Discharge Control (Source: J.O.A.)

Appendix Q
Combustible Dust Electrical Classification and Control

29 CFR 1910.307 and 1910.399 provide the standards that CSHOs need to understand to complete *Electrical (Hazard) Class II Considerations*. NFPA 70 and FM Global 5-1 can also be used as a resource when conducting these inspections. 29 CFR 1910.307, *Hazardous (Classified) Locations*, is the standard to follow for the documentation of classified locations and for the installation of electrical equipment in electrically classified locations.

Equipment in Classified Locations

29 CFR 1910.307(c) requires that electrical equipment in these areas are intrinsically safe, approved for, or safe for the locations.

Intrinsically safe equipment includes wiring, circuits, equipment, and apparatus that are approved using specific testing methods (see 29 CFR 1910.307(c)(1)). Intrinsically safe, though not formally defined means that a spark or thermal effect is incapable of causing ignition of a flammable or combustible material in air under the prescribed test method. NFPA 70 provides guidelines for determining whether equipment is intrinsically safe.

Approved means acceptable to the authority enforcing this subpart. The authority enforcing this subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of "acceptable" indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of this subpart" (See 29 CFR 1910.399).

"Safe for the hazardous (classified) location means equipment shall be of a type and design that the employer demonstrates will provide protection from the hazards arising from the combustibility and flammability of vapors, liquids, gases, dusts, or fibers involved" (See 29 CFR 1910.307(c)(3)).

Classifying Electrical Hazardous Locations

29 CFR 1910.307(b) requires that electrically classified locations be properly documented at facilities. Classified locations where combustible dusts are present are designated as Class II locations. These locations are further described by the type of dust present (Group E, F, or G) and further again by the seriousness of the hazard (Division 1 or 2) in the location. 29 CFR 1910.399 provides the definitions for these Class II locations.

The locations defined above are summarized in Table XIX-1. The description of groups, which is based on NFPA 70, is provided as guidance.

Table XIX-1: Summary of Class II Hazardous Locations			
Class	**Groups**	**Divisions**	
		1	**2**
Class II Combustible Dusts	**Group E**: Metal dusts. Conductive, ignitable, and potentially explosive.* **Group F**: Carbon dusts. Some are conductive, all are ignitable, and are potentially explosive. **Group G**: Flour, starch, grain, combustible plastic or chemical dust. Most are non-conductive, but all are ignitable and are potentially explosive.	Group E dusts are in hazardous quantities (accumulations not necessarily airborne). **Or**, Group E, F, or G dusts are in the air in hazardous quantities during normal operations. **Or**, Mechanical failure or abnormal operation of electrical equipment could produce a hazardous dust cloud and could ignite the cloud.	Group F or G dusts are in the air in hazardous quantities during abnormal operations (not during normal operations). [Note: Group E dusts in hazardous quantities are always Division 1.] **Or**, Malfunction of handling or processing equipment could produce a hazardous dust cloud. **Or**, Group F or G dust is on, in, or around electrical equipment in quantities that could present a hazard.
*Note: Group E also includes other combustive dusts whose particle size, abrasiveness, and conductivity present similar hazards to metals in the use of electrical equipment.			

Bounding Classified Locations

Although 29 CFR 1910.307(b) requires documentation of classified locations, this standard, and other OSHA standards, do not provide the requirements for the boundaries of the hazardous locations. Guidance for bounding Class II locations is found in NFPA 70 and in NFPA 499. NFPA 499 provides the most detailed guidance for bounding Class II locations. An explanation of the bounding provisions as well as figures for different types of locations and dust-generating equipment are provided in this recommended practice.

Protection Techniques

29 CFR 1910.307(f) delineates the protection techniques allowed for electrical and electronic equipment in classified locations. However, this paragraph applies not only to Class II locations, but also to Class I locations (containing flammable liquids and gases) and to Class III locations (containing fibers). Table XIX-2 may be useful for review during equipment inspections in Class II locations. This table identifies the techniques that meet Class II, Division 1 and 2 locations, and further identifies the National Electrical Manufacturers Association (NEMA) enclosures that meet these requirements.

Table XIX-2: Acceptable protection techniques for electric and electronic equipment in Class II hazardous (classified) locations.

Type of Equipment	Description	Class II Div. 1	Class II Div. 2
Explosion-proof Apparatus	Equipment enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor. National Electric Manufacturers Association (NEMA) Type 7 and 8 enclosures.	No	No
Dust Ignition-proof	Enclosed in a manner that will not permit arcs, sparks, or heat generated, or liberated inside the enclosure to cause ignition of exterior accumulation or atmospheric suspensions of specified dusts on or in the vicinity of the enclosure. NEMA Type 9 enclosures.	**Yes**	**Yes**
Dust Tight	Enclosed in a manner that will exclude dusts. NEMA Type 4, 4X, 5, 12, 12K, and 13.	No	**Yes**
Purged & Pressurized	Pressurized enclosure that prevents dusts from entering. See NFPA 496.	No	**Yes**
Nonincendive Circuit	Under normal operation conditions, any arcing or thermal effects are not capable of igniting the flammable gas, vapor or dust-in-air mixture.	No	**Yes**
Nonincendive Equipment	Same as above.	No	**Yes**
Nonincendive Component	Same as above.	No	**Yes**

Table XIX-2: Acceptable protection techniques for electric and electronic equipment in Class II hazardous (classified) locations.			
Type of Equipment	**Description**	**Class II Div. 1**	**Class II Div. 2**
Oil Immersion (for current interrupting contacts)	Fused or unfused disconnect and isolating switches immersed in oil. NEMA Type 8 enclosure.	No	No
Hermetically Sealed	Equipment sealed against the entrance of an external atmosphere where the seal is made by fusion, for example, soldering, brazing, welding, or the fusion of glass to metal.	No	**Yes**
Other: Intrinsic Safety	A spark or thermal effect is incapable of causing ignition of a flammable or combustible material in air under prescribed test methods. NEMA Type 9 enclosures.	**Yes**	**Yes**