NFPA 652

Standard on Combustible Dusts

Proposed 2015 Edition

Committee Scope: This Committee shall have primary responsibility for information and documents on the management of fire and explosion hazards from combustible dusts and particulate solids.

THIS DRAFT PREPARED BY NFPA STAFF LIAISON, G. COLONNA, HAS BEEN COMPLETED FOLLOWING THE COMPLETION OF THE SECOND DRAFT MEETING HELD JANUARY 15 – 17, 2014. COMMITTEE DETERMINED THAT IT IS NECESSARY TO SLIP CYCLE; THIS INTERIM DRAFT BASED ON COMPLETED ITEMS FROM SECOND DRAFT MEETING IS ONLY FOR THE USE OF THE TECHNICAL COMMITTEE ON THE FUNDAMENTALS OF COMBUSTIBLE DUST.

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex F. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2

Chapter 1 Administration

1.1 Scope.

This standard shall provide the basic principles of and requirements for identifying and managing the fire and explosion hazards of combustible dusts and particulate solids.

1.2 Purpose.

This standard shall provide the minimum general requirements ~~and direct~~ necessary to manage the fire, flash fire, and explosion hazards posed by combustible dusts and directs the user to other NFPA standards for industry and commodity-specific requirements.[SR 1, related to PC 372]

1.3 Application.

1.3.1

~~The provisions of this standard shall be applied in accordance with Figure 1.3.1.~~[SR 26; Per PC 503]

~~Figure 1.3.1 Document Flow Diagram for Combustible Dust Hazard Evaluation [RESERVED]~~

1.3.~~2~~1

This standard ~~establishes the basic principles and requirements that shall be applied~~ shall apply to all facilities ~~where~~ and operations manufacturing, processing, blending, conveying, repackaging, generating, or handling combustible dusts or combustible particulate solids ~~are present~~.

1.3.2 This standard shall not apply to the following:

(1) Storage or use of consumer quantities of such materials on the premises of residential or office occupancies

(2) Storage or use of commercially packaged materials at retail facilities

(3) Such materials displayed in original packaging in mercantile occupancies and intended for personal or household use or as building materials

(4) Warehousing of sealed containers of such materials when not associated with an operation that handles or generates combustible dust

(5) Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes [SR 2, related to PC 130]

1.3.3 Where an industry or commodity-specific NFPA standard exists, its requirements shall be applied in addition to those in this standard. [per SR 2]

1.4 Conflicts.

1.4.1* For the purposes of this standard, the industry or commodity-specific NFPA standards shall include the following:

NFPA 61

NFPA 484

NFPA 654

NFPA 655

NFPA 664

A.1.4.1 Other industry or commodity-specific NFPA documents that might be considered include NFPA 30B, NFPA 33, NFPA 85, NFPA 120, NFPA 495, NFPA 820, NFPA 850, NFPA 1124, and NFPA 1125.

1.4.2 Where a requirement specified in an industry or commodity-specific NFPA standard ~~is more stringent than~~ differs from the requirement specified in this standard, the requirement in the industry or commodity-specific standard shall be permitted to be used ~~applied~~.

1.4.~~2~~3*

Where ~~a requirement in~~ an industry or commodity-specific NFPA standard ~~is less stringent than this standard, the owner/operator shall either comply with the requirement of this standard or justify how the~~ specifically prohibits a requirement specified in this standard, the prohibition in the industry or commodity-specific standard shall be applied ~~requirement achieves the safety objectives of this standard for the situation~~.

A.1.4.3

Chapter 6 on performance-based design can be used as a tool to justify when an industry or commodity-specific NFPA standard requirement achieves the safety objectives.

1.4.~~3~~4 Where an industry or commodity-specific NFPA standard neither prohibits nor provides a requirement, the requirement in this standard shall be applied.

1.4.~~3~~5 Where a conflict between a general requirement of this standard and a specific requirement of this standard exists, the specific requirement shall apply. [SR 3, related to various PC]

~~1.5 Goal.~~

~~The goal of this standard is to provide safety measures to prevent and mitigate fires and dust explosions in facilities that handle combustible particulate solids.~~ [SR 10, deletes 1.5 per PC 465 and other related PC]

1.6 Retroactivity.

1.6.1

The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.6.2

Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.6.3

In those cases where the authority having jurisdiction (AHJ) determines that the existing situation presents an unacceptable degree of risk, the AHJ shall be permitted to apply retroactively any portions of this standard that, based on the application of clear criteria derived from the objectives in this standard, the AHJ determines to be necessary to achieve an acceptable degree of risk.

1.6.4

The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that the modification does not result in an unacceptable degree of risk.

1.7 Equivalency.

1.7.1

Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.7.2

Technical documentation shall be ~~submitted~~ made available to the authority having jurisdiction to demonstrate equivalency. [SR 11, per PC 133]

1.7.3

The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.8 Units and Formulas.

1.8.1 SI Units.

Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI).

1.8.2* Primary and Equivalent Values.

If a value for a measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement.

A.1.8.2

A given equivalent value could be approximate.

1.8.3 Conversion Procedure.

SI units shall be converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.)

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471. [To be updated to most current edition, prior to completion of this revision]

NFPA 10, *Standard for Portable Fire Extinguishers,* 2013 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2010 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2011 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2009 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2013 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2012 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2011 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2013 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2013 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 2013 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2013 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2011 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2011 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2009 edition.

NFPA 54, *National Fuel Gas Code,* 2012 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.

NFPA 70®, *National Electrical Code®,* 2011 edition.

NFPA 72®, *National Fire Alarm and Signaling Code,* 2013 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2014 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2011 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2015 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2012 edition.

NFPA 484, *Standard for Combustible Metals,* 2012 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2013 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2013 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems*, 2010 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2012 edition.

NFPA 2112, *Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire,* 2012 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*, 2012 edition.

2.3 Other Publications.

2.3.1 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME B31.3, *Process Piping*, 2012.

ASME *Boiler and Pressure Vessel Code*, 2010.

2.3.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E 1226, *Standard Test Method for Explosibility of Dust Clouds*, 2012.

2.3.3 IEC Publications.

International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 61340-4-4, Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC), 2005.

2.3.4 NEMA Publications.

National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.

NEMA 250, Enclosures for Electrical Equipment, 2008.

2.3.3 UN Publications.

United Nations Publications, Room DC2-853, 2 UN Plaza, New York, NY 10017.

UN Recommendations on the Transport of Dangerous Goods: Model Regulations – Manual of Tests and Criteria, 13th edition.

2.3.4 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."

2.3.5 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

[To be updated to most current edition during this revision]

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2009 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 2010 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2012 edition.

NFPA 484, *Standard for Combustible Metals,* 2012 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2013 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2011 edition.

NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program,* 2013 edition.

Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1* Air–Material Separator (AMS).

A device designed to separate the conveying air from the material being conveyed. **[654,** 2013**]**

3.3.1.1 Enclosureless AMS.

An air-material separator designed ~~and used to remove dust from the transport air~~ to separate the conveying air from the material being conveyed where the filter medium is not enclosed or in a container. [SR 12, per PC 59]

3.3.2* Air-Moving Device (AMD).

A power-driven fan, blower, or other device that establishes an airflow by moving a given volume of air per unit time. **[654**, 2013**]**

A.3.3.2 Air-Moving Device (AMD).

An air-moving device is a fan or blower. A general description of each follows:

(1) Fans:

(a) A range of devices that use an impeller, contained within a housing, that when rotated creates air/gas flow by negative (vacuum) or positive differential pressure.

(b) These devices are commonly used to create comparatively high air/gas volume flows at relatively low differential pressures.

(c) These devices are typically used with ventilation and/or dust collection systems.

(d) Examples are centrifugal fans, industrial fans, mixed or axial flow fans, and inline fans.

(2) Blowers:

(a) A range of devices that use various shaped rotating configurations, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.

(b) These devices are commonly used to create comparatively high differential pressures at comparatively low air/gas flows.

(c) The most common use of these devices is with pneumatic transfer, high-velocity, low-

volume (HVLV) dust collection and vacuum cleaning systems.

(d) Examples are positive displacement (PD) blowers, screw compressors, multistage centrifugal compressors/blowers and regenerative blowers.

*[**654**, 2013]*

3.3.3* Centralized Vacuum System.

A fixed-pipe system utilizing variable-volume negative-pressure (i.e., vacuum) air flows from remotely located hose connection stations to allow the removal of dust accumulations from surfaces and conveying those dusts to an air-material separator (AMS). [**654**, 2013]

A.3.3.3 Centralized Vacuum Cleaning System.

*This system normally consists of multiple hose connection stations hard-piped to an AMS located out of the hazardous area. Positive displacement or centrifugal AMDs can be used to provide the negative pressure air flow. The hoses and vacuum cleaning tools utilized with the system should be designed to be conductive or static-dissipative in order to minimize any risk of generating an ignition source. Low minimum ignition energy materials should be given special consideration in the system design and use. A primary and secondary AMS separator combination (e.g., cyclone and filter receiver) can be used if large quantities of materials are involved. However, most filter receivers are capable of handling the high material loadings without the use of a cyclone. [**654**, 2013]*

3.3.4* Combustible Dust.

A finely divided combustible particulate solid that presents a flash fire or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. [**654**, 2013]

A.3.3.4 Combustible Dust. *The term combustible dust when used in this standard includes powders, fines, fibers, etc.*

Dusts traditionally were defined as material 420 µm or smaller (capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 µm (capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 µm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameter usually do not pass through a 500 µm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 µm could behave as a combustible dust if suspended in air or the process specific oxidizer. If the minimum dimension of the particulate is greater than 500 µm, it is unlikely that the material would be a combustible dust, as determined by test. The determination of whether a sample of combustible material presents a *flash fire or explosion hazard could be based on a screening test methodology such as provided in the ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds. Alternatively, a standardized test method such as ASTM E 1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts, could be used to determine dust explosibility. [**654,** 2013]*

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E 1226 screening test or the ASTM E 1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale (≥1 m^3*) enclosure, which is less susceptible to overdriving and thus will provide more realistic results. [**654,** 2013] This possibility for false positives has been known for quite some time and is attributed to "overdriven" conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m*^{3} *chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m*^{3} *chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E 1226) states, "The objective of this test method is to develop data that can be correlated to those from the 1 m*^{3} *chamber (described in ISO 6184-1, Explosion Protection Systems — Part 1: Determination of Explosion Indices of Combustible Dusts in Air, and VDI 3673, Pressure Venting of Dust Explosions)…" ASTM E 1226 further states, "Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose* K_{St} *and* P_{max} *parameters are known in the 1 m*^{3} *chamber." [**654,** 2013]*

NFPA 68, Standard on Explosion Protection by Deflagration Venting, also recognizes this problem and addresses it stating that "the 20 L test apparatus is designed to simulate results of the 1 m^3 *chamber; however, the igniter discharge makes it problematic to determine* K_{St} *values less than 50 bar-m/sec. Where the material is expected to yield* K_{St} *values less than 50 bar-m/sec, testing in a 1 m*^{3} *chamber might yield lower values." [**654,** 2013]*

Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard varies, depending on the type of combustible dust and the processing methods used. ***[654, 2013]***

A dust deflagration has the following four requirements:

(1) Combustible dust

(2) Dust dispersion in air or other oxidant

(3) Sufficient concentration at or exceeding the minimum explosible concentration (MEC)

(4) Sufficiently powerful ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, a welding slag, frictional heat, or a flame

*[**654,** 2013]*

If the deflagration is confined and produces a pressure sufficient to rupture the confining *enclosure, the event is, by definition, an "explosion." [**654,** 2013]*

Evaluation of the hazard of a combustible dust should be determined by the means of actual test data. Each situation should be evaluated and applicable tests selected. The following list represents the factors that are sometimes used in determining the deflagration hazard of a dust:

(1) MEC

(2) MIE

(3) Particle size distribution

(4) Moisture content as received and as tested

(5) Maximum explosion pressure at optimum concentration

(6) Maximum rate of pressure rise at optimum concentration

(7) K_{St} (normalized rate of pressure rise) as defined in ASTM E 1226

(8) Layer ignition temperature

(9) Dust cloud ignition temperature

(10) Limiting oxidant concentration (LOC) to prevent ignition

(11) Electrical volume resistivity

(12) Charge relaxation time

(13) Chargeability

*[**654,** 2013]*

*It is important to keep in mind that as a particulate is processed, handled, or transported, the particle size generally decreases due to particle attrition. Consequently, it is often necessary to evaluate the explosibility of the particulate at multiple points along the process. Where process conditions dictate the use of oxidizing media other than air (nominally taken as 21 percent oxygen and 79 percent nitrogen), the applicable tests should be conducted in the appropriate process-specific medium. [**654,** 2013]*

3.3.5* Combustible Metal.

Any metal composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that will burn. **[484,** 2012**]**

A.3.3.5 Combustible Metal.

See NFPA 484, Standard for Combustible Metals, for further information on determining the characteristics of metals.

3.3.6* Combustible Particulate Solid.

Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition that, when processed, stored, or handled in the facility has the potential to produce a combustible dust ~~presents a fire hazard~~. **~~[654,~~** ~~2013~~**~~]~~[SR 17, related to PC 381 and others]**

A.3.3.6 Combustible Particulate Solid.

The term particulate solid is intended to include those materials that are typically processed using bulk material handling techniques such as silo storage, pneumatic or mechanical transfer, etc. For the purposes of this document, the term particulate solid does not include an upper size limitation.

*Combustible particulate solids include dusts, fibers, fines, chips, chunks, flakes, granules, or pellets, or mixtures of these. The term combustible particulate solid addresses the attrition of material as it moves within the process equipment. Particle abrasion breaks the material down and produces a mixture of large and small particulates, some of which could be small enough to be classified as dusts. Consequently, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material. ~~[**654**, 2013]~~*

While particulate solids can present a fire hazard, they are unlikely to present a dust deflagration hazard unless they contain a significant fraction of dust, which can segregate and accumulate within the process or facility.[Also SR 17, related to PC 381]

3.3.7 Conductive Dusts.

Dusts with a volume resistivity of less than 10^8 ohms*m.

3.3.8* Deflagration.

Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68**, 2013]

A.3.3.8 Deflagration.

The primary concern of this document is a deflagration that produces a propagating flame front or pressure increase that can cause personnel injuries or the rupture of process equipment or buildings. Usually these deflagrations are produced when the fuel is suspended in the oxidizing medium.

3.3.9 Detachment.

~~To be located in a separate building with physical clear space between or in an outside area located away from other structures of interest.~~ Location in a separate building or an outside area removed from other structures to be protected by a distance as required by this standard. [SR 13, per PC 195 and others]

3.3.10 Duct.

Pipes, tubes, or other enclosures used for the purpose of ~~pneumatically~~ conveying materials pneumatically or by gravity. **~~[91,~~ ~~2010]~~** [SR 13, per PC 195 and others]

~~3.3.11* Dust.~~

~~A particulate material composed of particles typically having dimensions from effectively zero to maximum upper dimension, depending on particle shape, in the range of 200 microns to 2000 microns (2 mm).~~ [SR 14, per PC 339 and others]

[Move this content to annex for combustible particulate solid, A.3.3.6]*A.3.3.11 Dust.*

The terms particulate solid, dust, and fines are interrelated. It is important to recognize that while these terms refer to various size thresholds or ranges, most particulate solids are composed of a range of particle sizes making comparison to a size threshold difficult. For example, a bulk material that is classified as a particulate solid could contain a significant fraction of dust as part of the particle size distribution.

While hazards of bulk material are addressed in this document using the provisions related to particulate solids, it might be necessary to apply the portions of the document relating to dust where there is potential for segregation of the material and accumulation of only the fraction of the material that fits the definition of dust. Furthermore, it is difficult to establish a fractional cutoff for the size threshold, such as 10 percent below the threshold size or median particle size below the threshold size, as the behavior of the material depends on many factors including the nature of the process, the dispersibility of the dust, and the shape of the particles.

For the purposes of this document, the term particulate solid does not include an upper size limitation. This is intended to encompass all materials handled as particulates, including golf balls, pellets, wood chunks and chips, etc.

The term particulate solid is intended to include those materials that are typically processed using bulk material handling techniques such as silo storage, pneumatic or mechanical transfer, etc. While particulate solids can present a fire hazard, they are unlikely to present a dust deflagration hazard unless they contain a significant fraction of dust, which can segregate and accumulate within the process or facility.

Dusts traditionally were defined as material 420 μm or smaller (capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area–to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameters usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charges in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or the process specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm, it is unlikely that the material would be a combustible dust, as determined by test.

Typically, the term fines refers to the fraction of material that is below 75 μm or that will pass through a 200-mesh sieve. Alternately, fines can be characterized as the material collected from the final dust collector in a process or the material collected from the highest overhead surfaces *in a facility. Fines typically represent a greater deflagration hazard than typical dusts of the same composition because they are more likely to remain suspended for an extended period of time and to have more severe explosion properties (higher K_{st}, lower MIE, etc.).*

3.3.12* Dust Collection System.

A combination of equipment designed to capture, contain, and pneumatically convey fugitive dust to an AMS in order to remove the dust from the process equipment or surrounding area. [SR 15, PC 61]

A.3.3.12 Dust Collection System.

A typical dust collection system consists of the following:

1. *Hoods — devices designed to contain, capture, and control the airborne dusts by using an induced air flow in close proximity to the point of dust generation (local exhaust zone) to entrain fugitive airborne dusts.*
2. *Ducting — piping, tubing, fabricated duct, etc., used to provide the controlled pathway from the hoods to the dust collector (AMS). Maintaining adequate duct velocity (usually 4000 fpm or higher) is a key factor in the proper functioning of the system.*
3. *Dust collector — an AMS designed to filter the conveyed dusts from the conveying air stream. Usually these devices have automatic methods for cleaning the filter media to allow extended use without blinding. In some systems, a scrubber or similar device is used in place of the filter unit.*
4. *Fan package — an AMD designed to induce the air flow through the entire system.*

*The system is designed to collect only suspended dusts at the point of generation and not dusts at rest on surfaces. The system is also not designed to convey large amounts of dusts as the system design does not include friction loss due to solids loading in the pressure drop calculation. Thus, material loading must be minimal compared to the volume or mass of air flow. [**654**, 2013]*

3.3.13 Dust Deflagration Hazard.

The presence of explosible dust that is suspended in an oxidizing medium in concentrations at or above its minimum explosive concentration; or the presence of accumulations of explosible dust where a means of suspending the dust is present.

3.3.14 Dust Explosion Hazard.

A dust deflagration hazard in an enclosure that is capable of bursting or rupturing the enclosure due to the development of internal pressure from the deflagration.

3.3.15* Enclosure.

A confined or partially confined volume. [**68**, 2007]

A.3.3.15 Enclosure.

Examples of enclosures include a room, building, vessel, silo, bin, pipe, or duct. [**68**, 2013]

3.3.16 Explosion.

The bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration. [**69**, 2008]

3.3.17 Fire Hazard.

Any situation, process, material, or condition that, on the basis of applicable data, can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property.

3.3.18* Flash Fire.

A fire that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitible liquid, without the production of damaging pressure.[**921**, 2011]

A.3.3.18 Flash Fire.

A flash fire requires an ignition source and a hydrocarbon or an atmosphere containing combustible, finely divided particles (e.g., coal dust or grain) having a concentration greater than the lower explosive limit of the chemical. Both hydrocarbon and dust flash fires generate temperatures from 538°C to 1038°C (1000°F to 1900°F). The intensity of a flash fire depends on the size of the gas, vapor, or dust cloud. When ignited, the flame front expands outward in the form of a fireball. The resulting effect of the fireball's energy with respect to radiant heat significantly enlarges the hazard areas around the point of ignition.

3.3.19 Fugitive Dusts. (Reserved)

3.3.20 Hot Work.

Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [**51B**, 20~~09~~14][SR 16]

3.3.21* Hybrid Mixture.

An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥10 percent of the minimum explosible concentration (MEC). ~~A mixture of a flammable gas at greater than 10 percent of its lower flammable limit with either a combustible dust or a combustible mist.~~ [**68**, 20~~07~~14] [SR 18]

A.3.3.21 Hybrid Mixture.

The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, adds to the violence of a dust–air combustion.

The resulting dust–vapor mixture is called a hybrid mixture and is discussed in NFPA 68, Standard on Explosion Protection by Deflagration Venting. In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitible by weak ignition sources can sometimes be ignited when part of a hybrid mixture.

Examples of hybrid mixtures are a mixture of methane, coal dust, and air or a mixture of gasoline vapor and gasoline droplets in air.[update annex also to most current]

3.3.22* Industry- or Commodity-Specific NFPA Standard.

An NFPA code or standard whose intent as documented within its purpose or scope is to address fire and explosion hazards of a combustible particulate solid.

A.3.3.22 Industry- or Commodity-Specific NFPA Standard.

It is possible that within a single building or enclosure, more than one industry- or commodity-specific NFPA standard could apply. The following documents are commonly recongized as commodity-specific standards:

1. *NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
2. *NFPA 120, Standard for the Prevention and Control in Coal Mines*
3. *NFPA 484, Standard for Combustible Metals*
4. *NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Dusts*
5. *NFPA 655, Standard for Preventing Sulfur Fires and Explosions*
6. *NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

3.3.23 Intermediate Bulk Containers.

3.3.23.1* Flexible Intermediate Bulk Container (FIBC).

Large bags typically made from nonconductive woven fabric that are used for storage and handling of bulk solids. [**654**, 2013]

A.3.3.23.1 Flexible Intermediate Bulk Container (FIBC).

*FIBCs are usually made from nonconductive materials. Electrostatic charges that develop as FIBCs are filled or emptied can result in electrostatic discharges, which can pose an ignition hazard for combustible dust or flammable vapor atmospheres within or outside the bag. The four types of FIBCs — Type A, Type B, Type C, and Type D — are based on their characteristics for control of electrostatic discharges. [**654,** 2013]*

3.3.23.1.1 Type A FIBC.

An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards. [**654**, 2013]

3.3.23.1.2 Type B FIBC.

An FIBC made from nonconductive fabric where the fabric or the combination of the fabric shell, coating, and any loose liner has a breakdown voltage of less than 6000 volts. [**654**, 2013]

3.3.23.1.3 Type C FIBC.

An FIBC made from conductive material or nonconductive woven fabric incorporating interconnected conductive threads of specified spacing with all conductive components connected to a grounding tab. [**654**, 2013]

3.3.23.1.4 Type D FIBC.

An FIBC made from fabric and/or threads with special static properties designed to control electrostatic discharge energy without a requirement for grounding the FIBC. [**654**, 2013]

3.3.23.2* Rigid Intermediate Bulk Container (RIBC).

An intermediate bulk container (IBC) that can be enclosed in or encased by an outer structure consisting of a steel cage, a single-wall metal or plastic enclosure, or a double wall of foamed or solid plastic. [**654,** 2013]
A.3.3.23.2 Rigid Intermediate Bulk Container (RIBC).
*These are often called composite IBCs, which is the term used by the U.S. Department of Transportation (DOT). The term rigid nonmetallic intermediate bulk container denotes an all-plastic single-wall IBC that might or might not have a separate plastic base and for which the containment vessel also serves as the support structure. [**654,** 2013]*

3.3.23.2.1 Insulating RIBC.

An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. [**654**, 2013]

3.3.24* Minimum Explosible Concentration (MEC).

The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration. [**654**, 2013]
A.3.3.24 Minimum Explosible Concentration (MEC).
Minimum explosible concentration is defined by the test procedure in ASTM E 1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts. [654, 2013]

3.3.25* Minimum Ignition Energy (MIE).

The lowest capacitive spark energy capable of igniting the most ignition-sensitive concentration of a flammable vapor–air mixture or a combustible dust–air mixture as determined by a standard test procedure. [**654**, 2013]
A.3.3.25 Minimum Ignition Energy (MIE).
*The standard test procedure for MIE of combustible particulate solids is ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, and the standard test procedure for MIE of flammable vapors is ASTM E 582, Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures. [**654,** 2013]*

3.3.26* Pneumatic Conveying System.

An equipment system that transfers a controlled flow of solid particulate material from one location to another using air or other gases as the conveying medium, and that is comprised of the following components: a material feeding device; an enclosed ductwork, piping, or tubing network; an air–material separator; and an air-moving device.
A.3.3.26 Pneumatic Conveying System.
Pneumatic conveying systems include a wide range of equipment systems utilizing air or other gases to transport solid particles from one point to another. A typical system comprises the following:

1. *A device used to meter the material into the conveying air stream*

2. *Piping, tubing, hose, etc., used to provide the closed pathway from the metering device to the AMS*
3. *An AMS designed for the separation of comparatively large amounts of material from the conveying air/gas stream*
4. *An additional metering device (typically a rotary airlock valve or similar device) that might be used to allow discharge of the separated material from the conveying air stream without affecting the differential pressure of the system*
5. *An AMD designed to produce the necessary pressure differential and air/gas flow in the system (positive or negative)*

*[**654,** 2013]*
*A pneumatic conveying system requires the amount of material conveyed by the system to be considered as a major factor in the system pressure drop calculations. [**654,** 2013]*
*Both positive and negative (i.e., vacuum) differential pressure are used for pneumatic conveying. The decision of which is the best for a specific application should be based upon a risk analysis, equipment layout, and other system operational and cost factors. [**654,** 2013]*
*Dense phase conveying can also be considered for the application, especially with more hazardous materials (e.g., low MIE). The inherent design and operational features of this approach can provide significant safety and operational advantages over other types of pneumatic conveying systems. [**654,** 2013]*

3.3.27* Process Hazards Analysis.

A systematic review ~~of~~ to identify and evaluate the potential fire, flash fire, and explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility ~~compartment~~. [SR 4, related to PC 383 and others]
A.3.3.27 Process Hazards Analysis.
In the context of this definition, the process hazards analysis (PHA) is not intended to imply performance of a PHA that is often associated with a portion of OSHA requirements 29 CFR 1910.119. While the PHA process can be used to perform a PHA as it applies to this standard, other methods can also be used. (See Annex B.)

3.3.28 Qualified Person.

A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project. [**1451**, 2013]

3.3.29 Replacement-in-Kind.

A replacement that satisfies the design specifications of the replaced item.

3.3.30* Risk Assessment.

An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [**1250**, 2010]
A.3.3.30 Risk Assessment.
A risk assessment is a process that performs the following:

1. *Identifies hazards*
2. *Quantifies the consequences and probabilities of the identified hazards*
3. *Identifies hazard control options*
4. *Quantifies the effects of the options on the risks of the hazards*
5. *Establishes risk acceptability thresholds (minimum acceptable levels of risk)*
6. *Selects the appropriate control options that meet or exceed the risk acceptability thresholds*

Steps 1 through 3 are typically performed as part of a process hazards analysis.
Risk assessments can be qualitative, semi-quantitative, or quantitative. Qualitative methods are usually used to identify the most hazardous events. Semi-quantitative methods are used to determine relative hazards associated with unwanted events and are typified by indexing methods or numerical grading. Quantitative methods are the most extensive and use a probabilistic approach to quantify the risk based on both frequency and consequences.
See SFPE Engineering Guide to Fire Risk Assessment or AIChE Center for Process Safety, Guidelines for Hazard Evaluation Procedures for more information.

3.3.31 Segregation.

The establishment of a physical barrier between the hazard area and an area to be protected ~~locations of interest~~. [SR 19, related to PC 549]

3.3.32 Separation.

The interposing of distance between the combustible particulate solid process and other operations that are in the same room. [654, 2013]
~~The establishment of a clear space between locations of interest.~~ [SR 20, related to PC 550]

3.3.33 Spark.

A moving particle of solid material that emits radiant energy due to either its temperature or the process of combustion on its surface. [**654,** 2013]

3.3.34 Threshold Housekeeping Dust Accumulations.

The maximum quantity of dust permitted to be present before cleanup is required.

3.3.35 Transient Releases. (Reserved)

3.3.36 Wall.

3.3.36.1 Fire Barrier Wall.

A wall, other than a fire wall, having a fire resistance rating. [**221**, 2012]

3.3.36.2 Fire Wall.

A wall separating buildings or subdividing a building to prevent the spread of fire and having a fire resistance rating and structural stability. [**221**, 2012]

3.3.37 Ullage Space.

The open space above the surface of the stored solids in a storage vessel.

Chapter 4 General Requirements

4.1*

The owner/operator of a facility with potentially combustible dust shall be responsible for the following activities:

1. ~~Identify, sample, analyze, and test materials to determine if they are combustible or explosible~~ Determining the combustibility or explosibility hazards of materials per Chapter 5
2. ~~Assess the hazards of combustible or explosible materials~~ Identifying and assessing any fire, flash fire, and explosion hazards per Chapter 7
3. ~~Manage~~ Managing the identified fire, flash fire, and explosion hazards in accordance with 4.2.5
4. Communicating the hazards to affected personnel in accordance with 9.5 [SR 21, per PC 134 and related others]

A.4.1

Combustible particulate solids and dust hazard identification, assessment, and mitigation should address known hazards, including the following:

1. *Reactivity hazards (e.g., binary compatibility or water reactivity)*
2. *Smoldering fire in a layer or pile*
3. *Flaming fire of a layer or a pile*
4. *Deflagration resulting in flash fire (dust cloud combustion)*
5. *Deflagration resulting in dust explosion in equipment*
6. *Deflagration resulting in dust explosion in rooms and buildings*

Include table or list of applicable NAICS codes to identify occupancies that are likely to handle combustible particulate solids and dust.

4.2 Objectives.

4.2.1 Life Safety.

4.2.1.1

4.2.1.1.1* The facility, processes and equipment~~, and human element programs~~ shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably protect occupants not in the immediate proximity of the ignition from the effects of fire~~, deflagration, and explosion~~ for the time needed to evacuate, relocate, or take refuge.

4.2.1.1.2 The facility, processes and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably prevent serious injury from flash fires.

4.2.1.1.3 The facility, processes and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably prevent serious injury from explosions. [SR No. 23, Related to PC 62 and others]

NOTE: TG to develop A.4.2.1.1.1 address what is intended by providing these changes and this could include the concept that the building should be structurally strong enough to remain standing long enough for occupants to exit in the event of an explosion.

4.2.1.2

The structure shall be located, designed, constructed, and maintained to ~~minimize the propagation of fire or explosion to adjacent properties and to avoid injury to the public~~ reasonably protect adjacent properties and the public from the effects of fire, flash fire, or explosion. [SR 5, Related to PC 283]

~~**4.2.2 Structural Integrity.**~~

~~The facility shall be designed, constructed, and equipped to maintain its structural integrity in spite of the effects of fire or explosion for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.~~ [SR 22, PC 272]

4.2.3* Mission Continuity.

The facility, processes and equipment~~, and human element program~~ shall be designed, constructed, equipped, and maintained and management systems shall be implemented to limit damage to levels that ensure the ongoing mission, production, or operating capability of the facility to a degree acceptable to the owner/operator. [SR 6, PC 63]

A.4.2.3

Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective.

The mission continuity objective encompasses the survival of both real property, such as the building, and the production equipment and inventory beyond the extinguishment of the fire. Traditionally, property protection objectives have addressed the impact of the fire on structural elements of a building as well as the equipment and contents inside a building. Mission continuity is concerned with the ability of a structure to perform its intended functions and with how that affects the structure's tenants. It often addresses post-fire smoke contamination, cleanup, and replacement of damaged equipment or raw materials.

4.2.4 Mitigation of Fire Spread and Explosions.

The facility and processes shall be designed to prevent or mitigate fires and explosions that can cause failure of adjacent buildings or building compartments, other enclosures, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements. [SR 7, PC 64]

~~**4.2.4.1***~~

~~The structure shall be designed, constructed, and maintained to prevent fire or explosions from causing failure of load-bearing structural members, propagating into adjacent interior compartments, and incapacitating fire protective and emergency life safety systems in adjacent compartments.~~ [SR 25, PC 560]

A.4.2.4.1 ***[Annex to be retained, but renumbered as A.4.2.4, per SR 25]***

Adjacent compartments share a common enclosure surface (wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion.

~~**4.2.4.2**~~

~~The structure shall be located, designed, constructed, equipped, and maintained to prevent the propagation of fire or explosion to or from adjacent storage or structures.~~ [SR 24, PC 561]

4.2.5* Compliance Options.

The ~~goal in Section 1.5 and the~~ objectives in Section 4.2 shall be achieved by either of the following means:

1. ~~The~~ A prescriptive ~~provisions~~ approach in accordance with Chapters 5, 7, 8, and 9 in conjunction with any ~~additional~~ prescriptive provisions of applicable commodity-specific NFPA standards.
2. ~~The~~ A performance-based ~~provisions~~ approach in accordance with Chapter 6. [SR 8, PC 65]

A.4.2.5

Usually a facility or process system is designed using the prescriptive criteria until a prescribed solution is found to be infeasible or impracticable. Then the designer can use the performance-based option to develop a design, addressing the full range of fire and explosion scenarios and the impact on other prescribed design features. Consequently, facilities are usually designed not by using performance-based design methods for all facets of the facility but rather by using a mixture of both design approaches as needed.

Chapter 5 Hazard Identification

5.1* Responsibility.

The owner/operator of a facility with potentially combustible dusts shall be responsible for ~~identifying and assessing the material to determine~~ determining whether the materials are combustible or explosible and, if so, to ~~ensure their combustibility and explosibility hazards are adequately assessed~~ characterize their properties as required to support the process hazard assessment. [SR 9, related to PC 135 and others]

A.5.1

Test data derived from testing material within a facility will result in the most accurate results for the process hazard analysis, performance-based design, and hazard management options. Testing is not required to determine whether the material has combustibility characteristics where reliable, in-house commodity-specific testing data or published data of well-characterized samples (i.e., particle size, moisture content, and test conditions) are available. Published data should be used for preliminary assessment of combustibility only. However, for protection or prevention design methods, the data can be acceptable after a thorough review to ensure that they are representative of owner/operator conditions.

The protection or prevention designs are based on explosivity properties, which can vary based on the specific characteristics of the material. (See 5.2.2 for characteristics that can affect explosibility properties.) Historical knowledge and experience of occurrence or nonoccurrence of process incidents such as flash fires, small fires, sparkling fires, pops, or booms, or evidence of vessel, tank, or container overpressure should not be used as a substitute for hazard analysis.

Process incidents are indications of a material or process resulting in combustibility or explosion propensity. Process incidents can be used to guide or select samples for and supplement testing.
The following material properties should be addressed by a process hazard analysis for the combustible particulate solids present:

1. *Particle Size. Sieve analysis is a crude and unreliable system of hazard determination. Its greatest contribution in managing the hazard is the ease, economy, and speed at which it can be used to discover changes in the process particulate. In any sample of particulate, very rarely are all the particles the same size. Sieve analysis can be used to determine the fraction that would be generally suspected of being capable of supporting a deflagration.*

   For a sub-500 micron fraction:

    1. *Data presented in terms of the percent passing progressively smaller sieves.*
    2. *Particles that have high aspect ratios produce distorted, nonconservative results.*
2. *Particle Size Distribution. The particle size distribution of a combustible particulate solid must be known if the explosion hazard is to be assessed. Particle size implies a specific surface area (SSA) and affects the numerical measure of other parameters such as MEC, MIE, dP/dtmax,* P_{max} *and* K_{St}*. Particles greater than 500 microns in effective mean particle diameter are generally not considered deflationary. Most combustible particulate solids include a range of particle sizes in any given sample. The process hazards analysis should anticipate and account for particle attrition and separation as particulate is handled.*
3. *Particle Shape. Due to particle shape and agglomeration, some particulates cannot be sieved effectively . Particulates with nonspheric or noncubic shapes do not pass through a sieve as easily as spheric or cubic particles. For this purpose, fibers can behave just as explosively as spherical particulate. This leads to underestimation of small particle populations and to underassessment of the hazard. Particulates with an aspect ratio greater than 3:1 should be suspect. When particulates are poured into vessels, it is common for the fine particles to separate from the large, creating a deflagration hazard in the ullage space.*
4. *Particle Aging. Some combustible particulate solid materials could undergo changes in their safety characteristics due to aging. Changes in morphology and chemical composition, for example, can occur from the time a sample is collected to the time it takes to get that sample into the lab for a test. For materials that are known to age, care must be taken in packaging and shipment. The use of vacuum seals, or an inert gas such as nitrogen, could be required to ensure that the tested sample has not changed appreciably due to aging. The lab should be notified in advance of shipment that the material is sensitive to change due to age so that they will know how to handle it and store it until it is tested.*
5. *Particle Attrition. The material submitted for testing should be selected to address the effects of material attrition as it is moved through the process. As particulates move through a process they usually break down into smaller particles. Reduction in particle*

size leads to an increase in total surface area to mass ratio of the particulate and increases the hazard associated with the unoxidized particulate.

6. *Particle Suspension. Particle suspension maximizes the fuel – air interface. It occurs wherever particulate moves relative to the air or air moves relative to the particulate, such as in pneumatic conveying, pouring, fluidizing, mixing and blending, or particle size reduction.*
7. *Particle Agglomeration. Some particulates tend to agglomerate into clumps. Agglomerating particulates can be more hazardous than the test data imply if the particulate was not thoroughly deagglomerated when testing was conducted. Agglomeration is usually affected by ambient humidity.*
8. *Triboelectric Attraction. Particles with a chemistry that allows electrostatic charge accumulation will become charged during handling. Charged particles attract oppositely charged particles. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Humidification decreases the triboelectric effect.*
9. *Hydrogen Bonding. Hydrophilic particulates attract water molecules that are adsorbed onto the particle surface. Adsorbed water provides hydrogen bonding to adjacent particles, causing them to agglomerate. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Desiccation reduces this agglomerated effect.*
10. *Entrainment Fraction. The calculation for a dust dispersion from an accumulated layer should be corrected for the ease of entrainment of the dust. Fuel chemistry and agglomeration/adhesion forces should be considered. The dispersion is generally a function of humidity, temperature, and time. Particle shape and morphology and effective particle size should be considered.*
11. *Combustible Concentration. When particles are suspended, a concentration gradient will develop where concentration varies continuously from high to low. There is a minimum concentration that must exist before a flame front will propagate. This concentration depends on particle size and chemical composition and is measured in grams/cubic meter (ounces/cubic foot). This concentration is called the minimum explosible concentration (MEC). A dust dispersion can come from a layer of accumulated fugitive dust. The concentration attained depends on bulk density of dust layer (measured in grams/m* ^{3} *), layer thickness, and the extent of the dust cloud. Combustible concentration is calculated as: Concentration = (bulk density)*[(layer thickness)/(dust cloud thickness)]*
12. *Competent Igniter. Ignition occurs where sufficient energy per unit of time and volume is applied to a deflationary particulate suspension. Energy per unit of mass is measured as temperature. When the temperature of the suspension is increased to the auto-ignition temperature, combustion begins. Ignitability is usually characterized by measuring the minimum ignition energy (MIE). The ignition source must provide sufficient energy per unit of time (power) to raise the temperature of the particulate to its autoignition temperature (AIT).*
13. *Dustiness/dispersibility. Ignition and sustained combustion occurs where a fuel and competent ignition course come together in an atmosphere (oxidant) that supports combustion. The fire triangle represents the three elements required for a fire. Not all dusts are combustible, and combustible dusts exhibit a range in degree of hazard. All dusts can exhibit explosion hazards accompanied by propagation away from the source. In the absence of confinement, a flash fire hazard results. If confined, the deflagration*

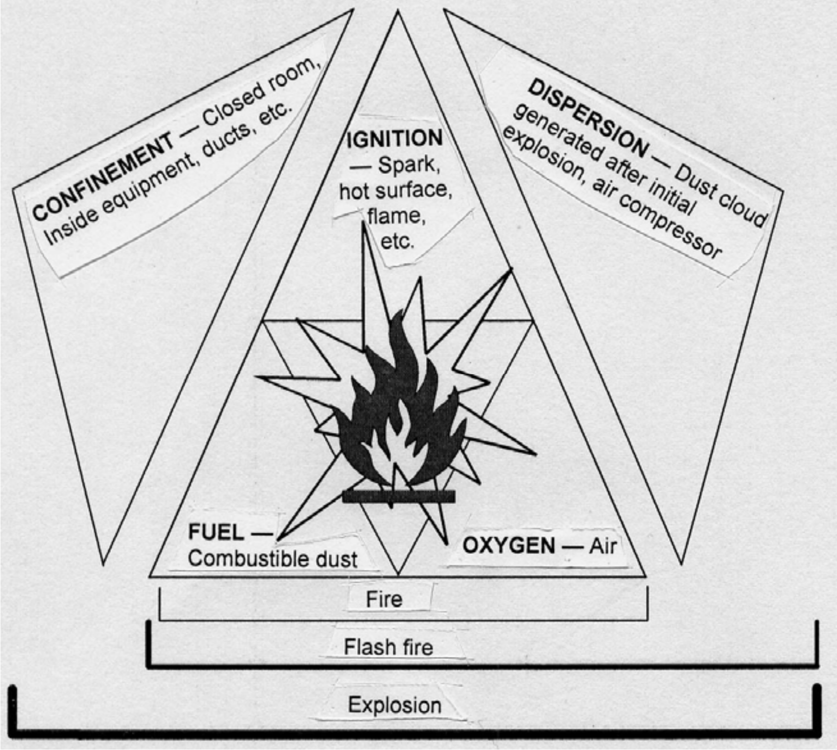
can result in damaging overpressures. Deflagration is the process resulting in a flash fire or an explosion. The four elements for a flash fire are the following:

1. *A combustible dust sufficiently small enough to burn rapidly and propagate flame*
2. *A suspended cloud at a concentration greater than the minimum explosion concentration*
3. *The atmosphere to support combustion*
4. *An ignition source of adequate energy or temperature to ignite the dust cloud*

The heat flux from combustible metal flash fires areis greater than organic materials (see Figure A.5.1). A dust explosion requires the following five conditions:

1. *A combustible dust sufficiently small enough to burn rapidly and propagate flame*
2. *A suspended cloud at a concentration greater than the minimum explosion concentration*
3. *Confinement of the dust cloud by an enclosure or partial enclosure*
4. *The atmosphere to support combustion*
5. *An ignition source of adequate energy or temperature to ignite the dust cloud*

Figure A.5.1 Elements required for fires, flash fires, and explosions.



5.1.1

Where dusts are determined ~~If the dust is known~~ to be combustible or explosible, the hazards associated with the dusts shall be assessed in accordance with ~~by~~ the requirements in Chapter 7.

5.1.2 Where dusts are determined to be combustible or explosible, controls to address the hazards associated with the dusts shall be identified and implemented in accordance with 4.2.5.

5.2 ~~Overview~~ Screening for Combustibility and Explosibility.

5.2.1* The determination of combustibility or explosibility shall be permitted to be based upon either of the following:

1. Historical facility data or published data that are deemed to be representative of current materials and process conditions

2. Analysis of representative samples in accordance with the requirements of 5.4.1 and 5.4.3

A.5.2.1 becomes the tables of 5.2.2 of First Draft

~~Dusts shall be assessed under Section 5.4 to determine their combustibility and explosibility characteristics.~~

A.5.2.1 [What's do we do with existing A.5.2.1???]

General categories of combustible dusts are metal dust (aluminum, magnesium, titanium, zirconium, etc.), agricultural (grain dust), wood dust (cellulosic, paper, etc.), chemicals (polymers, plastics, resins, rubber), formulations and mixtures, biosolids, coal dust, organic dust (flour, sugar, soap, etc.), and dust from certain textiles. Assessing the combustibility and explosibility can be performed by testing or by utilizing literature values. While some materials are well-characterized, testing is still the preferred method. Tables with explosibility properties often lack specific information such as particle size; therefore, it is recommended that literature values that do not provide particle size information be used with extreme caution. 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 of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, NFPA 68, Standard on Explosion Protection by Deflagration Venting, and NFPA 484, Standard for Combustible Metals, have lists of combustible and explosible metals and dusts that are used for guidance or informational use only and not to be used for design purposes. Composition, particle size and distribution, and moisture content are the three factors that are known to strongly influence test results. It is recognized that some industries have historical data on the same material; therefore, the frequency, number, and extent of testing where historical data exists should be made by informed judgment. The owner/operator assumes the risk of using data from tables and historical data. A person or team performing a process hazard analysis should scrutinize and make informed judgments about historical and published data and its applicability to the process.

5.2.2* Test results, historical data, and published data shall be documented and, when requested, provided to the AHJ.

~~The assessment of combustibility or explosibility shall be based, at a minimum, on the following items for test, historical, or published data of representative samples and materials, including in-process and fugitive dusts:~~

~~(1) Material properties~~

~~(a) Composition~~

~~i. Pure materials~~

~~ii. Mixtures (including diluents or grinding media)~~

~~iii. Treatment such as oxidation~~

~~iv. Aging~~

~~v. Moisture content~~

~~(b) Form~~

~~i. Particle size distribution~~

~~ii. Morphology (angular, acicular, spherical, fiber, irregular, or agglomerate)~~

~~(c) Friability of solids and particle attrition through the process~~

~~(d) Particle agglomeration~~

~~(2) Test method~~

A.5.2.2 [What about this annex??? Becomes A.5.2.1]

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

This section does not require the user to know all these items for the assessment but to review the important items in order to determine whether the material data are representative of the material in the facility. Even test data of material can be different from the actual conditions. The users should review the conditions of the test method as well to ensure that it is representative of the conditions of the facility. When that is not possible, the use of the worst-case values should be selected.

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

Refer to Tables A.5.2.2(a) through A.5.2.2(j) for guidance only and not as substitutes for actual test data. These tables are not all inclusive of all combustible dusts and noncombustible dusts. Additionally, material properties and testing methods can provide varied results than those presented in these tables.

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

Dust Name	P_{max}(bar g)	(1) K_{St} (bar m/sec)	Percent Moisture	Particle Size (µm)	Minimum ExplosiveConcentration (g/m^3)	Percent Greater Than 200 Mesh
Alfalfa	6.7	94	2.1	36		
Apple	6.7	34		155	125	
Beet root	6.1	30		108	125	
Carrageen	8.5	140	3.8			98
Carrot	6.9	65		29		
Cocoa bean dust	7.5	152				
Cocoa powder	7.3	128				
Coconut shell dust	6.8	111	6.5			51
Coffee dust	6.9	55	4.8	321		
Corn meal	6.2	47	8.2	403		
Cornstarch	7.8	163	11.2			
Cotton	7.2	24		44	100	
Cottonseed	7.7	35		245	125	
Garlic powder	8.6	164				
Gluten	7.7	110		150	125	
Grass dust	8.0	47		200	125	
Green coffee	7.8	116	5.0	45		
Hops (malted)	8.2	90		490		
Lemon peel dust	6.8	125	9.5	38		
Lemon pulp	6.7	74	2.8	180		
Linseed	6.0	17		300		
Locust bean gum	7.8	78	1.7			53
Malt	7.5	170	10.5	72		
Oat flour	6.4	81	8.6			
Oat grain dust	6.0	14		295	750	
Olive pellets	10.4	74			125	
Onion powder	9.0	157				
Parlsey (dehydrated)	7.5	110	5.4		26	
Peach	8.4	81		140	60	
Peanut meal and skins	6.4	45	3.8			
Peat	8.3	51		74	125	

Dust Name	**P_{max}(bar g)**	**(1) K_{St} (bar m/sec)**	**Percent Moisture**	**Particle Size (μm)**	**Minimum ExplosiveConcentration (g/m^3)**	**Percent Greater Than 200 Mesh**
Potato	*6.0*	*20*		*82*	*250*	
Potato flour	*9.1*	*69*		*65*	*125*	
Potato starch	*9.4*	*89*		*32*		
Raw yucca seed dust	*6.2*	*65*	*12.7*	*403*		
Rice dust	*7.7*	*118*	*2.5*			*4*
Rice flour	*7.4*	*57*			*60*	
Rice starch	*10.0*	*190*		*18*		*90*
Rye flour	*8.9*	*79*		*29*		
Semolina	*7.6*	*79*				*9*
Soybean dust	*7.5*	*125*	*2.1*			*59*
Spice dust	*6.9*	*65*	*10.0*			
Spice powder	*7.8*	*172*	*10.0*			
Sugar (10×)	*8.4*	*154*				
Sunflower	*7.9*	*44*		*420*	*125*	
Tea	*7.6*	*102*	*6.3*	*77*	*125*	
Tobacco blend	*8.8*	*124*	*1.0*	*120*		
Tomato				*200*	*100*	
Walnut dust	*8.4*	*174*	*6.0*			*31*
Wheat flour	*8.3*	*87*	*12.9*	*57*	*60*	*6*
Wheat grain dust	*9.3*	*112*		*80*	*60*	
Wheat starch	*9.8*	*132*		*20*	*60*	
Xanthan gum	*7.5*	*61*	*8.6*	*45*		

Notes:

1. *Normalized to l m^3 test vessel pressures, per ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds.)*
2. *See also Table F.1(a) in NFPA 68, Standard on Explosion Protection by Deflagration Venting, for additional information on agricultural dusts with known explosion hazards.*
3. *For those agricultural dusts without known explosion data, the dust should be tested in accordance with ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds.*

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*[**61:** Table A.6.2.1]*

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

Material	**Mass Median Diameter (µm)**	**Minimum Flammable Concentration (g/m^3)**	**P_{max} (bar)**	**K_{St} (bar-m/s)**	**Dust HazardClass**
Cellulose	33	60	9.7	229	2
Cellulose pulp	42	30	9.9	62	1
Cork	42	30	9.6	202	2
Corn	28	60	9.4	75	1
Egg white	17	125	8.3	38	1
Milk, powdered	83	60	5.8	28	1
Milk, nonfat, dry	60	—	8.8	125	1
Soy flour	20	200	9.2	110	1
Starch, corn	7	—	10.3	202	2
Starch, rice	18	60	9.2	101	1
Starch, wheat	22	30	9.9	115	1
Sugar	30	200	8.5	138	1
Sugar, milk	27	60	8.3	82	1
Sugar, beet	29	60	8.2	59	1
Tapioca	22	125	9.4	62	1
Whey	41	125	9.8	140	1
Wood flour	29	—	10.5	205	2

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

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

Material	**Mass Median Diameter (µm)**	**Minimum Flammable Concentration (g/m^3)**	**P_{max} (bar)**	**K_{St} (bar-m/s)**	**Dust Hazard Class**
Charcoal, activated	28	60	7.7	14	1
Charcoal, wood	14	60	9.0	10	1
Coal, bituminous	24	60	9.2	129	1
Coke, petroleum	15	125	7.6	47	1
Lampblack	<10	60	8.4	121	1
Lignite	32	60	10.0	151	1
Peat, 22% H2O	—	125	84.0	67	1
Soot, pine	<10	—	7.9	26	1

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

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

Material	***Mass Median Diameter (µm)***	***Minimum Flammable Concentration (g/m3)***	***P_{max} (bar)***	***K_{St} (bar-m/s)***	***Dust Hazard Class***
Adipic acid	*<10*	*60*	*8.0*	*97*	*1*
Anthraquinone	*<10*	*—*	*10.6*	*364*	*3*
Ascorbic acid	*39*	*60*	*9.0*	*111*	*1*
Calcium acetate	*92*	*500*	*5.2*	*9*	*1*
Calcium acetate	*85*	*250*	*6.5*	*21*	*1*
Calcium stearate	*12*	*30*	*9.1*	*132*	*1*
Carboxy- methyl-cellulose	*24*	*125*	*9.2*	*136*	*1*
Dextrin	*41*	*60*	*8.8*	*106*	*1*
Lactose	*23*	*60*	*7.7*	*81*	*1*
Lead stearate	*12*	*30*	*9.2*	*152*	*1*
Methyl-cellulose	*75*	*60*	*9.5*	*134*	*1*
Paraformaldehyde	*23*	*60*	*9.9*	*178*	*1*
Sodium ascorbate	*23*	*60*	*8.4*	*119*	*1*
Sodium stearate	*22*	*30*	*8.8*	*123*	*1*
Sulfur	*20*	*30*	*6.8*	*151*	*1*

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

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

Material	***Mass Median Diameter (µm)***	***Minimum Flammable Concentration (g/m3)***	***P_{max} (bar)***	***K_{St} (bar-m/s)***	***Dust Hazard Class***
Aluminum	*29*	*30*	*12.4*	*415*	*3*
Bronze	*18*	*750*	*4.1*	*31*	*1*
Iron carbonyl	*<10*	*125*	*6.1*	*111*	*1*
Magnesium	*28*	*30*	*17.5*	*508*	*3*
Phenolic resin	*55*	*—*	*7.9*	*269*	*2*
Zinc	*10*	*250*	*6.7*	*125*	*1*
Zinc	*<10*	*125*	*7.3*	*176*	*1*

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

Table A.5.2.2(f) 1 m^3 Vessel Test Data from Forschungsbericht Staubexposionen – Plastic Dusts

Material	***Mass Median Diameter (µm)***	***Minimum Flammable Concentration (g/m^3)***	***P_{max} (bar)***	***K_{St} (bar-m/s)***	***Dust Hazard Class***
(poly) Acrylamide	*10*	*250*	*5.9*	*12*	*1*
(poly) Acrylonitrile	*25*	*—*	*8.5*	*121*	*1*

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

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

Table A.5.2.2(g) Explosibility Properties of Metals

Material	Median Diameter (µm)	K_{st} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m^3)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Aluminum	~7	—	8	—	—	90			Cashdollar & Zlochower 4
Aluminum	22	—	—	—	—	—	—	5 (N)	BGIA3
Aluminum	<44	—	5.8	650	50	45		2 (C)	BuMines RI 6516
Aluminum flake	<44		6.1	650	20	45		<3 (C)	BuMines RI 6516

Material	Median Diameter (µm)	K_{st} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m^3)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Aluminum	<10	515	11.2	560	—	60	—	—	BGIA3
Aluminum	580	Not Ignited	—	—	—	—	—	—	BGIA
Beryllium	4	Not Ignited	—	—	—	—	—	—	BuMines RI 6516
Boron	<44	—	—	470	60	<100	—	—	BuMines RI 6516
Boron	~3	—	6.0			≈110			Cashdollar & Zlochower
Bronze	18	31	4.1	390	—	750	BZ 4		Eckhoff
Chromium	6	—	3.3	660	5120	770		14 (C)	BuMines RI 6516
Chromium	3	—	3.9	580	140	230	—	—	BuMines RI 6517
Copper	~30	Not Ignited							Cashdollar & Zlochower
Hafnium	~8	—	4.2	—	—	~180	—	—	Cashdollar & Zlochower
Iron	12	50	5.2	580		500	—		Eckhoff
Iron	~45	—	2.1	—	—	~500	—	—	Cashdollar & Zlochower
Iron	< 44	—	2.8	430	80	170	—	13 (C)	BuMines RI 6516
Iron, carbonyl	< 10	111	6.1	310		125	BZ 3		Eckhoff
Manganese	< 44	—	—	460	305	125		—	BuMines RI 6516
Manganese(electrolytic)	16	157	6.3	330	—	—	—	—	Eckhoff
Manganese(electrolytic)	33	69	6.6	—	—	—	—	—	Eckhoff
Magnesium	28	508	17.5	—	—	—	—		Eckhoff

Material	Median Diameter (µm)	K_{st} (bar-m/s)	P_{max} (barg)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m^3)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Magnesium	240	12	7	760		500	BZ 5		Eckhoff
Magnesium	<44	—	—	620	40	40		—	BuMines RI 6516
Magnesium	<44	—		600	240	30	—	<3 (C)	BuMines RI 6516
Magnesium	~16	—	7.5	—	—	55	—	—	Cashdollar & Zlochower
Molybdenum	<10	Not Ignited							Eckhoff
Nickel	~6	Not Ignited							Cashdollar & Zlochower
Niobium	80	238	6.3	560	3	70		6 (Ar)	Industry
Niobium	70	326	7.1	591	3	50		5 (Ar)	Industry
Silicon	<10	126	10.2	>850	54	125	BZ 3		Eckhoff
Silicon, from dust collector	16	100	9.4	800	—	60	—		Eckhoff
Silicon, from filter	<10	116	9.5	>850	250	60	BZ 1		Eckhoff
Tantalum	<44	—	—	630	120	<200		3 (Ar)	BuMines RI 6516
Tantalum	~10		≈3			≈400			Cashdollar & Zlochower
Tantalum	100	149	6.0	460	<3	160		2 (Ar)	Industry
Tantalum	80	97	3.7	540	<3	160		2(Ar)	Industry
Tantalum	50	108	5.5	520	<3	160		2(Ar)	Industry
Tantalum	65	129	5.8	460	<3	160		2(Ar)	Industry
Tantalum	21		5.6	430	<3	125		<2(Ar)	Industry
Tantalum	25			400	>1<3	30		<2(Ar)	Industry
Tin	~8	—	3.3	—	—	~450	—	—	Cashdollar & Zlochower

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

1. Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen
2. UN Dust Layer Combustibility Categories are as follows:UN Dust Layer Combustibility Categories are as follows:

   BZ1 No self-sustained combustion;

   BZ2 Local combustion of short duration;

   BZ3 Local sustained combustion, but no propagation;

   BZ4 Propagating smoldering combustion;

BZ5 Propagating open flame;

BZ6 Explosive combustion.

3. *BGIA is the GESTIS-DUST-EX database maintained by BGIA-online.hvbg.de*
4. *Cashdollar, Kenneth, and Zlochower, Isaac, "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," J. Loss Prevention in the Process Industries, v 20, 2007.*

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

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

Particle Size (d_{50}) (µm)	**BET (m^2/g)**	**MEC (g/m^3)**	**P_{max} (psi)**	**dP/dt_{max} (psi/sec)**	**K_{St} (bar·m/sec)**	**Sample Concentration That Corresponds to P_{max} and dP/dt_{max}**	**MIE (mJ)**	**LOC (%)**	**Most Easily IgnitibleConcentration (g/m^3)**
Nonspherical, Nodular, or Irregular Powders									
53	0.18	170	123	3,130	59	1,250			
42	0.19	70	133	5,720	107	1,250 (P_{max}), 1,000 (dP/dt_{max})			
32	0.34	60	142	7,950	149	1,250	10		
32	0.58	65	133	8,880	167	750 (P_{max}), 1,500 (dP/dt_{max})	11	Ignition @ 8.0% Nonignition @ 7.5%	1,000
30	0.10	60					10		
28	0.11	55	140	6,360	119	1,000 (P_{max}), 1,250 (dP/dt_{max})	11		
28	0.21	55	146	8,374	157	1,500	11		
9	0.90	65	165	15,370	288	750 (P_{max}), 1,000 (dP/dt_{max})	4		
7	0.74	90	153	17,702	332	1,000 (P_{max}), 500 (dP/dt_{max})	12		
6	0.15	80	176	15,580	292	750	3.5		
6	0.70	75	174	15,690	294	500 (P_{max}), 1,000 (dP/dt_{max})	3		
5	1.00	70					4		
4	0.78	75	167	15,480	291	1,000 (P_{max}), 750 (dP/dt_{max})	3.5		
Spherical Powders									

Particle Size (d$_{50}$) (μm)	*BET (m^2/g)*	*MEC (g/m^3)*	*P$_{max}$ (psi)*	*dP/dt$_{max}$(psi/sec)*	*K$_{St}$ (bar·m/sec)*	*Sample Concentration That Corresponds to P$_{max}$ and dP/dt$_{max}$*	*MIE (mJ)*	*LOC (%)*	*Most Easily IgnitibleConcentration (g/m^3)*
63	0.15	120	101	1,220	23	1,250 (P_{max}), 1,000 (dP/dt_{max})	N.I.	Ignition @1 8.0% Nonignition @ 7.5%	1,750
36	0.25	60	124	4,770	90	1,250	13		
30	0.10	60	140	5,940	111	1,000	13		
15	0.50	45	148	10,812	203	1,000	7		
15	0.30	55					8		
6	0.53	75	174	16,324	306	750	6		
5	1.30		167	14,310	269	750		Ignition @ 6.0% Nonignition @ 5.5%	750
5	1.00	70	155	14,730	276	1,250	6	Ignition @ 6.0% Nonignition @ 5.5%	1,250
3	2.50	95	165	15,900	298	1,250	4		
2	3.00	130							

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

BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O$_2$) concentration.

Notes:

1. *The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.*
2. *Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E 1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts; MIE: ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air; maximum pressure rise (P$_{max}$), maximum pressure rise rate (dP/dt), and deflagration index (KSt): ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds; LOC: ASTM E 2079, Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors.*

3. Particle size data represent the d_{50} measurement determined by the laser light–scattering technique.
4. Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.

*[**484:** Table A.4.3.1]*
Table A.5.2.2(i) Explosion Characteristics of Unalloyed Magnesium Dust in Air (200 mesh (75μm))

Explosion Characteristics	***Values***
Explosibility index[a]	*10 K_{St}*
Ignition sensitivity[b]	*3.0 K_{St}*
Explosion severity[c]	*7.4 K_{St}*
Maximum explosion pressure (gauge)	*793 kPa (115 psi)*
Maximum rate of pressure rise (gauge)	*793 kPa/sec (15,000 psi/sec)*
Ignition temperature cloud	*1040°F (560°C)*
Minimum cloud ignition energy	*0.04 J (26.4 W/sec)*
Minimum explosion concentration	*0.328 kg/m^3 (0.03 oz/ft^3)*
Limiting oxygen percent for spark ignition[d]	*—*

Note: K_{St} values vary for specific particle sizes.
[a] Explosibility index = ignition sensitivity × explosion severity.
[b] Ignition sensitivity =

$$\frac{\left[\begin{array}{c}\text{Ignition temp. cloud} \times \text{min. cloud-ignition energy}\\ \times \text{ min. explosion concentration (LEL)}\end{array}\right]_{\text{Pittsburgh coal dust}}}{\left[\begin{array}{c}\text{Ignition temp. cloud} \times \text{min. cloud ignition energy}\\ \times \text{ min. explosion concentration}\end{array}\right]_{\text{Sample dust}}}$$

[c] Explosion severity =cExplosion severity =

$$\frac{\left[\text{Max. explosion pressure} \times \text{max. rate of pressure rise}\right]_{\text{Pittsburgh coal dust}}}{\left[\text{Max. explosion pressure} \times \text{max. rate of pressure rise}\right]_{\text{Sample dust}}}$$

[d] Burns in carbon dioxide, nitrogen, and halons.
*[**484:** Table D.2]*
Table A.5.2.2(j) Selected Combustible Dusts Layer or Cloud Ignition Temperature

Chemical Name	***CAS No.***	***NEC Group***	***Code***	***Layer or Cloud Ignition Temperature (°C)***
Acetal, linear		*G*	*NL*	*440*
Acetoacet-p-phenetidide	*122-82-7*	*G*	*NL*	*560*
Acetoacetanilide	*102-01-2*	*G*	*M*	*440*
Acetylamino-t-nitrothiazole		*G*		*450*
Acrylamide polymer		*G*		*240*

Chemical Name	*CAS No.*	*NEC Group*	*Code*	*Layer or Cloud Ignition Temperature (°C)*
Acrylonitrile polymer		*G*		*460*
Acrylonitrile-vinyl chloride-vinylidenechloride copolymer (70-20-10)		*G*		*210*
Acrylonitrile-vinyl pyridine copolymer		*G*		*240*
Adipic acid	*124-04-9*	*G*	*M*	*550*
Alfalfa meal		*G*		*200*
Alkyl ketone dimer sizing compound		*G*		*160*
Allyl alcohol derivative (CR-39)		*G*	*NL*	*500*
Almond shell		*G*		*200*
Aluminum, A422 flake	*7429-90-5*	*E*		*320*
Aluminum, atomized collector fines		*E*	*CL*	*550*
Aluminum—cobalt alloy (60-40)		*E*		*570*
Aluminum—copper alloy (50-50)		*E*		*830*
Aluminum—lithium alloy (15% Li)		*E*		*400*
Aluminum—magnesium alloy (dowmetal)		*E*	*CL*	*430*
Aluminum—nickel alloy (58-42)		*E*		*540*
Aluminum—silicon alloy (12% Si)		*E*	*NL*	*670*
Amino-5-nitrothiazole	*121-66-4*	*G*		*460*
Anthranilic acid	*118-92-3*	*G*	*M*	*580*
Apricot pit		*G*		*230*
Aryl-nitrosomethylamide		*G*	*NL*	*490*
Asphalt	*8052-42-4*	*F*		*510*
Aspirin [acetol (2)]	*50-78-2*	*G*	*M*	*660*
Azelaic acid	*109-31-9*	*G*	*M*	*610*
Azo-bis-butyronitrile	*78-67-1*	*G*		*350*
Benzethonium chloride		*G*	*CL*	*380*
Benzoic acid	*65-85-0*	*G*	*M*	*620*
Benzotriazole	*95-14-7*	*G*	*M*	*440*
Beta-naphthalene-axo- dimethylaniline		*G*		*175*
Bis(2-hydroxy- 5-chlorophenyl) methane	*97-23-4*	*G*	*NL*	*570*
Bisphenol-A	*80-05-7*	*G*	*M*	*570*
Boron, commercial amorphous (85% B)	*7440-42-8*	*E*		*400*
Calcium silicide		*E*		*540*
Carbon black (more than 8% total entrapped volatiles)		*F*		
Carboxymethyl cellulose	*9000-11-7*	*G*		*290*
Carboxypolymethylene		*G*	*NL*	*520*

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Cashew oil, phenolic, hard		G		180
Cellulose		G		260
Cellulose acetate		G		340
Cellulose acetate butyrate		G	NL	370
Cellulose triacetate		G	NL	430
Charcoal (activated)	64365-11-3	F		180
Charcoal (more than 8% total entrapped volatiles)		F		
Cherry pit		G		220
Chlorinated phenol		G	NL	570
Chlorinated polyether alcohol		G		460
Chloroacetoacetanilide	101-92-8	G	M	640
Chromium (97%) electrolytic, milled	7440-47-3	E		400
Cinnamon		G		230
Citrus peel		G		270
Coal, Kentucky bituminous		F		180
Coal, Pittsburgh experimental		F		170
Coal, Wyoming		F		180
Cocoa bean shell		G		370
Cocoa, natural, 19% fat		G		240
Coconut shell		G		220
Coke (more than 8% total entrapped volatiles)		F		
Cork		G		210
Corn		G		250
Corn dextrine		G		370
Corncob grit		G		240
Cornstarch, commercial		G		330
Cornstarch, modified		G		200
Cottonseed meal		G		200
Coumarone-indene, hard		G	NL	520
Crag No. 974	533-74-4	G	CL	310
Cube root, South America	83-79-4	G		230
Di-alphacumyl peroxide, 40-60 on CA	80-43-3	G		180
Diallyl phthalate	131-17-9	G	M	480
Dicyclopentadiene dioxide		G	NL	420

Chemical Name	*CAS No.*	*NEC Group*	*Code*	*Layer or Cloud Ignition Temperature (°C)*
Dieldrin (20%)	*60-57-1*	*G*	*NL*	*550*
Dihydroacetic acid		*G*	*NL*	*430*
Dimethyl isophthalate	*1459-93-4*	*G*	*M*	*580*
Dimethyl terephthalate	*120-61-6*	*G*	*M*	*570*
Dinitro-o-toluamide	*148-01-6*	*G*	*NL*	*500*
Dinitrobenzoic acid		*G*	*NL*	*460*
Diphenyl	*92-52-4*	*G*	*M*	*630*
Ditertiary-butyl-paracresol	*128-37-0*	*G*	*NL*	*420*
Dithane m-45	*8018-01-7*	*G*		*180*
Epoxy		*G*	*NL*	*540*
Epoxy-bisphenol A		*G*	*NL*	*510*
Ethyl cellulose		*G*	*CL*	*320*
Ethyl hydroxyethyl cellulose		*G*	*NL*	*390*
Ethylene oxide polymer		*G*	*NL*	*350*
Ethylene-maleic anhydride copolymer		*G*	*NL*	*540*
Ferbam™	*14484-64-1*	*G*		*150*
Ferromanganese, medium carbon	*12604-53-4*	*E*		*290*
Ferrosilicon (88% Si, 9% Fe)	*8049-17-0*	*E*		*800*
Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)		*E*	*CL*	*380*
Flax shive		*G*		*230*
Fumaric acid	*110-17-8*	*G*	*M*	*520*
Garlic, dehydrated		*G*	*NL*	*360*
Gilsonite	*12002-43-6*	*F*		*500*
Green base harmon dye		*G*		*175*
Guar seed		*G*	*NL*	*500*
Gulasonic acid, diacetone		*G*	*NL*	*420*
Gum, arabic		*G*		*260*
Gum, karaya		*G*		*240*
Gum, manila		*G*	*CL*	*360*
Gum, tragacanth	*9000-65-1*	*G*		*260*
Hemp hurd		*G*		*220*
Hexamethylene tetramine	*100-97-0*	*G*	*S*	*410*
Hydroxyethyl cellulose		*G*	*NL*	*410*
Iron, 98% H2 reduced		*E*		*290*

Chemical Name	***CAS No.***	***NEC Group***	***Code***	***Layer or Cloud Ignition Temperature (°C)***
Iron, 99% carbonyl	*13463-40-6*	*E*		*310*
Isotoic anhydride		*G*	*NL*	*700*
L-sorbose		*G*	*M*	*370*
Lignin, hydrolized, wood-type, fine		*G*	*NL*	*450*
Lignite, California		*F*		*180*
Lycopodium		*G*		*190*
Malt barley		*G*		*250*
Manganese	*7439-96-5*	*E*		*240*
Magnesium, grade B, milled		*E*		*430*
Manganese vancide		*G*		*120*
Mannitol	*69-65-8*	*G*	*M*	*460*
Methacrylic acid polymer		*G*		*290*
Methionine (l-methionine)	*63-68-3*	*G*		*360*
Methyl cellulose		*G*		*340*
Methyl methacrylate polymer	*9011-14-7*	*G*	*NL*	*440*
Methyl methacrylate-ethyl acrylate		*G*	*NL*	*440*
Methyl methacrylate-styrene- butadiene		*G*	*NL*	*480*
Milk, skimmed		*G*		*200*
N,N-dimethylthio- formamide		*G*		*230*
Nitropyridone	*100703-82-0*	*G*	*M*	*430*
Nitrosamine		*G*	*NL*	*270*
Nylon polymer	*63428-84-2*	*G*		*430*
Para-oxy-benzaldehyde	*123-08-0*	*G*	*CL*	*380*
Paraphenylene diamine	*106-50-3*	*G*	*M*	*620*
Paratertiary butyl benzoic acid	*98-73-7*	*G*	*M*	*560*
Pea flour		*G*		*260*
Peach pit shell		*G*		*210*
Peanut hull		*G*		*210*
Peat, sphagnum	*94114-14-4*	*G*		*240*
Pecan nut shell	*8002-03-7*	*G*		*210*
Pectin	*5328-37-0*	*G*		*200*
Pentaerythritol	*115-77-5*	*G*	*M*	*400*
Petrin acrylate monomer	*7659-34-9*	*G*	*NL*	*220*

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Petroleum coke (more than 8% total entrapped volatiles)		*F*		
Petroleum resin	*64742-16-1*	*G*		*500*
Phenol formaldehyde	*9003-35-4*	*G*	*NL*	*580*
Phenol formaldehyde, polyalkylene-p	*9003-35-4*	*G*		*290*
Phenol furfural	*26338-61-4*	*G*		*310*
Phenylbetanaphthylamine	*135-88-6*	*G*	*NL*	*680*
Phthalic anydride	*85-44-9*	*G*	*M*	*650*
Phthalimide	*85-41-6*	*G*	*M*	*630*
Pitch, coal tar	*65996-93-2*	*F*	*NL*	*710*
Pitch, petroleum	*68187-58-6*	*F*	*NL*	*630*
Polycarbonate		*G*	*NL*	*710*
Polyethylene, high pressure process	*9002-88-4*	*G*		*380*
Polyethylene, low pressure process	*9002-88-4*	*G*	*NL*	*420*
Polyethylene terephthalate	*25038-59-9*	*G*	*NL*	*500*
Polyethylene wax	*68441-04-8*	*G*	*NL*	*400*
Polypropylene (no antioxidant)	*9003-07-0*	*G*	*NL*	*420*
Polystyrene latex	*9003-53-6*	*G*		*500*
Polystyrene molding compound	*9003-53-6*	*G*	*NL*	*560*
Polyurethane foam, fire retardant	*9009-54-5*	*G*		*390*
Polyurethane foam, no fire retardant	*9009-54-5*	*G*		*440*
Polyvinyl acetate	*9003-20-7*	*G*	*NL*	*550*
Polyvinyl acetate/alcohol	*9002-89-5*	*G*		*440*
Polyvinyl butyral	*63148-65-2*	*G*		*390*
Polyvinyl chloride-dioctyl phthalate		*G*	*NL*	*320*
Potato starch, dextrinated	*9005-25-8*	*G*	*NL*	*440*
Pyrethrum	*8003-34-7*	*G*		*210*
Rayon (viscose) flock	*61788-77-0*	*G*		*250*
Red dye intermediate		*G*		*175*
Rice		*G*		*220*

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

Chemical Name	***CAS No.***	***NEC Group***	***Code***	***Layer or Cloud Ignition Temperature (°C)***
Urea formaldehyde-phenol formaldehyde	*25104-55-6*	*G*		*240*
Vanadium, 86.4%	*7440-62-2*	*E*		*490*
Vinyl chloride-acrylonitrile copolymer	*9003-00-3*	*G*		*470*
Vinyl toluene-acrylonitrile butadiene	*76404-69-8*	*G*	*NL*	*530*
Violet 200 dye		*G*		*175*
Vitamin B1, mononitrate	*59-43-8*	*G*	*NL*	*360*
Vitamin C	*50-81-7*	*G*		*280*
Walnut shell, black		*G*		*220*
Wheat		*G*		*220*
Wheat flour	*130498-22-5*	*G*		*360*
Wheat gluten, gum	*100684-25-1*	*G*	*NL*	*520*
Wheat starch		*G*	*NL*	*380*
Wheat straw		*G*		*220*
Wood flour		*G*		*260*
Woodbark, ground		*G*		*250*
Yeast, torula	*68602-94-8*	*G*		*260*
Zirconium hydride	*7704-99-6*	*E*		*270*
Zirconium (contains 0.3% O)	*7440-67-7*	*E*	*CL*	*330*

Notes:

1. *Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears in the "Code" column, then the layer ignition temperature is shown. "CL" means the cloud ignition temperature is shown. "NL" means that no layer ignition temperature is available, and the cloud ignition temperature is shown. "M" signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. "S" signifies that the dust layer sublimes before it ignites; the cloud ignition temperature is shown.*
2. *Certain metal dusts might have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium and thorium dusts can ignite spontaneously in air, especially at elevated temperatures.*
3. *Due to the impurities found in coal, its ignition temperatures vary regionally, and ignition temperatures are not available for all regions in which coal is mined.*

*[**499:** Table 5.2.2]*

5.~~1.~~2.3

Where ~~If the~~ dusts ~~is~~ are determined not to be combustible or explosible, the owner/operator shall maintain documentation to demonstrate that the dusts are ~~it is~~ not combustible or explosible.

~~5.2.3*~~

~~Published or historical data shall be permitted to be used to determine whether a dust is combustible or explosible. If there is no such data or it is not otherwise clear whether a dust is combustible or explosible, samples shall be subject to screening tests for combustibility or explosibility hazard characteristics described in Section 5.4.~~

~~A.5.2.3~~

~~Particle size and size distribution analyses, including polydispersity, are preliminary measures to assess the potential hazard of material. One instance in which it would not be clear whether a material is combustible or explosible is in a sample including mixtures. Chemical analyses can be used to identify the composition of the finest fraction.~~

~~Tests of representative samples are preferred. Historical and published data can also be used, but they require an assessment of data to determine if the historical or published data are truly representative of the material being analyzed. (See 5.2.2.)~~

~~5.2.4~~

~~If the assessment of sample or historical test data for combustibility or explosibility produces a positive result, the dust shall be considered a combustible dust and the hazards shall be addressed by 4.2.5.~~

5.2.5 [this was moved to 5.2.2]

~~Test results and historical data analysis shall be documented and provided when requested by the authority having jurisdiction (AHJ).~~

~~5.2.6*~~

~~For dusts that are combustible or explosible, additional specific tests shall be performed as required to comply with the requirements for performance-based design described in Chapter 6, for process hazards analysis described in Chapter 7, and for hazard mitigation and prevention specified in Chapter 8.~~

~~A.5.2.6~~

~~Additional testing is not required where reliable, in-house, commodity-specific testing data of well-characterized samples (i.e., particle size, moisture content, test conditions) are available. Published data can be used for preliminary assessment only; they should not be used for design.~~

~~5.2.7~~

~~A sampling plan shall be developed and documented per Section 5.5 to provide data needed to comply with the requirements of this chapter.~~

~~**5.2.8**~~

~~The owner/operator shall be permitted to use the worst-case characteristics of the most hazardous material being handled as a basis for design.~~ [Per PC 113, create SR to reflect these changes]

5.3* Self-Heating and Reactivity Hazards. (Reserved)

A.5.3

Some materials have multiple potential physical hazards such as combustibility, explosibility, reactivity, and propensity to self-heat. This standard does not specifically address reactivity hazards of solid particulate materials. Users should consult Safety Data Sheet (SDS) for specific information and guidance on safe handling, personal protective equipment, and storage and transportation of chemicals.

5.4 Combustibility and Explosibility Tests.

5.4.1* Determination of Combustibility.

A.5.4.1

This preliminary screening test used to demonstrate fire risk is the basis for the regulations governing the transport of dangerous goods for United Nations (UN) regulations, the U.S. Department of Transportation, International Air Transport Association (IATA), and the International Maritime Dangerous Goods (IMDG) Code.

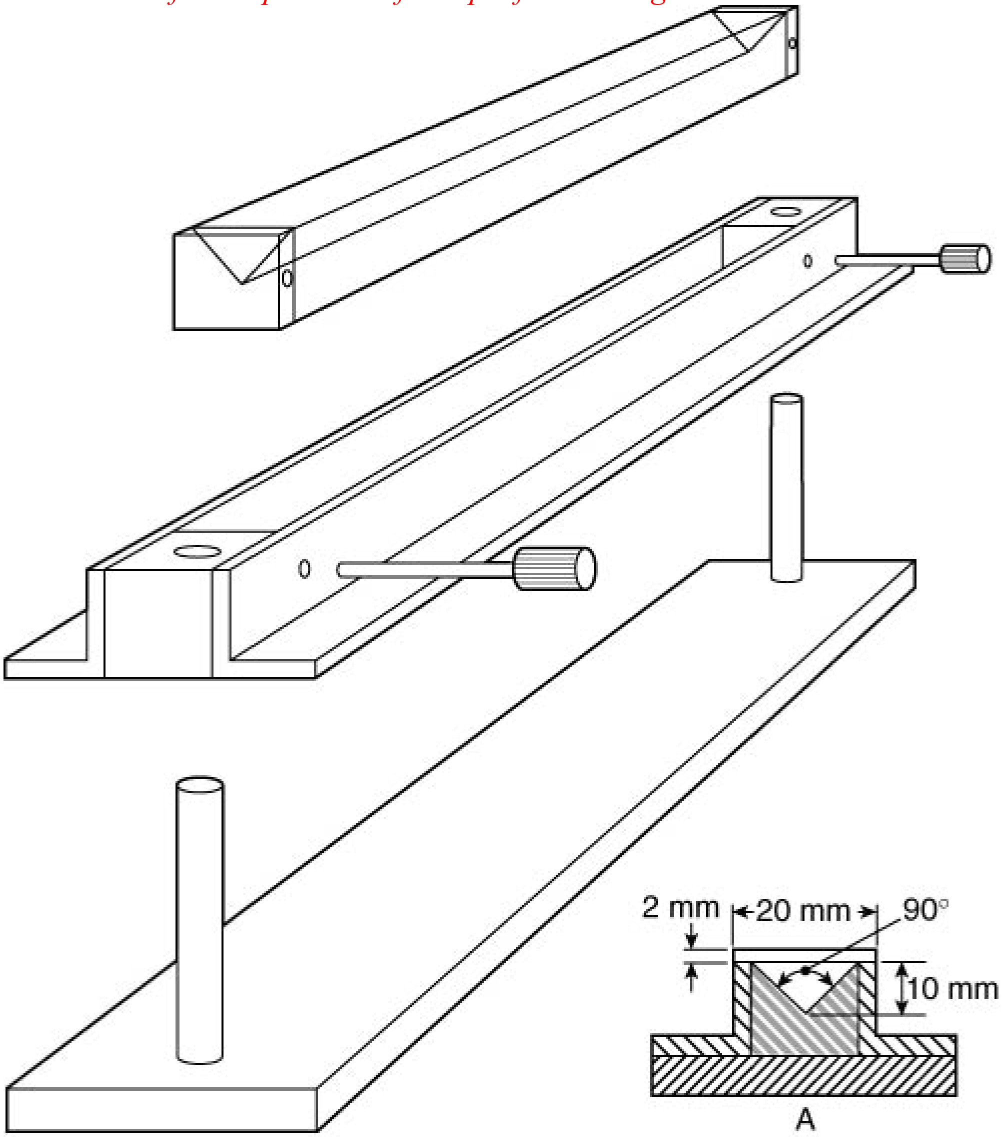
The preliminary screening test is conducted in the following fashion:

1. *The substance in its commercial form is formed into an unbroken strip or powder train about 9.84 in. (250 mm) long by 0.79 in. (20 mm) wide by 0.39 in. (10 mm) high on a cool, impervious, low heat conducting base plate.*
2. *A hot flame [minimum temperature of 1832°F (1000°C) from a gas burner] [minimum diameter of 0.20 in. (5 mm)] is applied to one end of the powder train until the powder ignites or for a maximum of 5 minutes. It should be noted whether combustion propagates along 7.87 in. (200 mm) of the train within a 20-minute test period.*
3. *If the substance does not ignite and propagate combustion either by burning with flame or smoldering along 7.87 in. (200 mm) of the powder train within the 20-minute test period, the material should not be considered a combustible dust.*
4. *If the substance propagates burning of the 7.87 in. (200 mm) length of the powder train in less than 20 minutes, the full burning rate test should be conducted.*

Because the specific form of the combustible dust and the properties of the form determine the flammability and degree of combustibility of the material, it is critical that the substance be tested precisely in the condition in which it is processed or handled. Changes in particle size distribution, moisture content, degree of fines, and chemical composition can change the results radically. No generic substitute is allowable for accurate determination of fire risk.

If propagation of the powder train occurs along a length of 7.87 in (200 mm) in 20 minutes or less, the burning rate test is required. The burning rate test requires specific preparation of the powder sample. The sample is prepared in a specific fixture as shown in Figure A.5.4.1.

Figure A.5.4.1 Fixture for Preparation of Sample for Burning Rate Test.



Note: For U.S. standard measurements, 1 mm = 0.039 in.

Preparation of the sample for the burning rate test should be done according to the following description.

The powdered or granular substance, in its commercial form, must be loosely filled into a mold. The mold, which must be 9.84 in. (250 mm) long with a triangular cross section of inner height 0.39 in. (10 mm) and width 0.79 in. (20 mm), is used to form the train for the burning rate test. On both sides of the mold, in the longitudinal direction, two metal sheets are mounted as lateral limitations that extend 0.079 in. (2 mm) beyond the upper edge of the triangular cross section. An impervious, noncombustible, low heat conducting plate is used to support the sample train. The mold is then dropped three times from a height of 0.79 in. (20 mm) onto a solid surface. The lateral limitations are then removed, and the impervious, noncombustible, low heat conducting plate is placed on top of the mold, the apparatus is inverted, and the mold is removed. Pasty substances must be spread on a noncombustible surface in the form of a rope 9.84 in. (250 mm)

in length with a cross section of about 0.16 in.^{2} (100 mm^2). In the case of a moisture-sensitive substance, the test must be carried out as quickly as possible after its removal from the container.
Test conditions are as follows:

1. *The pile is arranged across the draft in a fume cupboard. The air speed is sufficient to prevent fumes from escaping into the laboratory and is not varied during the test. A draft screen can be erected around the apparatus.*
2. *Any suitable ignition source such as a small flame or hot wire of minimum temperature 1832°F (1000°C) is used to ignite the pile at one end. When the pile has burned a distance of 3.15 in. (80 mm), the rate of burning is measured over the 3.94 in. (100 mm). The test is performed six times using a clean, cool plate each time, unless a positive result is observed earlier.*

5.4.1.1

Where the combustibility is not known, determination of combustibility shall be determined by a screening test based on the UN Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria, Part III, Subsection 33.2.1, Test N.1, or other equivalent fire exposure test methods.

5.4.1.1.1

If the dust is known to be explosible, it shall be permitted to assume that the dust is combustible and the requirements of 5.4.1 shall not apply.

5.4.1.2

For the purposes of determining the combustibility of dust, if the dust in the form tested ignites and propagates combustion, or ejects sparks from the heated zone after the heat source is removed, the material shall be considered combustible and the standard shall apply.

5.4.2 Determination of Flash Fire Hazard. (Reserved)

5.4.3 Determination of Explosibility.

5.4.3.1*

When determining explosibility, it shall be permitted to test the as-received sample.

A.5.4.3.1

In general, it is recommended to test in accordance with the test protocol. The test protocol for ASTM 1226, for example, calls for drying the sample so that moisture content is less than 5 percent by weight, and particle size is 95 percent sub-200 mesh screen by weight. The thought behind this approach is to obtain near worst-case test data that could be found within a facility (i.e., accumulations of fines, typically sub-200 mesh, at some locations or changes in processes) and by doing so ensure conservatism in the design of protection equipment.
This is a built-in safety factor for the tests, as the testing laboratory does not know if the samples are a good representation of the dust from the facility. By performing the test in this manner, it assumes a worse-case scenario to account for dust accumulations not taken into account by the

facility. On the other hand, testing material "as received" can result in a more realistic appreciation of the true nature of the hazard under assessment. Making the decision whether to test as received or in accordance with protocol is of considerable importance and should be done in consultation with experts or someone familiar with the process and material.

5.4.3.2*

It shall be permitted to test a sample sieved to less than 200 mesh (75 microns) from the location in the process or facility that has the finest particle size distribution.

A.5.4.3.2

Testing a worst-case (finest) particle size distribution will provide a conservative determination of the combustibility of the material. (See Table A.5.4.3.2.)

Table A.5.4.3.2 Standard Test Methods to Determine Explosibility Properties

Method	***Property***
ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air	*Minimum ignition energy (MIE) of dust cloud in air*
ASTM E 1491, Standard Test Method for Minimum Autoignition Temperature of Dust Clouds	*Minimum ignition temperature (T_c) of dust clouds*
ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds	*Maximum explosion pressure (P_{max}), rate and maximum rate of pressure rise (dP/dt), and explosion severity (K_{St})*
ASTM E 1515, Test Method for Minimum Explosible Concentration of Combustible Dusts	*Minimum explosible concentration (MEC)*
ASTM E 2021,Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers	*Minimum ignition temperature (T_c) of dust layers*
ASTM WK1680, Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds	*Limiting oxygen concentration (LOC)*

5.4.3.3

Where the explosibility is not known, the determination of explosibility of dusts shall be determined according to one of the following:

(1) The "Go/No-GO" screening test methodology described in ASTM E 1226, *Standard Test Method for Explosibility of Dust Clouds*

(2) ASTM E 1515, *Test Method for Minimum Explosible Concentration of Combustible Dusts*

(3) An equivalent test methodology

5.4.3.4

It shall be permissible to assume a material is explosive, forgoing the "Go/No-GO" screening test.

5.4.3.5*

If explosible, additional testing shall be performed as required for the performance-based design method described in Chapter 6, process hazard analysis described in Chapter 7, risk assessments described in Chapter 8, or hazard mitigation and prevention described in Chapter 8 using standard test methods.

A.5.4.3.5

ASTM E 2021, Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers, uses a constant temperature hot-plate to heat the dust on one side only. Routine tests use a 12.7 mm (0.5 in.) thick layer, which might simulate a substantial build-up of dust on the outside of hot equipment. However, since the ignition temperature normally decreases markedly with increased dust layer thickness, the method allows layer thickness to be varied according to the application.

ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, is used to determine the minimum ignition energy (MIE) for any given fuel concentration. The method uses the lowest energy, stored by a capacitor, that when released as a spark will ignite dust cloud-oxidant mixtures. By testing a range of concentrations, the lowest MIE is determined for the optimum mixture. Observed MIE and MIE values are highly sensitive to the test method, particularly the spark electrode geometry and characteristics of the capacitor discharge circuit. Dust ignition energy standard ASTM E 2019 describes test methods in current use that have been found to yield comparable results; however, it is a "performance standard" whereby the methodology adopted must produce data within the expected range for a series of reference dusts.

ASTM E 1491, Standard Test Method for Minimum Autoignition Temperature of Dust Clouds, is used to determine the dust cloud autoignition temperature (AIT). The test involves blowing dust into a heated furnace set at a predetermined temperature. The dust concentration is systematically varied to find the lowest temperature at which self-ignition occurs at ambient pressure, known as the minimum autoignition temperature (MAIT). A visible flame exiting the furnace provides evidence for ignition. Four different furnaces are described in ASTM E 1491 (0.27-L Godbert-Greenwald Furnace, 0.35-L BAM Oven, 1.2-L Bureau of Mines Furnace, and 6.8-L Bureau of Mines Furnace). Each yields somewhat different MAIT data, the largest deviations occurring at the greatest MAIT values. However, the lower AIT range is of more practical importance and here the agreement is better (for example 265±25°C for sulfur).

ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds, is used to determine the pressure and rate of pressure rise for suspended combustible dusts. The measurement of the explosibility parameters (P_{max} and K_{St}) requires the reproducible generation of a near homogeneous dust cloud inside a containment vessel of known volume. The explosibility parameters P_{max} (maximum pressure) and K_{St} (maximum rate of pressure rise of the worst case concentration times the cube root of the test volume) are obtained from such measurements. The determination of a P_{max} and K_{St} for a material first establishes that it is an explosible dust. A bench scale test method in ASTM E 1226 involves a vessel at least 20 liters in volume in which a dust cloud is formed using the discharge of a small cylinder of compressed air. After a prescribed time delay, the highly turbulent dust cloud is ignited using a strong ignition source of known energy. Pressure is monitored versus time by appropriate transducers and expressed as *pressure, P_{ex}, and pressure rate of rise, dP/d_{tex}. Dust concentration is varied to determine the maxima of both parameters. Particle size and moisture are other variables that must be considered. Particle size should be less than 75 microns ensuring a design that is conservative. The primary use of the test data P_{max} and K_{St} is for the design of explosion protection systems: venting, suppression, isolation. Vent designs provide a relief area that will limit damage to the process equipment to an acceptable level. The required vent area is calculated using equations from NFPA 68, Standard on Explosion Protection by Deflagration Venting, and requires knowledge of the process — volume, temperature, operating pressure, design strength, vent relief pressure — and of the fuel, P_{max} and K_{St}. Suppression is the active extinguishment of the combustion and again limits the explosion pressure to an acceptable level. Suppression designs require similar process and hazard data in order to determine the hardware requirements such as size, number, and location of containers, detection conditions, and the final or reduced explosion pressure. Isolation, the prevention of flame propagation through interconnections, requires the same process and hazard data to determine hardware needs and locations. The extent of testing should depend on what the scenario or evaluation such as explosion venting for a dust collector would require K_{St} and P_{max}.*

Refer to Table A.5.4.3.2 for standard test methods for determining explosibility characteristics of dusts that are used for the process hazard analysis, performance-based design method risk assessments, and hazard management of combustible dusts.

5.5 Sampling.

5.5.1 Sampling Plan.

5.5.1.1

Representative samples of dusts shall be identified and collected for testing according to a sampling plan.

5.5.1.2

The sampling plan shall include the following:

(1) Identify locations where fine particulate and dust is present

(2) Identify representative samples

(3) Collect representative samples

(4) Preserve sample integrity

(5) Communication with the test laboratory regarding sample handling

(6) Documentation

5.5.2 Mixtures.

5.5.2.1*

If the dust sample is a mixture, the relative concentration of each general category of particulate solid shall be determined based on available information or laboratory analysis.

A.5.5.2.1

If the dust sample is a mixture of organic, inorganic, or combustible metals, the amount or concentration of each constituent should be determined by laboratory analysis. Common methods for an analysis of mixture composition include material seperation, mass fraction analysis, energy dispersive x-ray spectroscopy, Fourier transform infrared spectroscopy, inductively coupled plasma spectroscopy, and x-ray fluorescence spectroscopy.

5.5.2.2

The hazard management of a mixture shall be based on the predominant constituent by mass unless there are specific constituents imparting unique chemical reactivity issues to the mixture.

5.5.2.2.1*

Unique chemical reactivity issues shall include, but not be limited to, the following:

(1) Water reactivity

(2) Reactivity with extinguishing agents or other mixture constituent

(3) Pyrophoricity

(4) Chemical instability

(5) Oxidizer

A.5.5.2.2.1

For example, a mixture that contains some metal powder or dust should be analyzed to determine whether that metal is reactive with water. If so, then the entire mixture must be analyzed to determine whether it is water reactive.

5.5.3 Representative Samples.

5.5.3.1*

Samples collected from each location shall be representative of the material at that location, process, equipment, or surface.

A.5.5.3.1

Special consideration should be given to samples from equipment in facilities such as dust collectors, impact equipment, silos and bins, processing equipment, ovens, furnaces, dryers, conveyors, bucket elevators, and grain elevators.

If a sample is from a dust collection or pneumatic conveying system, the sample should be a representative of the hazard subject to evaluation.

Samples should be collected from rooms and building facilities where combustible dusts can exist including rooms where abrasive blasting, cutting, grinding, polishing, mixing, conveying, sifting, screening, bulk handling or storage, packaging, agglomeration, and coating are performed.

Where there are numerous or a range of products and processes, worst-case samples can be used with process hazard analysis to assess the hazards. Performance-based design allows the user to identify and sample select materials instead of the prescriptive approach where all materials are collected and tested. Where multiple pieces of process equipment are present and *contain essentially the same material, a single representative sample can be acceptable. While the composition can be constant, attrition and separation based on particle size should be assessed. If and where attrition occurs, samples should be collected from such process equipment from start to finish and representative of the material with reduced particle size. For example, a belt conveyor can have larger particles on the belt but finer dusts along the sides or under or at the bottom of the conveyor. The sampling plan should include samples of the accumulated fines as one sample and a sample from the center of the belt as a second separate sample. Material to be used for the screening tests, and for the determination of material hazard characteristics such as* K_{St}*, MIE, Tc, etc., should be collected from the areas or inside equipment presenting the worst-case risk.*

5.5.3.2*

Special consideration shall be given to collecting samples from processes and equipment that result in attrition or reduction of particle size.

A.5.5.3.2

Some processes require further evaluation such as grinding. Grinding can result in a broad range of particle size. A representative sample should be tested. Combustible particulate solids include dusts, fibers, fines, chips, chunks, flakes, or mixtures of these. The term combustible particulate solid addresses the attrition of material as it moves within the process equipment. Particle abrasion breaks the material down and produces a mixture of large and small particulates, some of which could be small enough to be classified as dusts. Consequently, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material.

5.5.3.3*

When changes in the materials or processes occur, the owner/operator shall comply with Chapter 9.

A.5.5.3.3

The following changes in material or process can initiate the management of change in Chapter 8, and new samples should be collected and analyzed:

1. *New process equipment is installed that presents new hazards.*
2. *New operating conditions for existing equipment create a new hazard.*
3. *A new material is used in the process.*

5.5.4* Sample Collection.

Dust samples shall be collected in a safe manner using acceptable tools, containers, and methodologies so that the sample is preserved.

A.5.5.4

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

5.5.4.1*

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

A.5.5.4.1

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

5.6* Fire Identification/Hazards. (Reserved)

A.5.6

Specific fire hazards include self-heating, heat of reaction (i.e., heat of hydration), pyrophoricity, water reactivity, and thermite reactions.

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

6.1.1 Approved Qualifications.

The performance-based design shall be prepared by a person with qualifications acceptable to the owner/operator.

6.1.2* Document Requirements.

Performance-based designs shall be documented to include all calculations, references, assumptions, and sources from which material characteristics and other data have been obtained, or on which the designer has relied for some material aspect of the design in accordance with 6.1.2.

A.6.1.2

Chapter 5 of NFPA 101, Life Safety Code, provides a more complete description of the performance-based design process and requirements. In addition, the SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings outlines a process for developing, evaluating, and documenting performance-based designs.

6.1.2.1* General.

All aspects of the design, including those described in 6.1.2.2 through 6.1.2.14, shall be documented in a format and content acceptable to the authority having jurisdiction.

A.6.1.2.1

The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings describes the documentation that will be provided for a performance-based design. Proper documentation of a performance-based design is critical to design acceptance and construction. Proper documentation will ensure that all parties involved understand the factors necessary for the implementation, maintenance, and continuity of the fire protection design. If

attention to detail is maintained in the documentation, there should be little dispute during approval, construction, startup, and use.
Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically.

6.1.2.2* Technical References and Resources.

When requested by the authority having jurisdiction (AHJ), the AHJ shall be provided with sufficient documentation to support the validity, accuracy, relevance, and precision of the proposed methods. The engineering standards, calculation methods, and other forms of scientific information provided shall be appropriate for the particular application and methodologies used.
A.6.1.2.2
The sources, methodologies, and data used in performance-based designs should be based on technical references that are widely accepted and used by the appropriate professions and professional groups. This acceptance is often based on documents that are developed, reviewed, and validated under one of the following processes:

1. *Standards developed under an open consensus process conducted by recognized professional societies, codes or standards organizations, or governmental bodies*
2. *Technical references that are subject to a peer-review process and published in widely recognized peer-reviewed journals, conference reports, or other publications*
3. *Resource publications, such as the SFPE Handbook of Fire Protection Engineering, which are widely recognized technical sources of information*

The following factors are helpful in determining the acceptability of the individual method or source:

1. *Extent of general acceptance in the relevant professional community, including peer-reviewed publications, widespread citations in technical literature, and adoption by or within a consensus document*
2. *Extent of documentation of the method, including the analytical method itself, assumptions, scope, limitations, data sources, and data reduction methods*
3. *Extent of validation and analysis of uncertainties, including comparison of the overall method with experimental data to estimate error rates, as well as analysis of the uncertainties of input data, uncertainties and limitations in the analytical method, and uncertainties in the associated performance criteria*
4. *Extent to which the method is based on sound scientific principles*
5. *Extent to which the proposed application is within the stated scope and limitations of the supporting information, including the range of applicability for which there is documented validation, and considering factors such as spatial dimensions, occupant characteristics, and ambient conditions, which can limit valid applications*

In many cases, a method will be built from and include numerous component analyses. Such component analyses should be evaluated using the same acceptability factors that are applied to the overall method, as outlined in items A.6.1.2.2(1) through A.6.1.2.2(5).

A method to address a specific fire or explosion safety issue, within documented limitations or validation regimes, might not exist. In such a case, sources and calculation methods can be used outside of their limitations, provided that the design team recognizes the limitations and addresses the resulting implications.

The technical references and methodologies to be used in a performance-based design should be closely evaluated by the design team, the authority having jurisdiction, and possibly by a third-party reviewer. The strength of the technical justification should be judged using criteria in items A.6.1.2.2(1) through A.6.1.2.2(5). This justification can be strengthened by the presence of data obtained from fire or explosion testing.

6.1.2.3 Building Design Specifications.

All details of the proposed building, facilities, equipment, and process designs that affect the ability of the facility to meet the stated goals and objectives shall be documented.

6.1.2.4 Performance Criteria.

Performance criteria, with sources, shall be documented.

6.1.2.5 Occupant Characteristics.

Assumptions about occupant characteristics shall be documented.

6.1.2.6 Design Fire and Explosion Scenarios.

Descriptions of combustible dust fire and explosion design scenarios shall be documented.

6.1.2.7 Input Data.

Input data to models and assessment methods, including sensitivity analyses, shall be documented.

6.1.2.8 Output Data.

Output data from models and assessment methods, including sensitivity analyses, shall be documented.

6.1.2.9 Safety Factors.

The safety factors utilized shall be documented.

6.1.2.10 Prescriptive Requirements.

Retained prescriptive requirements shall be documented.

6.1.2.11 Modeling Features.

6.1.2.11.1

Assumptions made by the model user and descriptions of models and methods used, including known limitations, shall be documented.

6.1.2.11.2

Documentation shall be provided to verify that the assessment methods have been used validly and appropriately to address the design specifications, assumptions, and scenarios.

6.1.2.12 Evidence of Modeler Capability.

The design team's relevant experience with the models, test methods, databases, and other assessment methods used in the performance-based design proposal shall be documented.

6.1.2.13 Performance Evaluation.

The performance evaluation summary shall be documented.

6.1.2.14 Use of Performance-Based Design Option.

Design proposals shall include documentation that provides anyone involved in the ownership or management of the building with notification of the following:

(1) Approval of the building, facilities, equipment or processes, in whole or in part, as a performance-based design with certain specified design criteria and assumptions

(2) Need for required re-evaluation and reapproval in cases of remodeling, modification, renovation, change in use, or change in established assumptions

6.1.3*

Performance-based designs and documentation shall be updated and subject to re-approval if any of the assumptions on which the original design was based are changed.
A.6.1.3
Relevant aspects that could require a re-evaluation include, but are not limited to, changes to the following:

1. *Information about the hazardous characteristics of the materials*
2. *Information about the performance capabilities of protective systems*
3. *Heretofore unrecognized hazards*

Intentional changes to process materials, technology, equipment, procedures, and facilities are controlled by Section 9.9.

6.1.4 Sources of Data.

6.1.4.1

Data sources shall be identified and documented for each input data requirement that must be met using a source other than a design fire scenario, an assumption, or a building design specification.

6.1.4.2

The degree of conservatism reflected in such data shall be specified, and a justification for the sources shall be provided.

6.1.5 Maintenance of the Design Features.

To continue meeting the performance goals and objectives of this standard, the design features required for each hazard area shall be maintained for the life of the facility.

6.1.5.1

This shall include complying with originally documented design assumptions and specifications.

6.1.5.2

Any variation from the design shall be acceptable to the authority having jurisdiction.

6.2 Risk Component and Acceptability. (Reserved)

6.3 Performance Criteria.

A system and facility design shall be deemed to meet the objectives specified in Section 4.2 if its performance meets the criteria in 6.3.1 through 6.3.5.

6.3.1 Life Safety.

6.3.1.1*

The life safety objectives of 6.3.1 with respect to a fire hazard shall be achieved if either of the following criteria is met:

(1) Ignition has been prevented.

(2) Under all fire scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions due to the fire, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation.

A.6.3.1.1

When evaluating tenable conditions, the toxicity of hazardous materials released as a result of a fire or explosion should be considered.

6.3.1.2

The life safety objectives of 6.3.1 with respect to an explosion hazard shall be achieved if either of the following criteria are met:

(1) Ignition has been prevented.

(2) Under all explosion scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions, including missile impact or overpressure, due to the occurrence of an explosion, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation.

6.3.2 Structural Integrity.

The structural integrity objective of 6.3.2 with respect to fire and explosion shall be achieved when no critical structural element of the building is damaged to the extent that it can no longer support its design load under all fire and explosion scenarios.

6.3.3 Mission Continuity.

The mission continuity objectives of 6.3.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

6.3.4 Mitigation of Fire Spread and Explosions.

When limitation of fire spread is to be achieved, all of the following criteria shall be demonstrated:

(1) Adjacent combustibles shall not attain their ignition temperature.

(2) Building design and housekeeping shall prevent combustibles from accumulating exterior to the enclosed process system to a concentration that is capable of supporting propagation.

(3) Particulate processing systems shall prevent fire or explosion from propagating from one process system to an adjacent process system or to the building interior.

6.3.5 Effects of Explosions.

Where the prevention of damage due to explosion is to be achieved, deflagrations shall not produce any of the following conditions:

(1) Internal pressures in the room or equipment sufficient to threaten its structural integrity

(2) Extension of the flame front outside the compartment or equipment of origin except where intentionally vented to a safe location

(3) Rupture of the compartment or equipment of origin and the ejection of fragments that can constitute missile hazards

6.4* Design Scenarios.

A.6.4

The process hazard analysis conducted according to the requirement in Chapter 7 might be useful in identifying the scenarios for Section 6.4.The fire and explosion scenarios defined in Section 6.4 assume the presence of an ignition source, even those scenarios limited by administrative controls (such as a hot work permit program). It is the responsibility of the design professional to document any scenario that has been excluded on the basis of the absence of an ignition source.

6.4.1 Fire Scenarios.

6.4.1.1*

Each fuel object in the compartment shall be considered for inclusion as a fire scenario.

A.6.4.1.1
A compartment is intended to include the area within fire-rated construction.

6.4.1.2

The fuel object that produces the most rapidly developing fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.3

The fuel object that produces the most rapidly developing fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.1.4

The fuel object that produces the greatest total heat release during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.5

The fuel object that produces the greatest total heat release under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.1.6

Each fuel object that can produce a deep-seated fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.7

Each fuel object that can produce a deep-seated fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.2 Explosion Scenarios.

6.4.2.1

Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

6.4.2.2

Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

6.4.2.3

Each building or building compartment containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

6.4.2.4

Each building or building compartment containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

6.4.2.5*

Where combustible dust can cause other explosion hazards, such as generation of hydrogen or other flammable gases, those hazards shall be included as explosion scenarios.

A.6.4.2.5

For instance, some combustible metals can generate hydrogen when in contact with water. See NFPA 484, Standard for Combustible Metals, for additional information.

6.5 Evaluation of Proposed Design.

6.5.1*

A proposed design's performance shall be assessed relative to each performance objective in Section 6.3 and each applicable scenario in Section 6.4, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

A.6.5.1

The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings outlines a process for evaluating whether trial designs meet the performance criteria.

6.5.2

The design professional shall establish numerical performance criteria for each of the objectives in Section 6.3.

6.5.3

The design professional shall use the assessment methods to demonstrate that the proposed design will achieve the goals and objectives, as measured by the performance criteria in light of the safety margins and uncertainty analysis, for each scenario, given the assumptions.

6.6 Retained Prescriptive Requirements.

6.6.1

Portions of a facility design in accordance with Chapter 6 shall also meet the following requirements:

(1) Housekeeping - 8.4

(2) PPE - 8.6

(3) Management Systems - Chapter 9

Chapter 7 Process Hazard Analysis

7.1* General Requirements.

A.7.1

This chapter provides the minimum requirements for performing a hazard assessment to identify and analyze the hazards presented by the presence of combustible particulate solids for the purpose of identifying relevant management strategies necessary to provide a reasonable degree of protection to life and property.

The intent of this chapter is to establish a requirement to analyze the potential hazards of an operation regardless of size. The process hazards analysis (PHA) methodology is not necessarily the same as that in the OSHA process safety management (PSM) regulation and is not intended to trigger such a requirement. Annex B provides an example of how one might perform a PHA.

7.1.1 Responsibility.

The owner/operator of a facility where combustible particulate solids are present in either a process or a facility compartment shall be responsible to ensure a process hazards analysis is completed in accordance with the requirements of this chapter.

7.1.2

The requirements of Chapter 7 shall be applied retroactively.

7.2 Criteria.

7.2.1* Overview.

The process hazards analysis shall consider the fire, deflagration, and explosion hazards and provide recommendations to ensure that the objectives in Section 4.2 are met.

A.7.2.1

NFPA standards rely on the determination of "where an explosion hazard or deflagration hazard exists." There are other physical and health hazards to consider such as toxicity, reactivity with water, and so forth that can be considered when conducting a process hazard analysis. The process hazards analysis should consider the four conditions that are required for a deflagration:

1. *A combustible particulate solid of sufficiently small particle size to deflagrate*
2. *A combustible particulate solid suspended in air to deflagrate (or other oxidizing medium)*
3. *A combustion particulate solid suspension of sufficiently high concentration to deflagrate*
4. *A competent igniter applied to the suspension of combustible particulate solids where the concentration is sufficient for flame propagation.*

A deflagration leading to an explosion will occur whenever all four criteria occur within a compartment or container at the same time. Since gravity is a concentrating effect and we always assume an ignition source is present unless we can prove one cannot exist, even under conditions of equipment failure, this list reduces to:

1. *A combustible particulate solid of sufficiently small particle size to deflagrate*
2. *A means for suspending the combustible particulate solid in air (or other oxidizing medium)*
3. *A sufficient concentration can be achieved*

Most dust explosions occur as a series of deflagrations leading to a series of explosions in stages. While a single explosion is possible, it is the exception rather than the rule. Most injuries are the result of the "secondary" deflagrations rather than the initial event. Most "explosion" events are a series of deflagrations each causing a portion of the process or facility to explode. Primary deflagrations lead to secondary deflagrations, usually fueled by accumulated fugitive dust that has been suspended by the following:

1. *Acoustic impulse waves of the initial, primary, deflagration*
2. *Entrainment by deflagration pressure front*

The majority of the property damage and personnel injury is due to the fugitive dust accumulations within the building or process compartment. The elimination of accumulated fugitive dust is CRITICAL and the single most important criterion for a safe workplace.

7.2.1.1

The process hazards analysis shall determine where a fire, deflagration, and explosion hazard exists.

7.2.2* Qualifications.

The process hazards analysis shall be performed or led by a qualified person.
A.7.2.2
The qualified person who is leading or performing the process hazard analysis should be familiar with conducting a process hazard analysis. The qualified person should also be familiar with the hazards of combustible dusts. Typically, a team performs a process hazard analysis. For some processes this team may be a little as two persons, or for larger and more complex processes, the team might require a many more than two persons. This team is made of a variety of persons whose background and expertise can include the following:

1. *Familiarity with the process*
2. *Operations and maintenance*
3. *Process equipment*
4. *Safety systems*
5. *History of operation*
6. *The properties of the material*
7. *Emergency procedures*

The individuals involved in the process hazard analysis could include facility operators, engineers, owners, equipment manufacturers, or consultants.

7.2.3* Minimum Interval.

A revalidation of the process hazards analysis shall be performed a minimum of every 5 years.
A.7.2.3
The requirement to review the process hazard analysis should apply even if no changes have been made to the overall process. The process hazard analysis should be maintained for the life of the process.

7.2.4 Documentation.

The results of the process hazards analysis review shall be documented, including any necessary action items requiring change to the process materials, physical process, process operations, or facilities associated with the process.

7.3 Methodology.

7.3.1 General.

The process hazards analysis shall include the following:

(1) Identify the portions of the process or facility areas where a fire, deflagration, and explosion hazard exists

(2) Identify specific fire and deflagration scenarios and determine their consequences, including fires, deflagrations, and explosions

(3) Identify the means and develop a plan by which fire, deflagration, and explosion events can be prevented or mitigated

(4) Identify operating ranges

7.3.2 Material Evaluation.

7.3.2.1

The process hazards analysis shall be based on data used in Chapter 5 of material that is representative of the dust present.

7.3.3 Process Systems.

7.3.3.1*

Each part of the process system where combustible dust is present shall be evaluated.
A.7.3.3.1
This includes the process systems and ancillary equipment such as dust collection systems. Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate.

7.3.3.2*

The potential for a dust fire, deflagration, or explosion in a process system component shall be based on whether the dust fire, deflagration, or explosion hazard exists.
A.7.3.3.2

Each and every process component should be evaluated, including ducts, conveyors, silos, bunkers, vessels, fans, and other pieces of process equipment. Each point along the process should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined. Usually the relevant industry or commodity-specific NFPA standard will provide options. The process and process equipment will often determine which option is most appropriate. (Refer to Annex B for an example of a process hazard analysis.)

7.3.3.3

Where a dust fire, deflagration, or explosion hazard exists within a process system, the hazards shall be managed in accordance with this standard.

7.3.4 Facility Compartments.

7.3.4.1*

Each facility compartment where combustible dust is present shall be evaluated.
A.7.3.4.1
Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate.

7.3.4.2*

The potential for a dust fire, deflagration, or explosion in a facility compartment shall be based upon whether a dust fire, deflagration, or explosion hazard exists.
A.7.3.4.2
Each and every facility compartment containing combustible particulate solids should be evaluated. The complete contents of the compartment should be considered, including hidden areas. Each area in the compartment should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined. Usually the relevant industry or commodity-specific NFPA standard will provide options. (See Annex C.)

7.3.4.2.1*

The evaluation of dust deflagration hazard in a facility compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure.
A.7.3.4.2.1
Refer to 6.1.1.3 and 6.1.1.8 of NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, and 6.4.2.2 of NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, for examples of methods to determine acceptable threshold accumulation level.

7.3.4.2.2

Threshold housekeeping dust accumulation levels and non-routine dust accumulation levels (i.e., from a process upset) shall be in accordance with relevant industry or commodity-specific NFPA standards.*(See 1.3.1.)*

7.3.4.3

Where a dust fire, deflagration, or explosion hazard exists within a facility compartment, the effects of the fire, deflagration, or explosion shall be managed in accordance with this standard.

Chapter 8 Hazard Management: Mitigation and Prevention

8.1 Inherently Safe Designs. (Reserved)

8.2 Building Design.

8.2.1* Construction.

The type of construction shall be in accordance with the building code adopted by authority having jurisdiction.

A.8.2.1

It is preferable for buildings that handle combustible dust to be of either Type I or II construction, as defined by NFPA 220, Standard on Types of Building Construction.

8.2.2 Building/Room Protection.

8.2.2.1*

Each room, building, or other enclosure where a dust deflagration hazard exists shall be protected from the consequence of deflagration.

A.8.2.2.1

Chapter 7 provides the process to determine where and whether a dust deflagration hazard exists. Section 8.2 is not intended to cover process equipment such as bins and silos.

8.2.2.2

If a room or building contains a dust explosion hazard in a facility compartment and outside of equipment, such areas shall be provided with deflagration venting to a safe area in accordance with NFPA 68, Standard on Explosion Protection by Deflagration Venting.

8.2.2.2.1

Venting shall be located to relieve pressure through an outside wall or roof.

8.2.2.2.2

The fireball, blast hazards, and missile hazards that are created by deflagration venting shall not expose additional personnel or property assets.

8.2.3 Life Safety.

Building configuration and appurtenances shall comply with the life safety requirements of the building and fire prevention codes adopted by the authority having jurisdiction.

8.2.3.1

Where a dust deflagration hazard exists in a facility compartment and outside of equipment, building configuration and appurtenances shall comply with the life safety requirements of the building and fire prevention codes for a hazardous occupancy adopted by the authority having jurisdiction.

8.2.3.2*

Where a dust explosion hazard exists in a facility compartment and outside of equipment, enclosed exit and egress paths shall be designed to withstand potential overpressures from a dust explosion.

A.8.2.3.2

Damage-limiting construction should be considered for those sections of enclosed egress paths, based on withstanding building/room overpressure determined according to NFPA 68, Standard on Explosion Protection by Deflagration Venting. The methodology of NFPA 68 uses an evaluation of the quantity of dust accumulation to determine the necessary building/room vent area and resulting overpressure.

8.2.4 Methods to Limit Accumulation.

8.2.4.1*

Interior surfaces where dust accumulations can occur shall be designed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations.

A.8.2.4.1

To the extent feasible and practical from a cost and sanitation standpoint, horizontal surfaces should be minimized to prevent accumulation of dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops. Overhead steel I-beams and similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. The additional weight of the box enclosures should be considered in the structural design. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning. One option based on clean design concepts is to construct the building walls so that the structural supports, electrical conduit, and so forth are on the exterior side of the building walls; therefore, the interior building compartment walls are smooth and less likely to collect fugitive dust.

8.2.4.2

Enclosed building spaces inaccessible to routine housekeeping shall be sealed to prevent dust accumulation.

8.2.4.3*

Enclosed building spaces that are difficult to access for routine housekeeping shall be designed to facilitate routine inspection for the purpose of determining the need for periodic cleaning.

A.8.2.4.3

The space above suspended ceilings is an example of a space that is difficult to access for routine housekeeping. Periodic inspection of such spaces is necessary to ensure accumulations do not result in a deflagration hazard area.

8.2.5 Separation of Hazard Areas from Other Hazard Areas and from Other Occupancies.

8.2.5.1

Areas where a dust deflagration hazard exists in a facility compartment (excluding hazard within equipment) shall be segregated, separated, or detached from other occupancies to minimize damage from a fire or explosion.

8.2.5.2 Use of Segregation.

8.2.5.2.1

Physical barriers erected for the purpose of limiting fire spread shall be designed in accordance with NFPA 221, Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls.

8.2.5.2.2

Physical barriers erected to segregate fire hazard areas, including all penetrations and openings of floors, walls, ceilings, or partitions, shall have a minimum fire resistance rating based on the anticipated fire duration.

8.2.5.2.3

Physical barriers, including all penetrations and openings of floors, walls, ceilings, or partitions, that are erected to segregate dust explosion hazard areas shall be designed to preclude failure of those barriers during a dust explosion in accordance with NFPA 68, Standard on Explosion Protection by Deflagration Venting.

8.2.5.3 Use of Separation.

8.2.5.3.1*

Separation shall be permitted to be used to limit the dust explosion hazard or deflagration hazard area within a building when it is supported by a documented engineering evaluation acceptable to the authority having jurisdiction.

A.8.2.5.3.1

A building could be considered as a single combustible dust hazard area, or as a collection of smaller, separated combustible dust hazard areas. When the owner/operator chooses to consider the building as a single area, then the hazard analysis should consider the entire building floor area, and the considerations for mitigation apply to the entire building. Where the combustible dust hazard areas are sufficiently distant to assert separation and the owner/operator chooses to consider each hazard area separately, the hazard analysis should consider each separated area, and the considerations for mitigation should be applied to each area independently. Due consideration should be given to overhead dust accumulations, such as on beams or ductwork, *which would negate the use of separation to limit combustible dust hazard areas. If the separation option is chosen, a building floor plan, showing the boundaries considered, should be maintained to support housekeeping plans.*

8.2.5.3.2*

The required separation distance between the dust explosion hazard or deflagration hazard area and surrounding exposures shall be determined by an engineering evaluation that addresses the following:

(1) Properties of the materials

(2) Type of operation

(3) Amount of material likely to be present outside the process equipment

(4) Building and equipment design

(5) Nature of surrounding exposures

A.8.2.5.3.2

Separation distance is the distance between the outer perimeter of a primary dust accumulation area and the outer perimeter of a second dust accumulation area. Separation distance evaluations should include the area and volume of the primary dust accumulation area as well as the building or room configuration.

8.2.5.3.3

The separation area shall be free of dust, or where dust accumulations exist on any surface, the surface colors below shall be readily discernible.

8.2.5.3.4

When separation is used to limit the dust explosion or deflagration hazard area determined in Chapter 7, the minimum separation distance shall not be less than 35 ft (11 m).

8.2.5.3.5*

When separation is used, housekeeping, fixed dust collection systems employed at points of release, and the use of physical barriers shall be permitted to be used to limit the extent of the dust explosion hazard or flash-fire hazard area.

A.8.2.5.3.5

The assertion of separation must recognize the dust accumulation on all surfaces in the intervening distance, including floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures, and walls. Process equipment or ductwork containing dust can also provide a connecting conduit for propagation between accumulation areas. In order to prevent flame propagation across the separation distance, the dust accumulation should be very low. The National Grain and Feed Association study, Dust Explosion Propagation in Simulated Grain Conveyor Galleries, has shown that a layer as thin as 1/100 in. is sufficient to propagate flame in a limited expansion connection, such as an exhaust duct or a hallway. In the subject study, the flame propagated for at least 80 ft (24.4 m) in an 8 ft (2.4 m) tall by 8 ft (2.4 m) wide gallery.

8.2.5.4 Use of Detachment.

8.2.5.4.1

Detachment shall be permitted to be used to limit the dust hazard area to a physically separated adjacent building.

8.2.5.4.2*

The required detachment distance between the dust explosion hazard or deflagration hazard area and surrounding exposures shall be determined by an engineering evaluation that addresses the following:

(1) Properties of the materials

(2) Type of operation

(3) Amount of material likely to be present outside the process equipment

(4) Building and equipment design

(5) Nature of surrounding exposures

A.8.2.5.4.2

Detachment distance is the radial distance between nearest points of two unconnected adjacent buildings.

8.3 Equipment Design.

8.3.1* Risk Assessment.

A documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, protection measures addressed in Section 8.3.

A.8.3.1

A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety.

8.3.2* Design for Dust Containment.

A.8.3.2

Reserved.

8.3.2.1

All components of enclosed systems that handle combustible particulate solids shall be designed to prevent the escape of dust, except for openings intended for intake and discharge of air and material.

8.3.2.2

Where the equipment cannot be designed for dust containment, dust collection shall be provided. (*See also 8.3.3.)*

8.3.3* Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

A.8.3.3

All three of these types of systems commonly utilize air (or inert gases) to convey the combustible dusts from one location to another. However, each of the systems has unique design, function, and operational characteristics that are significantly different from each other. Each of these types of systems, due to these factors, represents a different level of risk that must be considered when used.

Compared to typical dust collection systems and centralized vacuum cleaning systems handling combustible dusts, typical dilute and dense phase pneumatic conveying systems represent a significantly lower deflagration risk. However, that does not mean there is not a deflagration risk present. Risk assessment should be used to determine the level of risk involved and the correct means to minimize that risk.

8.3.3.1 General Requirements.

8.3.3.1.1*

Where used to handle combustible particulate solids, systems shall be designed by and installed under the supervision of qualified persons who are knowledgeable about these systems and their associated hazards.

A.8.3.3.1.1

The system information and documentation should include the following:

(1) System design specifications
(2) System installation specifications
(3) Equipment specifications
(4) Operational description
(5) System deflagration protection and specifications, including explosibility information
(6) System mechanical and electrical drawings
(7) System controls and specifications

The design of these systems should be coordinated with the architectural and structural designs of the areas involved.

8.3.3.1.2*

Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with Chapter 9.

A.8.3.3.1.2

Pneumatic conveying and dust collection systems are designed for specific conveying requirements. Changing any of those requirements can significantly change the ability of the system to provide the original design performance. An analysis of any proposed changes should be done to assure the system will still be able to perform as required to meet safety and operational requirements

8.3.3.1.3*

The system shall be designed and maintained to ensure that the air/gas velocity used shall meet or exceed the minimum required to keep the interior surfaces of all piping or ducting free of accumulations under all operating modes.

A.8.3.3.1.3

The design minimum velocity for each of these systems differs significantly. Refer to the specific sections to follow on the type of system for that information. For guidance on designing acquisition, operation, and maintenance of dust collection systems, refer to ACGIH, Industrial Ventilation: A Manual of Recommended Practice.

8.3.3.1.4* Operations.

A.8.3.3.1.4

The requirements in 7.3.2.1.4[8.3.3.1.4?] are applicable to dilute phase pneumatic conveying systems. Dense phase systems require a separate analysis.

8.3.3.1.4.1 Sequence of Operation.

Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed with the operating logic, sequencing, and timing outlined in 8.3.3.1.4.2 and 8.3.3.1.4.3.

8.3.3.1.4.2* Startup.

Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed such that, on startup, the system achieves and maintains design air velocity prior to the admission of material to the system.

A.8.3.3.1.4.2

Some chemical and plastic dusts release residual flammable vapors such as residual solvents, monomers, or resin additives. These vapors can be released from the material during handling or storage. Design of the system should be based on a minimum airflow sufficient to keep the concentration of the particular flammable vapor in the airstream below 25 percent of the LFL of the vapor.

8.3.3.1.4.3 Shutdown.

(A) Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed such that, on normal shutdown of the process, the system maintains design air velocity until material is purged from the system.

(B) The requirements of 8.3.3.1.4.3(A) shall not apply during emergency shutdown of the process, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

(C) Dilute phase pneumatic conveying systems shall be designed such that, upon restart after an emergency shutdown, residual materials can be cleared and design air velocity can be achieved prior to admission of new material to the system.

(D) Dense Phase. (Reserved)

8.3.3.2* Specific Requirements for Pneumatic Conveying Systems.

A.8.3.3.2

There is a wide variety in the types of pneumatic conveying systems used for the transfer of combustible particulates from one or more locations to a single or multiple locations. These types include, but are not limited to, dilute, dense, and semi-dense phase with varying levels of vacuum (negative pressure) or positive pressure used in each case.

The current historical data and operational characteristics of these systems combine to offer the user an alternative that can provide a safer alternative to other, more risk-inherent methods of conveying the combustible particulate solid. Properties of the particulate solid, beyond just the explosibility parameters, should be considered in design and feasibility of the use of pneumatic conveying for a particular application and material.

8.3.3.2.1*

The design of the pneumatic conveying system shall address required performance parameters and properties of the materials being conveyed.

A.8.3.3.2.1

Properties can include the following:

(1) Bulk density
(2) Data on the range of particulate size
(3) Concentration in conveying air/gas stream
(4) The potential for reaction between the transported particulate and the extinguishing media used to protect the process equipment systems
(5) Conductivity of the particulate
(6) Other physical and chemical properties that affect the fire protection of the process and equipment systems.

8.3.3.2.2*

Where a pneumatic conveying system or any part of such a system operates as a positive-pressure-type system and the air-moving device's gauge discharge pressure is 15 psi (103 kPa) or greater, the system shall be designed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code, or ASME B31.3, *Process Piping*, or international equivalents.

A.8.3.3.2.2

Rotary valves and diverter valves are not addressed within the ASME Boiler and Pressure Vessel Code or ASME B.31.3, Process Piping, so they would not be required to comply with those codes.

8.3.3.2.3*

Pneumatic conveying systems conveying combustible particulate solids shall be protected in accordance with Section 8.8.

A.8.3.3.2.3

Where a raw material or supply transport vehicle or container is connected to a pneumatic conveying system, it is considered a part of the pneumatic conveying system with regard to explosion protection requirements. As such, the requirements of isolation should be evaluated for this type of situation to determine if isolation is needed to protect the conveying system from the raw material supply. It is preferable to locate the filter receivers outside; however, this is often not feasible. Therefore, since deflagration hazards do exist, it is typically necessary to provide the proper protection for deflagration in the filter receiver (AMS) and propagation through the system.

8.3.3.3* Specific Requirements for Dust Collection Systems.

A.8.3.3.3

Dust collection systems for combustible dusts represent a significant increase in deflagration risk compared to most pneumatic conveying systems. This is due to the inherent design and operational characteristics of dust collection systems. A properly designed system is critical to minimizing that risk. For guidance on determining proper dust collection system design refer to ACGIH, Industrial Ventilation: A Manual of Recommended Practice.

8.3.3.3.1*

At each collection point, the system shall be designed to achieve the minimum required face velocity for dust capture over the entire opening of the hood or pickup point.

A.8.3.3.3.1

Proper dust collection design requires that a minimum air volume flow be maintained for each dust collection source point (hood). This value must be determined as part of the design process. This value should be documented to allow for field-testing to determine if the system is providing that flow and operating properly.

This design also requires that the hood be constructed to assure that a continuous airflow is provided at all times.

The ACGIH, Industrial Ventilation: A Manual of Recommended Practice has extensive information on the design basis for dust collection hoods and the necessary minimum air volumes and velocities to assure the containment, capture (i.e., collection), and control of the aerated dusts being generated.

8.3.3.3.2*

The hood or pickup point for each dust source shall have a documented minimum air volume flow based upon the system design.

A.8.3.3.3.2

Proper dust collection design requires that a minimum air volume flow be maintained for each dust collection source point (e.g., hood). This value must be determined as part of the design process. This value should be documented to allow for field-testing to determine if the system is providing that flow and operating properly.

8.3.3.3.3*

Branch lines shall not be disconnected, and unused portions of the system shall not be blanked off without providing a means to maintain required and balanced airflow.

A.8.3.3.3.3

Proper system design requires that airflows in the various branch lines be balanced to assure minimum air volume flow at each dust source collection point. When a branch line is disconnected, blanked off, or otherwise modified it changes the airflows in all the other branches of the system. This can lead to an imbalance of air flows that result in flows below the minimum required to keep the dust from accumulating in the ducts.

Use of manual slide or "blast" gates is not recommended. Use of such gates can lead to uncontrolled modification of the flow volumes for both a single line and the system as a whole. The results often lead to improper balance of the system airflows and material accumulations in the ducts. Proper design methods inherently assure minimum airflows and duct velocities without the use of manual slide or "blast" gates.

8.3.3.3.4*

The addition of branch lines shall not be made to an existing system without first confirming that the entire system will maintain the required and balanced airflow.

A.8.3.3.3.4

Installation of branch lines for additional dust sources to an existing dust collection system will result in lower air volumes and duct velocities for the existing portions of the system. Without providing for additional system performance this can result in a system performing below the minimum required for keeping the ducts free from material accumulations.

8.3.3.3.5*

Dust collection systems that remove material from operations that generate flames, sparks, or hot material under normal operating conditions shall not be interconnected with dust collection systems without isolation that transport combustible particulate solids or hybrid mixtures. (*See 8.8.4.*)

A.8.3.3.3.5

Examples of operations that under normal operating conditions could generate flames, sparks, or hot material can include grinding, saws, etc. This section is intended to segregate the equipment and operations that are recognized ignition sources from those that are not.

8.3.3.3.6*

The air-material separator selected for the system shall be designed to allow for the characteristics of the combustible dust being separated from the air or gas flow.

A.8.3.3.3.6

Combustible dusts vary considerably in their characteristics and the type of equipment necessary to separate them from the conveying air or gas stream. While the typical bag or cartridge dust collector (AMS) can be used with most combustible dusts, an exception would be most metal dusts, which can require a scrubber or wet collector. Refer to NFPA 484, Standard for Combustible Metals, for metal dust collection.

8.3.3.3.7*

Air-moving devices (AMD) shall be of appropriate type and sufficient capacity to maintain the required rate of air flow in all parts of the system.

A.8.3.3.3.7

The majority of dust collection systems use centrifugal fans for inducing the air flow through the system. Various models are available that will provide the performance characteristics required. Care must be taken to consider the worst-case situation, when the filters are nearly blinded or the scrubber is at maximum differential, as well as the situation where the system is new during start-up.

8.3.3.4* Specific Requirements for Centralized Vacuum Cleaning Systems.

A.8.3.3.4

A centralized vacuum cleaning system represents a significant deflagration risk due to the fact that it is designed to both collect and convey combustible dusts, and that tramp metals and other foreign materials, which could create an ignition source, can enter the system through the vacuum cleaning process. However, through proper design and protection of the system against deflagration, this system can provide for the removal of combustible dusts from plant areas where dust accumulations represent a risk to personnel and property. In addition, the dust removed through the vacuum cleaning process will now be located in an area where it can be properly handled with minimal risk.

8.3.3.4.1*

The system shall be designed to assure minimum conveying velocities at all times whether the system is used with a single or multiple simultaneous operators.

A.8.3.3.4.1

It is recommended that no more than two simultaneous operators (hose vacuuming stations) be allowed on any one line to the AMS (a.k.a. filter receiver). This is to assure that adequate conveying velocity can be maintained with just a single operator on the same line. Multiple lines to the AMS can be used to allow for more than two simultaneous operators on the whole system (with no more than two simultaneous operators allowed on each line).

The minimum conveying velocity will vary with the combustible dusts being conveyed. Typically, the minimum conveying velocities should be the same as the minimum required for pneumatic conveying of the same material.

8.3.3.4.2*

The hose length and diameter shall be sized for the application and operation.

A.8.3.3.4.2

It is recommended that 1.5 in. (38.1 mm) and/or 2.0 in. (50.8 mm) I.D. hoses be used for housekeeping purposes. It is also recommended that 25 ft (7.6 m) maximum hose length be used. In most systems the pressure losses (i.e., energy losses) through the hose represent more than 50 percent of the overall system differential pressure requirements. Shorter hose lengths can be used to improve system performance.

I.D. hoses of 1.5 in. (38.1 mm) are most commonly used for cleaning around equipment and for lighter duty requirements, while 2 in. (50.8 mm) I.D. hoses are used for larger dust accumulations and for cleaning large open areas.

8.3.3.4.3*

Where ignition-sensitive materials are collected, vacuum tools shall be constructed of metal or static dissipative materials and provide proper grounding to the hose.
A.8.3.3.4.3
Ignition-sensitive materials typically have an MIE of 30 mJ or less.

8.3.3.4.4*

Vacuum cleaning hose shall be static dissipative or conductive and grounded.
A.8.3.3.4.4
The creation of static electrical charges is a risk factor that can be minimized through the use of conductive vacuum cleaning tools and static dissipative and grounded hoses. This is a higher risk factor when low MIE combustible dusts are being vacuumed. Metal dusts represent a significantly increased risk when vacuum cleaning and require additional considerations as stated in the NFPA 484, Standard for Combustible Metals.

8.3.4 AMS Locations.

8.3.4.1 AMS Indoor Locations.

8.3.4.1.1* Dry AMS.
A.8.3.4.1.1
See NFPA 68, Standard on Explosion Protection by Deflagration Venting, for guidance on calculating the dirty side volume.

8.3.4.1.1.1

If the dirty side volume of the air–material separator is greater than 8 ft3 (0.2 m3), it shall be protected in accordance with Section 8.8.

8.3.4.1.1.2

Enclosureless AMS shall not be permitted to be located indoors unless specifically allowed by an industry or commodity-specific NFPA standard.

8.3.4.1.2 Wet AMS.

8.3.4.1.2.1

Wet air–material separators shall be permitted to be located inside when all of the following criteria are met:

(1) Interlocks are provided to shutdown the system if the flow rate of the scrubbing medium is less than the designed minimum flow rate.

(2) The scrubbing medium is not a flammable or combustible liquid.

(3) The separator is designed to prevent the formation of a combustible dust cloud within the air-material separator.

(4) The design of the separator addresses any reaction between the separated material and the scrubbing medium.

8.3.4.2 AMS Outdoor Locations. (Reserved)

8.3.5 Recycle of Clean Air AMS.

8.3.5.1

Exhaust air from the final air–material separator shall be discharged outside to a restricted area and away from air intakes.

8.3.5.2*

Air from air–material separators shall be permitted to be recirculated directly back to the pneumatic conveying system.

A.8.3.5.2

This section is in reference to closed-loop pneumatic conveying systems.

8.3.5.3*

Recycling of air-material separator exhaust to buildings or rooms shall be permitted when all of the following requirements are met:

A.8.3.5.3

Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in Chapter 7 of the ACGIH Industrial Ventilation: A Manual of Recommended Practice, should be followed.

(1) Combustible or flammable gases or vapors are not present either in the intake or the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the LFL, whichever is lower.

(2)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the MEC, whichever is lower.

A.8.3.5.3(2)

The system should be designed, maintained, and operated according to accepted engineering practice, and the air–material separator efficiency should be sufficient to prevent dust in the recycled air from causing hazardous accumulations of combustible dust in any area of the building.

(3)* The oxygen concentration of the recycled air stream is between 19.5 percent and 23.5 percent by volume.

A.8.3.5.3(3)

OSHA has established limits on oxygen concentration in the workplace. Permissible limits range from no lower than 19.5 percent by volume to no higher than 23.5 percent by volume in air. See 29 CFR, Part 1910.146.

(4) Provisions are incorporated to prevent transmission of flame and pressure effects

from a deflagration in an air-material separator back to the facility unless a process hazards analysis indicates that those effects do not pose a threat to the facility or the occupants.

(5) Provisions are incorporated to prevent transmission of smoke and flame from a fire in an air–material separator back to the facility unless a process hazards analysis indicates that those effects do not pose a threat to the facility or the occupants.

(6) The system includes a method for detecting air–material separator malfunctions that would reduce collection efficiency and allow increases in the amount of combustible particulate solids returned to the building.

(7) The building or room to which the recycled air is returned meets the requirements of Section 8.4.

(8) Recycled-air ducts are inspected and cleaned at least annually.

8.3.6 Transfer Points. (Reserved)

8.4 Housekeeping.

8.4.1 General.

Unless otherwise specified, the requirements of Section 8.4 shall be applied retroactively.

8.4.2* Methodology.

A.8.4.2

Model Programs Annex. ***(Reserved)***

8.4.2.1 Procedure.

8.4.2.1.1*

Housekeeping procedures shall be documented in accordance with the requirements of Chapters 7 and 9.

A.8.4.2.1.1

Items that should be included in the housekeeping procedure include the following:

1. *A risk assessment that considers the specific characteristics of the dust being cleaned (particle size, moisture content, MEC, MIE) and other safety risks introduced by the cleaning methods used*
2. *Personal safety procedures, including fall protection when working at heights*
3. *Personal protective equipment (PPE), including flame-resistant garments in accordance with the hazard analysis required by NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*
4. *Cleaning sequence*
5. *Cleaning methods to be used*

(6) Equipment, including lifts, vacuum systems, attachments, and so forth
(7) Cleaning frequency

8.4.2.1.2

Surfaces shall be cleaned in a manner that minimizes the risk of generating a fire or explosion hazard.

8.4.2.1.3*

Cleaning methods shall be in accordance with this standard and the industry or commodity-specific NFPA standard. *(See 1.3.1.)*
A.8.4.2.1.3
Cleaning methods can be industry specific.

8.4.2.1.4

Cleaning methods to be used shall be based on the characteristics of the material and quantity of material present.

8.4.2.2 Vacuum Cleaning Method.

8.4.2.2.1*

For residual accumulations, vacuum cleaning shall be the preferred method.
A.8.4.2.2.1
If a large quantity of material is spilled in an unclassified area, the bulk material should be collected by sweeping or shoveling or with a portable vacuum cleaner listed as suitable for Class II locations. Vacuum cleaners meeting the requirements in 8.4.2.2.2 can be used to clean up residual material after the bulk of the spill has been collected.

8.4.2.2.2*

Portable vacuum cleaners that meet the following minimum requirements shall be permitted to be used to collect combustible particulate solids:
A.8.4.2.2.2
Portable vacuum units are susceptible to additions risks that are not present in centralized vacuum cleaning systems. When electric drive motors are used, the fan and motor are often directly exposed to the combustible dust and represent an ignition source. Using vacuum blowers and drives designed to minimize that risk is critical. In addition, it is not possible to provide deflagration protection with these devices. Thus, it is necessary to minimize the risks involved through design and construction of the device.
It is also possible to use compressed air as a vacuum source (venturi), which inherently has no moving parts or direct ignition source. Wet separators are also available for high-risk materials and applications.

(1) Materials of construction shall comply with 8.5.7.1.

(2) Hoses shall be conductive or static dissipative.

(3) All conductive components, including wands and attachments, shall be bonded and grounded.

(4) Dust-laden air shall not pass through the fan or blower.

(5) Electrical motors shall not be in the dust-laden air stream unless listed for Class II, Division 1 locations.

(6)* When liquids or wet materials are picked up by the vacuum cleaner, paper filter elements shall not be used.

A.8.4.2.2.2(6)

Liquids or wet material can weaken paper filter elements causing them to fail, which can allow combustible dust to reach the fan and motor.

(7) Vacuum cleaners used for metal dusts shall meet the requirements of NFPA 484, Standard for Combustible Metals.

8.4.2.2.3*

In Class II electrically classified (hazardous) locations, electrically powered vacuum cleaners shall be listed for the purpose and location, or shall be a fixed-pipe suction system with a remotely located exhauster and air-material separator installed in conformance with Section 8.3, and shall be suitable for the dust being collected.

A.8.4.2.2.3

The Committee is not aware of vendors providing equipment listed for Class III electrically classified (hazardous) locations. A common practice is to use equipment listed for Class II in areas classified as Class III.

8.4.2.2.4

Where flammable vapors or gases are present, vacuum cleaners shall be listed for Class I and Class II hazardous locations.

8.4.2.3* Sweeping/Shoveling/Scoop and Brush Cleaning Method.

For spills, cleaning with scoops and brushes shall be the preferred method.

A.8.4.2.3

With manual cleaning, such as using a scoop and brush, generating a dust cloud should be avoided. Where appropriate for the specific commodity, the use of natural bristle brushes should be considered to reduce the risk of static sparking.

8.4.2.4* Water Wash Down Cleaning Method.

A.8.4.2.4

Use of high-pressure water can generate dust clouds, and care should be taken when using this method. Use of water wash-down for some metal dusts can result in hydrogen generation. Refer to NFPA 484, Standard for Combustible Metals, for restrictions on the use of water wash-down.

8.4.2.4.1

The use of water wash down shall be a permitted cleaning method.

8.4.2.4.2

Where the combustible dust being removed is metal or metal-containing dust or powder within the scope of NFPA 484, Standard on Combustible Metals, the requirements of NFPA 484 shall be followed.

8.4.2.4.3*

Where the combustible dust being removed is a water-reactive material, additional precautions shall be taken to control the associated hazards.
A.8.4.2.4.3
Examples of additional precautions to be taken can include, but are not limited to, the following:

1. *Operating management has full knowledge of and has granted approval for the use of water.*
2. *Ventilation, either natural or forced, is sufficient to maintain concentrations of flammable or toxic gasses at safe levels.*
3. *Complete drainage of all water effluent to a safe, contained area is available.*

8.4.2.5 Water Foam Wash Down Systems. (Reserved)

8.4.2.6 Compressed Air–Blow Down Method.

8.4.2.6.1*

Blow downs using compressed air or steam shall be permitted to be used for cleaning inaccessible surfaces or surfaces where other methods of cleaning result in greater personal safety risk.
A.8.4.2.6.1
Compressed air blow-down used for cleaning purposes has been demonstrated to present significant hazards and should only be employed where no other cleaning method is available. Compressed air blow-down does not remove accumulated dust, it simply moves the dust somewhere else, which will then have to be cleaned. It is always preferable to use engineering design controls to eliminate areas that can be inaccessible or difficult to clean by other methods.

8.4.2.6.2*

Where blow down using compressed air is used, the following precautions shall be followed:
A.8.4.2.6.2
All of the listed precautions might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts. A risk assessment should be conducted to determine which precautions are required for the specific conditions under which compressed air is being used.

(1) Vacuum cleaning, sweeping, or water wash down methods are used first to clean surfaces that can be safely accessed prior to using compressed air.

(2) Dust accumulations in the area after vacuum cleaning, sweeping, or water wash down do not exceed the threshold housekeeping dust accumulation.
(3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 30 psi (207 kPa) in accordance with OSHA requirements in 29 CFR 1910.242(b).
(4) All electrical equipment potentially exposed to airborne dust in the area meets, at a minimum, *NFPA 70*, *National Electrical Code*; NEMA 12 as defined by NEMA 250; or the equivalent.
(5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.
(6) Where metal or metal-containing dust or powder under the scope of NFPA 484, *Standard for Combustible Metal*, are present, the requirements of NFPA 484 apply.

8.4.2.7 Steam Blow Down Method. (Reserved)

8.4.3 Training.

Operator and contractor training shall include housekeeping procedures, required personal protective equipment during housekeeping, and proper use of equipment.

8.4.4 Equipment. (Reserved)

8.4.5 Vacuum Trucks.

8.4.5.1

Vacuum trucks shall be grounded and bonded.

8.4.5.2

Vacuum truck hoses and couplings shall be static dissipative or conductive and grounded.

8.4.6 Frequency and Goal.

8.4.6.1*

Housekeeping frequency and accumulation goals shall be established to ensure that the accumulated fugitive dust levels on surfaces do not exceed the threshold housekeeping dust accumulation limits.

A.8.4.6.1

Surfaces on which dust can accumulate can include walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, beams, and above suspended ceilings and other concealed surfaces such as the interior of electrical enclosures.

Factory Mutual recommends that surfaces should be cleaned frequently enough to prevent hazardous accumulations (FM Data Sheet 7-76, Prevention and Mitigation of Combustible Dust Explosives and Fire, 2.3.5). Housekeeping for fugitive dusts is most important where the operational intent is that the dust accumulations are not normally present in the occupancy and the building has no deflagration protection features, such as damage limiting/explosion venting construction or classified electrical equipment, and additional personal protection from dust *deflagration hazards is also not provided. Factors that should be considered in establishing the housekeeping frequency include the following:*

(1) Variability of fugitive dust emissions
(2) Impact of process changes and non-routine activities
(3) Variability of accumulations on different surfaces within the room (i.e., walls, floors, overheads)

8.4.6.2

The threshold housekeeping dust accumulation limits shall be in accordance with the industry or commodity-specific NFPA standard. *(See 1.3.1.)*

8.4.6.3*

Housekeeping frequency and provisions for unscheduled housekeeping shall include specific requirements establishing time to clean local dust spills or transient releases.

A.8.4.6.3

One example of a transient release of dust is a temporary loss of containment due to a failure of a seal in process equipment or conveying systems. Table A.8.4.6.3 provides an example of an unscheduled housekeeping procedure to limit the time that a local spill or transient releases of dust are allowed to remain before cleaning the local area to less than the threshold housekeeping dust accumulation. The "level accumulation" of combustible dust should be established in the housekeeping program based on the risk of flash fires and secondary explosions from the process hazard analysis.

Table A.8.4.6.3 Unscheduled Housekeeping

Level Accumulation	***Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces (hours)***	***Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces (hours)***
1	*8*	*24*
2	*4*	*12*
3	*1*	*3*

8.4.7 Auditing and Documentation.

8.4.7.1*

Housekeeping effectiveness shall be assessed based on the results of routine scheduled cleaning and inspection, not including transient releases.

A.8.4.7.1

Typically, the housekeeping effectiveness is verified on an annual basis or after a significant change in the operation. If transient releases are becoming more frequent, the housekeeping effectiveness and equipment integrity should be verified.

8.4.7.2

The owner/operator shall retain documentation that routine scheduled cleaning occurs in accordance with the frequency and accumulation goals established in 8.4.6.1.

8.5 Ignition Source Control.

8.5.1* General.

Unless otherwise specified, the requirements of Section 8.5 shall be applied retroactively.

A.8.5.1

It is not always possible or practical for existing facilities to be in compliance with the new provisions of a standard at the effective date of that standard. Therefore, retroactivity in this section means that a plan should be established to achieve compliance within a reasonable time frame.

8.5.2* Risk Assessment.

A documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of ignition source control to be provided including, but not limited to, the controls addressed in Section 8.5.

A.8.5.2

A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety.

8.5.3 Hot Work.

8.5.3.1*

All hot work activities shall comply with the requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.*

A.8.5.3.1

Hot work activities include the following:

(1) Cutting and welding
(2) Other maintenance, modification, or repair activities involving the application of an open flame or the generation of hot sparks.

8.5.3.2*

The area affected by hot work shall be thoroughly cleaned of combustible dust prior to commencing any hot work.

A.8.5.3.2

The hot work area specified in NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work, is 11 m (35 ft).

8.5.3.3

Equipment that contains combustible dust and is located within the hot work area shall be shut down, shielded, or both.

8.5.3.4

When the hot work poses an ignition risk to the combustible dust within equipment, the equipment shall be shut down and cleaned prior to commencing such hot work.

8.5.3.5

Floor and wall openings within the hot work area shall be covered or sealed.

8.5.3.6 Portable Electrical Equipment. (Reserved)

8.5.4 Hot Surfaces.

8.5.4.1

This section shall not be required to be applied retroactively.

8.5.4.2*

Heated external surfaces of process equipment and piping in dust deflagration hazard areas containing combustible dust shall be maintained at a temperature at least 50°C below the dust layer hot surface ignition temperature measured in a standardized test acceptable to the authority having jurisdiction.

A.8.5.4.2

Consensus standard hot surface dust layer ignition temperature tests include ASTM E 2021, Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers, and IEC 61241-2-1, Electrical Apparatus for Use in the Presence of Combustible Dust — Methods for Determining the Minimum Ignition Temperatures of Dust. The dust layer thickness used in these tests is nominally 1.27 cm (0.5 in.). Thicker dust layers produce lower hot surface ignition temperatures.

8.5.4.3*

Internal surfaces of process equipment heated with hot air and having a potential for dust accumulation shall be maintained at a temperature at least 20°C below a standard dust layer hot air ignition temperature acceptable to the authority having jurisdiction.

A.8.5.4.3

Examples of standard dust layer hot air ignition temperature tests include the Bureau of Mines Dust Layer Ignition Test described in Bureau of Mines Report RI 5624, and the Aerated Powder Test developed by Gibson et al and described in Abbot's Prevention of Fires and Explosions in Dryers, published by the Institution of Chemical Engineers.

Most dryers and ovens are examples of equipment with internal surfaces heated by hot air. Rotating drum dryers and spray dryers are probably more suited to the dust layer air ignition *temperature test, whereas fluidized bed dryers are more suited to the aerated powder ignition temperature test. Where the internal surface temperature is not known, the hot air temperature can be conservatively used.*

8.5.5 Bearings.

8.5.5.1

This section shall not be required to be applied retroactively.

8.5.5.2*

Bearings that are directly exposed to a combustible dust atmosphere or subject to dust accumulation, either of which poses a deflagration hazard, shall be monitored for overheating.
A.8.5.5.2
The intent of this requirement is to address bearings that can have accumulations of dust on them or be in a suspended dust cloud. The concern is that if the bearing overheats it can present an ignition source to the dust cloud or the dust layer.
Such equipment can include, but is not limited to, the following:

- *(1) Bucket elevator head and boot areas*
- *(2) Particulate size-reduction equipment*
- *(3) Blenders*
- *(4) Belt-driven fans where combustible dust is present*

In addition to monitoring bearing temperatures directly, precursors to bearing or shaft overheating can also provide early warnings of bearing or shaft deterioration. These precursors include excessive shaft vibration or speed reduction. Monitoring can consist of periodic manual checks, installed devices, or automated monitoring.

8.5.5.3

The owner/operator shall establish frequencies for monitoring bearings in 8.5.5.2.

8.5.5.4*

It shall be permitted to eliminate bearing monitoring based on a risk assessment acceptable to the authority having jurisdiction.
A.8.5.5.4
The risk assessment should include the potential for propagation of an explosion from an unmonitored unit.

8.5.6 Electrical Equipment and Wiring.

8.5.6.1*

The identification of the possible presence and extent of Class II and Class III locations shall be made based on the criteria in NFPA 70, National Electrical Code, Article 500.5(C) and (D).
A.8.5.6.1

The best method to eliminate the need for electrically classified areas is to prevent the release of dust from equipment. The next best method to eliminate the need for electrically classified areas is the removal the dust, by developing proper housekeeping procedures to clean up dust. If you cannot prevent the release of dust from equipment, or clean up the dust, then that area might be an electrically classified area. NFPA 499, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, can be used as guidance to supplement the criteria in NFPA 70, National Electrical Code, Article 500.5. This guidance depends on a determination of whether the dusts in a particular area are combustible, the ignitability properties of the dust, and the nature of possible dust cloud formation and dust layer accumulations within and outside the electrical equipment near these dusts. There is limited guidance in identifying Class III locations. NFPA 499 is a good source for the guidance on the identification of Class III areas.

8.5.6.1.1*

The locations and extent of Class II and Class III areas shall be documented, and such documentation shall be preserved for access at the facility.

A.8.5.6.1.1

Local signage or floor indications should be considered. Having local floor signage provides the everyday operators and anyone else who would be in the facility with the awareness of the electrically classified areas. Knowledge of electrically classified areas gives anyone over the lifetime of the facility the awareness of immediate hazards within the facility.

8.5.6.2

Electrical equipment and wiring within Class II locations shall comply with NFPA 70, National Electrical Code, Article 502.

8.5.6.3

Electrical equipment and wiring within Class III locations shall comply with NFPA 70, National Electrical Code, Article 503.

8.5.6.4*

Preventive maintenance programs for electrical equipment and wiring in Class II and Class III locations shall include provisions to verify that dusttight electrical enclosures are not experiencing significant dust ingress.

A.8.5.6.4

NFPA 70B, Recommended Practice for Electrical Equipment Maintenance, contains recommendations on the development of an effective electrical equipment maintenance program. NFPA 70, National Electrical Code, Article 502.15, contains descriptions of seals for electrical enclosures and fittings. The description includes a requirement that sealing fittings be accessible. This requirement is intended to include cabinets and other enclosures such as MCCs, control panels, and main switch gear, but not conduit, raceways, junction boxes, or other similar equipment.

8.5.7 Electrostatic Discharges.

8.5.7.1 Conductive Equipment.

8.5.7.1.1*

Particulate handling equipment shall be conductive unless the provisions of 8.5.7.1.2 are applicable.

A.8.5.7.1.1

See NFPA 77, Recommended Practice on Static Electricity, for equipment component conductivity specifications and measurement methods.

8.5.7.1.2

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

(1) Hybrid mixtures are not present.
(2) Conductive dusts are not handled.
(3) *The minimum ignition energy (MIE) of the material being handled is greater than 3 mJ determined without inductance.

A.8.5.7.1.2(3)

ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, is a test method for determining particulate and dust MIE.

(4) The nonconductive components do not result in isolation of conductive components from ground.
(5) *The breakdown strength across nonconductive sheets, coatings, or membranes does not exceed 4 kV when used in high surface charging processes.

A.8.5.7.1.2(5)

The potential for propagating brush discharges exists where nonconductive materials with breakdown voltages exceeding 4 kV are exposed to processes that generate strong surface charges such as pneumatic conveying. Such discharges do not occur where the breakdown voltage is less than 4 kV.

8.5.7.1.3

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

8.5.7.1.4 Flexible Connectors.

8.5.7.1.4.1

Flexible connectors shall have an end-to-end resistance of less than 1.0×10^8 ohms to ground even when an internal or external bonding wire connects the equipment to which the flexible connector is attached.

8.5.7.1.4.2*

Flexible connectors with a resistance equal to or greater than 1.0 × 10^8 ohms shall be permitted under all the following conditions:

A.8.5.7.1.4.2

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

(1) The dust has a minimum ignition energy (MIE) greater than 2000 mJ.
(2) The maximum powder transfer velocity is 10 m/s.
(3) Flammable vapors are not present.

8.5.7.2 Maximum Particulate Transport Rates.

8.5.7.2.1*

The maximum particulate transport rates in 8.5.7.2.3 shall apply when the volume of the vessel being filled is greater than 1 m3, and a single feed stream to the vessel meets both of the following conditions:

A.8.5.7.2.1

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

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

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

A.8.5.7.2.1(1)

The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ. See Avoiding Static Ignition Hazards in Chemical Operations by L. Britton.

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

A.8.5.7.2.1(2)

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

8.5.7.2.2*

The maximum particulate transport rate in 8.5.7.2.3 shall apply when the volume of the vessel being filled is greater than 1 m3 and either of the following conditions is met:

A.8.5.7.2.2

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

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

A.8.5.7.2.2(1)

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

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

A.8.5.7.2.2(2)

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

8.5.7.2.3*

Where the conditions of 8.5.7.2.1 or 8.5.7.2.2 are met, the maximum permitted material transport rate of particles shall be limited by the following:

A.8.5.7.2.3

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

(1) 1.4 kg/s for particulates larger than 2 mm.
(2) 5.6 kg/s for particulates between 0.4 and 2 mm in size.
(3) 8.3 kg/s for particulates smaller than 0.4 mm.

8.5.7.3* Grounding of Personnel.

A.8.5.7.3

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

8.5.7.3.1

Personnel involved in manually filling or emptying particulate containers or vessels, or handling open containers of combustible particulates, shall be grounded during such operations.

8.5.7.3.2

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

(1) Flammable gases, vapors, and hybrid mixtures are not present.
(2) *The minimum ignition energy of the dust cloud is greater than 30 mJ.

A.8.5.7.3.2(2)

Based on information in Avoiding Static Ignition Hazards in Chemical Operations, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 µ fraction of the material (or material passing through a 200-mesh sieve) is typically tested for this purpose. Where a bulk material includes larger particles, the sub-75 µ MIE may be significantly lower than the bulk material MIE. ASTM E 2019-03, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, is the test method for determining particulate and dust MIE.

8.5.7.4* Flexible Intermediate Bulk Containers (FIBCs).

FIBCs shall be permitted to be used for the handling and storage of combustible particulate solids in accordance with the requirements in 8.5.7.4.1 through 8.5.7.4.7.

A.8.5.7.4

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

8.5.7.4.1*

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

A.8.5.7.4.1

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

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

8.5.7.4.2

Type A FIBCs shall be limited to use with noncombustible particulate solids or combustible particulate solids having minimum ignition energy (MIE) >1000 mJ.

8.5.7.4.2.1

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

8.5.7.4.2.2*

Type A FIBCs shall not be used with conductive dusts.

A.8.5.7.4.2.2

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

8.5.7.4.3

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

8.5.7.4.3.1

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

8.5.7.4.3.2*

Type B FIBCs shall not be used for conductive dusts.

A.8.5.7.4.3.2

See A.8.5.7.4.2.2.

8.5.7.4.4

Type C FIBCs shall be permitted to be used with combustible particulate solids and in locations where flammable vapors having MIE >0.14 mJ are present.

8.5.7.4.4.1

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

8.5.7.4.4.2

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

8.5.7.4.4.3

Type C FIBCs shall be permitted to be used for conductive dusts.

8.5.7.4.5

Type D FIBCs shall be permitted to be used with combustible particulate solids and in locations where flammable vapor atmospheres having MIE >0.14 mJ are present.

8.5.7.4.5.1

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

8.5.7.4.6*

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

A.8.5.7.4.6

Table A.8.5.7.4.6 provides a useful guide for the selection and use of FIBCs based on the MIE of product contained in the FIBC and the nature of the atmosphere surrounding it.

Table A.8.5.7.4.6 Use of Different Types of FIBCs

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

Notes:

1. *Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC, e.g., in the case of solvent wet solids.*

2. *Nonflammable atmosphere includes combustible particulate solids having a MIE >1000 mJ.*
3. *FIBC Types A, B, and D are not suitable for use with conductive combustible particulate solids.*

[a]Measured in accordance with ASTM E 2019, capacitive discharge circuit (no added inductance).
[b]Use of Type C and D is limited to Gas Groups C and D with MIE ≥ 0.14 mJ.

8.5.7.4.6.1

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

8.5.7.4.6.2

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

8.5.7.4.6.3

Documentation of test results shall be made available to the authority having jurisdiction.

8.5.7.4.6.4

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

8.5.7.4.7*

Deviations from the requirements in 8.5.7.4.1 through 8.5.7.4.6 for safe use of FIBCs shall be permitted based on a documented risk assessment acceptable to the authority having jurisdiction.
A.8.5.7.4.7
In special cases it might be necessary to use a type of FIBC that is not permitted for the intended application based on the requirements of 8.5.7.4. For such cases, it might be determined that the FIBC is safe to use provided that filling or emptying rates are restricted to limit electrostatic charging. In the case of conductive combustible particulate solids, the use of a Type A FIBC might be acceptable provided that the maximum ignition energy from the FIBC or charged product within it is less than the MIE of the combustible particulate solids.

8.5.7.5 Rigid Intermediate Bulk Containers (RIBCs).

8.5.7.5.1*

Conductive RIBCs shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided that the RIBCs are electrically grounded.
A.8.5.7.5.1

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

8.5.7.5.2*

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

A.8.5.7.5.2

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

8.5.8 Open Flames and Fuel Fired Equipment.

8.5.8.1*

Production, maintenance, or repair activities that can release or lift combustible dust shall not be conducted within 35 ft (11 m) of an open flame or pilot flame.

A.8.5.8.1

Maintenance and repair activities that can release or lift combustible dust include banging or shaking dust laden equipment components, blowing off dust accumulations from the surface of equipment, and inadvertently spilling combustible powder from a container. An example of a production activity that can generate a dust cloud is transporting an open drum of particulate past an operating fan. The dust clouds generated in these activities can be entrained into the airflow feeding a burner flame or pilot flame within nearby equipment.

8.5.8.2

Fuel fired space heaters drawing local ambient air shall not be located within 30 ft of equipment transporting, processing, or storing combustible dust.

8.5.8.3

Fuel-fired process equipment shall be operated and maintained in accordance with the pertinent NFPA standard for the equipment, including the following standards:

(1) NFPA 31, Standard for the Installation of Oil-Burning Equipment
(2) NFPA 54, National Fuel Gas Code
(3) NFPA 85, Boiler and Combustion Systems Hazards Code
(4) NFPA 86, Standard for Ovens and Furnaces

8.5.8.4

Inspections and preventive maintenance for fuel fired process equipment shall include verification that there are no significant combustible dust accumulations within or around the equipment.

8.5.8.5

Unless the equipment is operated within the limits of 8.5.4.2, provisions shall be made to prevent the accumulation of combustible dust on heated surfaces of heating units.

8.5.8.6

In facility locations where airborne dust or dust accumulations on horizontal surfaces are apt to occur, heating units shall be provided with a source of combustion air ducted directly from the building exterior.

8.5.9 Industrial Trucks.

8.5.9.1

Industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 8.5.6, and shall be used in accordance with NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations.

8.5.9.2*

Where industrial trucks, in accordance with NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations, are not commercially available, a documented risk assessment shall be permitted to be used to specify the fire and explosion prevention features for the equipment being used.
A.8.5.9.2
Diesel-powered front-end loaders suitable for use in hazardous locations have not been commercially available.

8.5.10 Process Air and Media Temperatures.

8.5.10.1*

Heated process equipment containing combustible dust shall have operating controls arranged to maintain the temperature of equipment interiors within the prescribed limits.
A.8.5.10.1
The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short-time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature.
However, if particulate solids accumulate on the dryer surfaces, the operating temperature should be maintained below the dust layer ignition temperature. The dust layer ignition temperature is a function of time, temperature, and the thickness of the layer. It can be several hundred degrees below the dust cloud ignition temperature. The operating temperature limit of the dryer should be based on an engineering evaluation, taking into consideration the preceding factors.

8.5.11 Self-Heating.

8.5.11.1*

Material in silos and other large storage piles of particulates prone to self-heating shall be managed to control self-heating or have self-heating detection provisions.

A.8.5.11.1

Particulate materials that are notorious self-heaters during extended bulk storage conditions include, but are not limited to, sawdust, sub-bituminous coal, activated carbon and charcoal, and bagasse. Tabulations of materials prone to self-heating can be found in the following references: P.C. Bowes, Self-Heating: Evaluating and Controlling the Hazards; U.S.Department of Energy handbook, Primer on Spontaneous Heating and Pyrophoricity; and V. Babrauskas, Ignition Handbook Database.. Test methods to assess the propensity for self-heating, critical storage pile sizes, and time to self-heating are also described in the Bowes and Babrauskas references. Methods of self-heating detection include temperature monitors within the pile or silo and carbon dioxide monitors in the silo. Self-heating management can be accomplished, for example, through timely processing of the affected particulate through the storage system before self-heating can become an issue.

Self-heating can be controlled through control of the temperature of the material as it is added to the storage and by controlling the residence time in storage. The permissible temperature and residence time can be determined based on the characteristics of the material, the size of the pile, and the environment around the pile.

8.5.11.2

Provisions shall be in place for managing the consequences of self-heating in storage silos or bins.

8.5.12 Friction and Impact Sparks.

8.5.12.1

Means shall be provided to prevent foreign material from entering the system when such foreign material presents an ignition hazard.

8.5.12.2*

Foreign materials, such as tramp metal, that are capable of igniting combustible material being processed shall be removed from the process stream.

A.8.5.12.2

Methods that are commonly used to remove foreign material include the following:

(1) Permanent magnetic separators or electromagnetic separators that indicate loss of power to the separators
(2) Pneumatic separators
(3) Grates or other separation devices

8.5.12.3

Tramp materials that present an ignition potential shall be permitted to be in the material inlet stream if the equipment is provided with explosion protection.

8.5.12.4*

Clearances and alignment of high-speed moving parts in equipment that is processing combustible particulates shall be checked at intervals established by the owner/operator based on wear experience unless the equipment is equipped with vibration monitors and alarms or routine manual monitoring is performed.

A.8.5.12.4

In the case of size reduction equipment with continuous screened outlets, high speeds that can generate friction and impact sparks are considered to be tip speeds in excess of 10 m/sec. In the case of blenders and other completely enclosed equipment processing material in batches, high speeds are considered to be blade tip speeds in excess of 1 m/sec.

8.5.12.5

The alignment and clearance of buckets in elevators that are transporting combustible particulates shall be checked at intervals established by the owner/operator based on facility wear experience unless the elevators are equipped with belt alignment monitoring devices.

8.6 Personal Protective Equipment.

8.6.1 Workplace Hazard Assessment.

8.6.1.1*

An assessment of workplace hazards shall be conducted as described in NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.*

A.8.6.1.1

A specific evaluation of the work environment to determine the requirement for the wearing of flame-resistant garments should be based on the potential hazards that workers are exposed to as part of their work duties.

8.6.1.2

When the assessment in 8.6.1.1 has determined that flame-resistant garments are needed, personnel shall be provided with and wear flame-resistant garments.

8.6.1.3*

When flame-resistant clothing is required for protecting personnel from flash fires, it shall comply with the requirements of NFPA 2112, *Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*.

A.8.6.1.3

It is important to distinguish between the different PPE requirements in NFPA 2112, Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire, and NFPA 70E, Standard for Electrical Safety in the Workplace, for different exposure hazards. The

PPE requirements in NFPA 2112 are not the same requirements in NFPA 70E and might not be sufficient protection for electric arc.

8.6.1.4*

Consideration shall be given to the following:
A.8.6.1.4
Portions of this list are taken from Section 4.3 of NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.

(1) Thermal protective characteristics of the fabric over a range of thermal exposures
(2) Physical characteristics of the fabric
(3) Garment construction and components
(4) Avoidance of static charge buildup
(5) Design of garment
(6) Conditions under which garment will be worn
(7) Garment fit
(8) Garment durability/wear life
(9) Recommended laundering procedures
(10) Conditions/features affecting wearer comfort

8.6.1.5

Flame-resistant garments shall be selected, procured, inspected, worn, and maintained in accordance with NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.

8.6.1.6*

The employer shall implement a policy regarding care, cleaning, and maintenance for flame-resistant garments.
A.8.6.1.6
At a minimum, the policy should address who is responsible for laundering, inspecting, repairing, and retiring garments. See also Section 6.1 from NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire. If flame-resistant clothing becomes contaminated with combustible particulate solids, the protective performance of the garments could be compromised. Wearers should maintain an awareness of and take precautions against the accumulation of combustible particulate solids on their protective clothing.

8.6.2 Limitations of PPE Application. (Flame-Resistant Garments)

8.6.2.1*

When required by 8.6.1.2, flame-resistant or non-melting undergarments shall be used.
A.8.6.2.1

This section does not include an incidental amount of elastic used in nonmelting fabric, underwear, or socks.

8.6.2.2*

When determined by 8.6.1.1 that flame-resistant garments are needed, only flame-resistant outerwear shall be worn over flame-resistant daily wear.

A.8.6.2.2

See also Section 5.1 from NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.

8.6.3 Limitations of PPE to Combustible Dust Flash-Fires. (Reserved)

8.6.4 Face, Hands, and Footwear Protection. (Reserved)

8.7 Dust Control.

8.7.1*

Continuous suction or some other means to control fugitive dust emissions shall be provided for processes where combustible dust is liberated in normal operation.

A.8.7.1

Other means to control fugitive dust emissions can include established housekeeping procedures where the fugitive emissions do not approach the MEC, and the housekeeping schedule does not allow settled dust accumulations to exceed the threshold housekeeping dust accumulation limit.

8.7.1.1

Where continuous suction is used, the dust shall be conveyed to air–material separators designed in accordance with 8.3.2.

8.7.2* Liquid Dust Suppression Methods for Dust Control.

A.8.7.2

Use of liquid dust suppression methods for dust control involves the use of fine, atomized, or fogging liquid sprays to limit the emission of combustible dusts. By using an atomized or fogging spray of liquid, which is often just water, dust can be controlled and prevented from accumulating in surrounding areas. This method is also often used in place of standard dust collection for both economical and operational reasons.

8.7.2.1

Where liquid dust suppression is used to prevent the accumulation of dust or to reduce its airborne concentration, the liquid dust suppressant shall not result in adverse reaction with the combustible dust.

8.7.2.2

Where liquid dust suppression is used, controls and monitoring equipment shall be provided to ensure the liquid dust suppression system is functioning properly.

8.7.3 Fans to Limit Accumulation. (Reserved)

8.8 Explosion Prevention/Protection.

8.8.1 General.

If an explosion hazard exists with a building, enclosure, or process system, measures shall be taken as specified in Section 8.8 to protect personnel from the consequences of an explosion.

8.8.2 Risk Assessment.

A documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, the measures addressed in Section 8.8.

8.8.3 Equipment Protection.

8.8.3.1* General.

Where an explosion hazard exists within an operating enclosure greater than 8 ft^3 (0.2^3 m) of containing volume, the enclosure shall be protected from the effects of a deflagration.

A.8.8.3.1

Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practical. Consideration should be given to explosion hazards when electing to omit protection; 8 ft^3 (0.2^3 m) is roughly the size of a 55-gallon drum.

8.8.3.2

Explosion protection systems shall incorporate one or more of the following methods of protection:

(1) Oxidant concentration reduction in accordance with NFPA 69, Standard on Explosion Prevention Systems
(2) Deflagration venting in accordance with NFPA 68, Standard on Explosion Protection by Deflagration Venting
(3) Deflagration venting through listed flame-arresting devices in accordance with NFPA 68
(4) Deflagration pressure containment in accordance with NFPA 69
(5) Deflagration suppression system in accordance with NFPA 69
(6) Dilution with a noncombustible dust to render the mixture noncombustible

8.8.3.3

Enclosures and all interconnections protected in accordance with 8.8.3.2shall be designed to withstand the resultant pressures produced during the deflagration event.

8.8.4 Equipment Isolation.

8.8.4.1* General.

Where a dust explosion hazard exists within any operating equipment, isolation devices shall be provided to prevent deflagration propagation between connected enclosures in accordance with NFPA 69, Standard on Explosion Prevention Systems.

A.8.8.4.1

A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources.

8.8.4.2*

Where a dust explosion hazard exists within any operating equipment, isolation devices shall be provided to prevent deflagration propagation to any work space in accordance with NFPA 69, Standard on Explosion Prevention Systems.

A.8.8.4.2

Some enclosures where a dust explosion hazard can exist include, but are not limited to, air-material separators, storage bins and silos, mixers/blenders, particle-size reductions, dryers, and fans/blowers.

8.8.4.3

Where a dust explosion hazard exists within any operating equipment, isolation devices shall be provided when recycling enclosure exhaust to building interiors to prevent deflagration propagation and transmission of energy from a fire or explosion in accordance with NFPA 69, Standard on Explosion Prevention Systems.

8.8.4.4

Isolation devices shall be provided when recycling enclosure exhaust to building interiors to prevent deflagration propagation and transmission of energy from a fire or explosion in accordance with NFPA 69, Standard on Explosion Prevention Systems.

8.9 Fire Protection.

8.9.1 General.

8.9.1.1

Where a fire hazard exists in a building or operating enclosure as determined in Chapter 7, manual or automatic fire protection means shall be provided in accordance with Section 8.9.

8.9.1.2*

Automatic fire protection systems shall be provided when at least one of the following conditions exists:

A.8.9.1.2

Fire protection systems for operating enclosures are often overlooked. This section is intended to help the user determine when fire protection systems are warranted. The design of the fire protection system should consider the hazards of the materials present. For example, water-based protection systems are generally not appropriate for combustible metals, as described in NFPA 484, Standard on Combustible Metals.

(1) *Manual fire-fighting poses an unacceptable risk to facility personnel and emergency responders.

A.8.9.1.2(1)

Manual fire fighting poses an unacceptable risk to facility personnel and emergency responders. The evaluation of the risk to facility personnel and fire fighters should be made based on discussions and review of the hazard assessment described in Chapter 7. Such a system(s) is (are) needed to meet the objectives stated in Section 4.2.

(2) *Manual fire-fighting is not expected to be effective for a fire hazard assessed in accordance with Chapter 7.

A.8.9.1.2(2)

The potential effectiveness of manual fire fighting should be assessed by experienced fire fighting personnel after reviewing the hazard assessment documentation developed in accordance with Chapter 7 requirements.

(3) They are required by the local building code adopted by the authority having jurisdiction.

8.9.2 System Requirements.

Fire protection systems where provided shall comply with 8.9.2.1 through 8.9.2.4.

8.9.2.1*

Fire-extinguishing agents shall be compatible with the conveyed, handled, and stored materials.

A.8.9.2.1

Pneumatic conveying, centralized vacuum , and dust collection systems that move combustible particulate solids can be classified as water compatible, water incompatible, or water reactive. Inasmuch as water is universally the most effective, most available, and most economical extinguishing medium, it is helpful to categorize combustible particulate solids in relation to the applicability of water as the agent of choice. For details on use of water as an extinguishing agent, see Annex F of NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.

8.9.2.2

Where fire detection systems are incorporated into pneumatic conveying, centralized vacuum, or dust collection systems, the process hazards analysis shall identify safe interlocking requirements for air-moving devices and process operations.

8.9.2.3

Where fire-fighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed in accordance with NFPA 91, Standard for Exhaust Systems for Air Conveying Vapors, Gases, Mists, and Noncombustible Particulate Solids.

8.9.2.4*

Extinguishing agents shall be applied to the combustible particulate fire at a sufficiently low momentum to avoid generating a suspended dust cloud.

A.8.9.2.4

In the case of automatic suppression systems, low momentum applications can be achieved by using small water drops or extinguishing powders and by avoiding accumulations of combustible particulate in the immediate vicinity of the discharge nozzle. In the case of dry pipe automatic sprinkler systems, it is particularly important to prevent fugitive combustible dust accumulations on or near the dry pipe because the initial discharge of compressed air can produce a suspended dust cloud and the potential for a flash fire or explosion.

In the case of manual application of extinguishing agents, 8.9.3.2 provides additional guidance on avoiding dust cloud formation during agent application.

8.9.3 Fire Extinguishers.

8.9.3.1*

Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

A.8.9.3.1

Refer to NFPA 484, Standard for Combustible Metals, for specific requirements regarding combustible metals.

8.9.3.2*

Personnel designated to use portable fire extinguishers shall be trained to use them in a manner that minimizes the generation of dust clouds during discharge.

A.8.9.3.2

Extreme care should be employed in the use of portable fire extinguishers in facilities where combustible dusts are present. The rapid flow of the extinguishing agent across or against accumulations of dust can produce a dust cloud. When a dust cloud is produced, there is always a deflagration hazard. In the case of a dust cloud produced as a result of fire fighting, the ignition of the dust cloud and a resulting deflagration are virtually certain. Consequently, when portable fire extinguishers are used in areas that contain accumulated combustible dusts, the extinguishing agent should be applied in a manner that does not disturb or disperse accumulated dust. Generally, fire extinguishers are designed to maximize the delivery rate of the extinguishing agent to the fire. Special techniques of fire extinguisher use should be employed to prevent this inherent design characteristic of the fire extinguisher from producing an unintended deflagration hazard.

8.9.4 Hose, Standpipes, Hydrants, and Water Supply.

8.9.4.1

Standpipes and hose, where provided, shall comply with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

8.9.4.2 Nozzles.

8.9.4.2.1*

Portable spray hose nozzles that are listed or approved for use on Class C fires shall be provided in areas that contain dust, to limit the potential for generating unnecessary airborne dust during fire-fighting operations.

A.8.9.4.2.1

A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust explosion potential

8.9.4.2.2*

Straight-stream nozzles and combination nozzles on the straight-stream setting shall not be used on fires in areas where dust clouds can be generated.

A.8.9.4.2.2

Fire responders should be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

8.9.4.2.3

It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with nozzles specified in 8.9.4.2.1.

8.9.4.3 Water Supply.

8.9.4.3.1

Private hydrants and underground mains, where provided, shall comply with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

8.9.4.3.2

Fire pumps, where provided, shall comply with NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*.

8.9.4.3.3

Fire protection water tanks, where provided, shall comply with NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

8.9.5 Automatic Sprinklers.

8.9.5.1*

Where a process that handles combustible particulate solids uses flammable or combustible liquids, a documented risk assessment that is acceptable to the authority having jurisdiction shall be used to determine the need for automatic sprinkler protection in the enclosure in which the process is located.

A.8.9.5.1

A risk assessment should consider the presence of combustibles both in the equipment and in the area around the process. Considerations should include the combustibility of the building construction, the equipment, the quantity and combustibility of process materials, the combustibility of packaging materials, open containers of flammable liquids, and the presence of *dusts. Automatic sprinkler protection in air–material separators, silos, and bucket elevators should be considered.*

8.9.5.2*

Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless permitted by NFPA 484, *Standard for Combustible Metals*.
A.8.9.5.2
Sprinkler systems in buildings or portions of buildings where combustible metals are produced, handled, or stored pose a serious risk for explosion. When water is applied to burning combustible metals, hydrogen gas is generated. When confined in an enclosed space, dangerous levels of hydrogen gas can collect and result in the potential for a hydrogen explosion. The metal will likely spread and spew burning material.

8.9.5.3

Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

8.9.5.4

Where automatic sprinklers are installed, dust accumulation on overhead surfaces shall be minimized to prevent an excessive number of sprinkler heads from opening in the event of a fire.

8.9.6 Spark/Ember Detection and Extinguishing Systems.

Where provided, spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*; NFPA 69, *Standard on Explosion Prevention Systems*; and NFPA 72, *National Fire Alarm and Signaling Code*.

8.9.7 Special Fire Protection Systems.

8.9.7.1

Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(1) NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam
(2) NFPA 12, Standard on Carbon Dioxide Extinguishing Systems
(3) NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems
(4) NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection
(5) NFPA 16, Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
(6) NFPA 17, Standard for Dry Chemical Extinguishing Systems
(7) NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
(8) NFPA 750, Standard on Water Mist Fire Protection Systems
(9) NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems

8.9.7.2

The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge.

Chapter 9 Management Systems

9.1 Retroactivity.

This chapter shall apply to new and existing facilities and processes.

9.2* General.

The procedures and training in this chapter shall be delivered in a language that the participants can understand.

A.9.2

See ANSI/AIHA Z10-2012, Occupational Health and Safety Management Systems.

9.3 Operating Procedures and Practices.

9.3.1*

The owner/operator shall establish written procedures for operating its facility and equipment to prevent or mitigate fires, deflagrations, and explosions from combustible particulate solids.

A.9.3.1

The operating procedures should address both the normal operating conditions as well as the safe operating limits. Where possible, the basis for establishing the limits and the consequences of exceeding the limits should also be described. The operating procedures should address all aspects of the operation, including the following (as applicable):

(1) Normal startup
(2) Continuous operation
(3) Normal shutdown
(4) Emergency shutdown
(5) Restart after normal or emergency shutdown
(6) Anticipated process upset conditions
(7) System idling

For manual operations, the procedures and practices should describe techniques, procedural steps, and equipment that are intended to minimize or eliminate hazards.
Operating procedures and practices should be reviewed on a periodic basis, typically annually, to ensure that they are current and accurate.

9.3.2*

The owner/operator shall establish safe work practices to address hazards associated with maintenance and servicing operations.

A.9.3.2

Safe work practices include, but are not limited to, hot work, confined space entry, and lockout/tagout, and the use of personal protective equipment. (See NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.) Consideration for extending the duration of the fire watch could be warranted based on characteristics of the material, equipment configuration, and conditions. For example, the PRB Coal Users' Group practice for hot work suggests fire watches could be warranted for 2 to 12 hours following the completion of hot work due to the exothermic chemical reaction of sub-bituminous coals. In addition to the hazards of combustible dust, safe work practices should address the hazards of mitigation systems such as inerting and suppression.

9.3.2.1

The safe work practices shall apply to employees and contractors.

9.4 Inspection, Testing, and Maintenance.

9.4.1*

Equipment affecting the prevention, control, and mitigation of combustible dust fires, deflagrations, and explosions shall be inspected and tested in accordance with the applicable NFPA standard and the manufacturers' recommendations.

A.9.4.1

Process interlocks and protection systems should be inspected, calibrated, and tested in the manner in which they are intended to operate, with written records maintained for review. In this context, "test" implies a nondestructive means of verifying that the system will operate as intended. For active explosion protection systems, this can involve the disconnection of final elements (i.e., suppression discharge devices or fast-acting valve actuators) and the use of a simulated signal to verify the correct operation of the detection and control system. Testing can also include slow-stroke activation of fast-acting valves to verify unrestricted travel. Some devices, such as explosion vent panels, suppression discharge devices, and some fast-acting valve actuators, cannot be functionally "tested" in a nondestructive manner, and so only periodic, preventive, and predictive inspection, maintenance, and replacement (if necessary) are applied.

Inspection and maintenance requirements for explosion vents and other explosion protection systems are found in NFPA 68, Standard on Explosion Protection by Deflagration Venting, and NFPA 69, Standard on Explosion Prevention Systems, respectively.

9.4.2

The owner/operator shall establish procedures and schedules for maintaining safe operating conditions for its facility and equipment in regard to the prevention, control, and mitigation of combustible dust fires and explosions.

9.4.3*

Where equipment deficiencies that affect the prevention, control, and mitigation of dust fires, deflagrations, and explosions are identified or become known, the owner/operator shall establish and implement a corrective action plan with an explicit deadline.

A.9.4.3

Corrective actions should be expedited on high-risk hazards (those that could result in a fatality or serious injury). Where in-kind repairs cannot be promptly implemented, consideration should be given to providing alternate means of protection.

9.4.4*

Inspections and testing activities that affect the prevention, control, and mitigation of dust fires, deflagrations, and explosions shall be documented.

A.9.4.4

See Section 9.10 for information regarding document retention.

9.4.5

A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in safe operating condition and that proper work practices are being followed.

9.5 Training and Hazard Awareness.

9.5.1*

Employees, contractors, temporary workers, and visitors shall be included in a training program according to the potential exposure to combustible dust hazards and the potential risks to which they might be exposed or could cause.

A.9.5.1

Safety of a process depends on the employees who operate it and the knowledge and understanding they have of the process. It is important to maintain an effective and ongoing training program for all employees involved. Operator response and action to correct adverse conditions, as indicated by instrumentation or other means, are only as good as the frequency and thoroughness of training provided.

9.5.2*

General safety training and hazard awareness training for combustible dusts and solids shall be provided to all affected employees.

A.9.5.2

All plant personnel, including management; supervisors; and operating, housekeeping, and maintenance personnel should receive general awareness training for combustible dust hazards, commensurate with their job responsibilities, including training on locations where hazards can exist on site, appropriate measures to minimize hazards, and response to emergencies.

9.5.2.1*

Job-specific training shall ensure that employees are knowledgeable about fire and explosion hazards of combustible dusts and particulate solids in their work environment.

A.9.5.2.1

Safe work habits are developed and do not occur naturally. The training program should provide enough background information regarding the hazards of the materials and the process so that *the employees can understand why it is important to follow the prescribed procedures. Training should address the following:*

(1) The hazards of their working environment and procedures in case of emergencies, including fires, explosions, and hazardous materials releases.
(2) Operating, inspection, testing, and maintenance procedures applicable to their assigned work
(3) Normal process procedures as well as emergency procedures and changes to procedures
(4) Emergency response plans, including safe and proper evacuation of their work area and the permissible methods for fighting incipient fires in their work area
(5) The necessity for proper functioning of related fire and explosion protection systems
(6) Safe handling, use, storage, and disposal of hazardous materials used in the employees' work areas
(7) The location and operation of fire protection equipment, manual pull stations and alarms, emergency phones, first-aid supplies, and safety equipment
(8) Equipment operation, safe startup and shutdown, and response to upset conditions

9.5.2.2

Employees shall be trained before taking responsibility for a task.

9.5.2.3*

Where explosion protection systems are installed, training of affected personnel shall include the operations and potential hazards presented by such systems.

A.9.5.2.3

The extent of this training should be based on the level of interaction the person is expected to have with the system. For example, operators need to be aware of the hazards presented by explosion suppression systems, but might not need to know how to operate the suppression system (i.e., interfacing with the system control panel or locking out devices.) Maintenance personnel, on the other hand, might need to know how and when to lock out the devices and how to return the system to its operational state.

9.5.3

Refresher training shall be provided as required by the authority having jurisdiction and as required by other relevant industry or commodity-specific NFPA standards. (See 1.3.1.)

9.5.4

The training shall be documented.

9.6 Contractors.

9.6.1

Owner/operators shall ensure the requirements of Section 9.6 are met.

9.6.2*

Only qualified contractors shall be employed for work involving the installation, repair, or modification of buildings (interior and exterior), machinery, and fire protection equipment that could adversely affect the prevention, control, or mitigation of fires and explosions.

A.9.6.2

Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps, professional licenses, and so forth.

9.6.3* Contractor Training.

A.9.6.3

It is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, and smoking and nonsmoking areas. The owner/operator does not necessarily need to provide the training to the contractor.

9.6.3.1

Contractors operating owner/operator equipment shall be trained and qualified to operate the equipment and perform the work.

9.6.3.2 Contractor training shall be documented.

9.6.3.3

Contractors working on or near a given process shall be made aware of the potential hazards from and exposures to fire, explosion, or toxic releases.

9.6.3.4

Contractors shall be trained and required to comply with the facility’s safe work practices and policies in accordance with 9.3.2.

9.6.3.5

Contractors shall be trained on the facility's emergency response and evacuation plan, including, but not limited to, emergency reporting procedures, safe egress points, and evacuation area.

9.7 Emergency Planning and Response.

9.7.1*

A written emergency response plan shall be developed for preventing, preparing for, and responding to work-related emergencies including, but not limited to, fire and explosion.

A.9.7.1

All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies.
The emergency plan should contain the following elements:

(1) A signal or alarm system
(2) Identification of means of egress

(3) Minimization of effects on operating personnel and the community
(4) Minimization of property and equipment losses
(5) Interdepartmental and interplant cooperation
(6) Cooperation of outside agencies
(7) The release of accurate information to the public

Emergency drills should be performed annually by plant personnel. Malfunctions of the process should be simulated and emergency actions undertaken. Disaster drills that simulate a major catastrophic situation should be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants. Specialized training for public fire department(s) and industrial fire brigades can be warranted due to facility specific hazards where the methods to control and extinguish a fire can be outside of their normal arena of traditional fire fighting.

9.7.2

The emergency response plan shall be reviewed and validated at least annually.

9.8* Incident Investigation.

A.9.8

To thoroughly assess the risks, analyze the incident, and take any corrective steps necessary, investigations should be conducted promptly based on the nature of the incident and in coordination with the authority having jurisdiction (as applicable).

The investigation should include root cause analysis and should include a review of existing control measures and underlying systemic factors. Appropriate corrective action should be taken to prevent recurrence and to assess and monitor the effectiveness of actions taken.

Such investigations should be carried out by trained persons (internal or external) and include participation of workers. All investigations should conclude with a report on the action taken to prevent recurrence.

Investigation reports should be reviewed with all affected personnel and their representatives (including contract employees where applicable) whose job tasks are relevant to the incident findings, and with the health and safety committee, to make any appropriate recommendations.

Any recommendations from the safety and health committee should be communicated to the appropriate persons for corrective action, included in the management review, and considered for continual improvement activities.

A system should be established to promptly address and resolve the incident report findings and recommendations.

Corrective actions resulting from investigations should be implemented in all areas where there is a risk of similar incidents and subsequently checked to avoid repetition of injuries and incidents that gave rise to the investigation.

Reports produced by external investigation agencies should be acted upon in the same manner as internal investigations.

Incident investigation reports should be made available to affected employees and their representatives at no cost.

9.8.1*

The owner/operator shall have a system to ensure that every incident that results in a fire, deflagration, or explosion is reported and investigated in a timely manner.

A.9.8.1

In addition to investigation of fires and explosions, it is also a good practice to investigate near misses (events that reasonably could have resulted in fires or explosions under different circumstances) as well as all activations of active fire and explosion mitigation systems. These events often indicate an underlying problem that should be corrected. See NFPA 654, Standard for the Prevention of Fire and Dust Explosions from Manufacturing, Processing, and Handling of Combustible Particulate Solids, for additional information. Barriers to reporting should be removed, as described in ANSI/AIHA Z10-2012, Occupational Health and Safety Management Systems. Investigations should include workers and their representatives, as appropriate.

9.8.2

The investigation shall be documented and include findings and recommendations.

9.8.3

A system shall be established to address and resolve the findings and recommendations.

9.8.4*

The investigation findings and recommendations shall be reviewed with affected personnel.

A.9.8.4

The term affected personnel is intended to include members of employee organizations such as safety committees and employee representatives of various types.

9.9 Management of Change.

9.9.1*

Written procedures shall be established and implemented to manage proposed changes to process materials, staffing, job tasks, technology, equipment, procedures, and facilities.

A.9.9.1

It is essential to have thorough written documentation, as the slightest changes to procedures, processes, resources, staffing, and equipment, including equipment from suppliers, can have a dramatic impact on the overall hazard analysis. Change includes something as benign as process materials sourcing from a different manufacturer, the same raw material manufacturer using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and materials. Individuals involved should include those involved in the process such as maintenance, engineering, and purchasing personnel, and all others as deemed necessary. Staffing and job tasks are not intended for shift changes, but for overall staff and their representative tasks . For reference, see the documentation form in ANSI/AIHA Z10-2012, Occupational Health and Safety Management Systems.

9.9.2

The procedures shall ensure that the following are addressed prior to any change:

(1) The technical basis for the proposed change

(2) *Safety and health implications

A.9.9.2(2)

Some fire and explosion protection systems introduce additional hazards into the process environment. These hazards can include, but are not limited to, energy in suppression canisters, asphyxiation hazards from inert gases, and mechanical laceration/amputation hazards from explosion isolation systems. While these are not fire or explosion hazards, they should be addressed as part of the management of change review per this document so that appropriate controls can be applied.

(3) Whether the change is permanent or temporary, including the authorized duration of temporary changes

(4) Modifications to operating and maintenance procedures

(5) Employee training requirements

(6) Authorization requirements for the proposed change

(7) Results of characterization tests used to assess the hazard, if conducted

9.9.3*

Implementation of the management of change procedure shall not be required for replacements-in-kind.

A.9.9.3

While implementation of the management of change procedure is not required for replacement in kind, it is critical that only qualified personnel are the ones who determine if the replacement is "in kind." These qualified personnel should be intimately familiar with the items listed in 8.8.2, as well as the broad scope of hazards associated with the particular process.

Replacement "in kind" for raw materials. Care must be taken when substituting raw materials. There have been cases where a seemingly equivalent material substitution resulted in a large change in the process hazard. Not all safety properties of a material are characterized in, for example, an MSDS. Chemical composition might be identical, but quite different static ignition hazards due to bulk resistivity and charge relaxation rate can appreciably increase the hazard. Flowability differences can affect the hazard probability too. Differences in natural raw materials are generally less of a concern than manufactured materials in this regard.

9.9.4

Design and procedures documentation shall be updated to incorporate the change.

9.10* Documentation Retention.

A.9.10

The creation and retention of documentation is necessary in order to implement and periodically evaluate the effectiveness of the management systems presented in this standard. Documentation in any form (e.g., electronic) should remain legible and be readily identifiable and accessible.

The documentation should be protected against damage, deterioration, or loss, and retained for the applicable period specified in this standard.

9.10.1

The owner/operator shall establish a program and implement a process to manage the retention of documentation, including, but not limited to, the following:

(1) Training records

(2) Equipment inspection, testing, and maintenance records

(3) Incident investigation reports

(4) Process hazards analyses

(5) *Process and technology information

A.9.10.1(5)

Process and technology information includes documents such as design drawings, design codes and standards used as the basis for both the process and the equipment, equipment manufacturers' operating and maintenance manuals, standard operating procedures, and safety systems.

(6) Management of change documents

(7) Emergency response plan documents

(8) *Contractor records

A.9.10.1(8)

Contractor records typically include information such as the contract documentation with scope of work and necessary insurance coverage, the contractor's safety programs, records demonstrating the contractor's safety performance, qualifications and certifications necessary for the work to be done, periodic evaluations of the contractor's work performance, and records demonstrating that the employees of the contractor have been trained to safely perform the assigned work.

9.11 Management Systems Review.

9.11.1

The owner/operator shall evaluate the effectiveness of the management systems presented in this standard by conducting a review of each management system.

9.11.2

The owner/operator shall be responsible for maintaining and evaluating the ongoing effectiveness of the management systems presented in this standard.

9.12* Employee Participation.

Owner/operators shall establish and implement a system to ensure effective participation of affected personnel in the implementation of this standard.

A.9.12

Effective employee participation is an essential element of the Occupational Health and Safety Management System (OHSMS) to achieve continuous improvement in risk reduction, as described in ANSI/AIHA Z10-2012, Occupational Health and Safety Management Systems. The OHSMS ensures that employees and their authorized representatives are involved, informed, and trained on all aspects of health associated with their work, including emergency arrangements. Employee participation includes items such as, but not limited to the following:

(1) Involving employees and their authorized representatives, where they exist, in establishing, maintaining, and evaluating the OSHMS
(2) An occupational health and safety committee
(3) Access to safety and health information
(4) Risk assessment, and implementation and review of risk control measures
(5) Incident and near-miss investigations
(6) Inspections and audits
(7) Reporting unsafe conditions, tools, equipment, and practices
(8) Mentoring of new employees, apprentices, and for on-site orientation
(9) Identifying hazards with strong emphasis on high-risk jobs and the application of the hierarchy of controls
(10) In accordance with established and maintained procedures, appropriate arrangements will ensure that concerns, ideas, and input employees and their representatives share are received, considered, and responded to
(11) Employees removing themselves from work situations that they have reasonable justification to believe present an imminent and serious danger to their safety or health

Employees who justifiably take those actions by notifying their supervisor should be protected from discrimination by removing those barriers as outlined in the OSHMS.

Where this standard and annex refers to employees and their represenatives (where representatives exist), the intention is that they should be consulted as the primary means to achieve appropriate participation in the development and implementation of all aspects of the OHSMS. In some instances, it might be appropriate to involve all employees and all representatives.

Employee participation is a key component of an OHSMS. When employees and their representatives are engaged and their contributions are taken seriously, they tend to be more satisfied and committed to the OHSMS, and the system is more effective. Engaging employees and their representatives in dialogue with management and each other about safety and health can lead to improved relationships, better overall communication, improved compliance, and reduced injury/illness/death rates. The improved morale translates to greater safety and health results.

Employees and their representatives need to be trained about how the OHSMS works and to evaluate it periodically to determine whether improvements need to be made. The information needs to be presented in a form and language that employees and their representatives easily understand. (See also A.9.8.4.)

Annex B Process Hazard Analysis — Example

B.1 Introduction.

This annex is intended to illustrate one example of how to develop a process hazard analysis for a facility. There are other methods to develop a process hazard analysis that include, but are not limited to, "what-if" analysis, failure mode and effects analysis, fault tree analysis, "Haz-Op," etc. Additional guidance on performing a process hazard analysis is available in the NFPA *Guide to Combustible Dusts*. It is not the intent of this standard to require all users to comply with OSHA Process Safety Management Regulation. The requirement is intentionally vague to allow users to match the complexity and extent of the analysis to the complexity and extent of the facility and its process.

B.2 Purpose.

The purpose of a process hazards analysis (PHA) is to identify hazards in the process and document how those hazards are being managed. The hazards addressed by this standard are the fire, deflagration, and explosion hazards of combustible dusts. There might be other hazards associated with a process such as industrial hygiene that are not covered in this annex. However, the process of analysis outlined in this annex could be applied to other hazards.

B.3 Overview.

B.3.1

A process hazard analysis is a detailed analysis and documentation of the process and the facility housing the process.

B.3.2

Each part of the process system is considered for potential deflagration hazard.

B.3.2.1

Where the hazard is managed, the means by which it is being managed is documented.

B.3.2.2

Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.3

Each building compartment, room, or identifiable space should be considered for potential deflagration hazard.

B.3.3.1

Where the hazard is managed, the means by which it is being managed is documented.

B.3.3.2

Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.4

The potential for a dust deflagration should be based upon the potential for all four necessary and sufficient conditions for a deflagration to exist at the point of consideration concurrently.

B.3.4.1

The conditions for a deflagration are as follows:

(1) A particulate of sufficiently small dimension to propagate a deflagration flame front

(2)A means of suspending or dispersing the particulate in air or other oxidizing atmosphere
(3) Sufficient quantity of particulate to achieve the minimum explosible concentration
(4) Competent source of ignition

B.3.4.2

As a general rule in the NFPA standards, there is an assumption that ignition will occur. However, some situations of ignition source control could be determined acceptable by taking into account the consequences (i.e., risk analysis). If a deflagration is possible, the results should be managed in such a way that the objectives of the standard are met.

B.3.4.3

The process hazard analysis should classify locations into three general categories:

(1) Not a hazard
(2) Maybe a hazard
(3) Deflagration hazard

This will help the owner/operator prioritize management of the hazards. Additionally, it will identify the locations where more information is necessary before a definitive determination can be made.

B.3.4.4

The individual assessments in the process hazard analysis are brought into a cohesive understanding of the hazards associated with the overall operations as well as the individual components.

B.3.4.5

A well-documented risk assessment that is acceptable to the authorities having jurisdiction can be used to supplement the process hazard analysis to determine what protection measures are to be used.

B.4 Sample Process Hazards Analysis.

B.4.1

This example is intended to provide the user with some of the deliberation that can be used in performing a process hazard analysis. It is not intended to cover all the methods, situations, and processes that might be encountered in facilities that handle combustible particulate solids. Refer to Figure B.4.1.for the process used in this example.

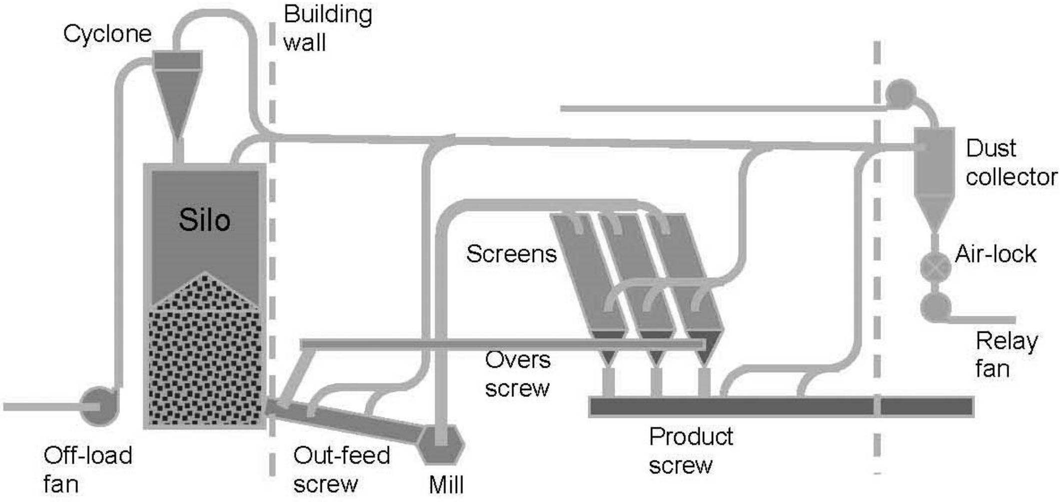


Figure B.4.1 An Example Process. ***(Source: J.M. Cholin Consultants, Inc.)***

B.4.2

This process receives wood chips via rail car and over the road trailer truck. The wood chips come from hogging (grinding) operations at other facilities. The chips are unloaded and conveyed pneumatically to a storage silo. From the storage silo the chips are conveyed via screw conveyor to a size reduction mill. The mill discharges particulate to a transport fan, which sends the particulate to a set of screens. The material that is sufficiently fine passes through the screens and proceeds via the product screw to some other location. The particles that exceed the size specification are sent back through the mill.

B.4.3

Dust collection is provided for this process. The dust collection system receives the exhaust from the cyclone, ullage space of the silo, out-feed screw conveyor, screens, and the product screw conveyor. The cleaned air is returned to the building interior.

B.4.4

Each and every process component should be evaluated, including ducts, conveyors, silos, bunkers, vessels, fans, and other pieces of process equipment. Each point along the process should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined. Usually the relevant occupancy standard will provide options. The process and process equipment will often determine which option is most appropriate.

B.4.5

Each point in the process is identified and considered a “compartment” in which a deflagration could occur, as follows:

(1) Each duct
(2) Each conveyor
(3) Each silo, bunker, or other vessel
(4) Each fan
(5) Each piece of process equipment

Usually a volume exemption of 8 ft^3 (0.2 m^3) or smaller is applied to enclosed pieces of process equipment in deflagration hazard management. This exemption comes from the difficulty in designing deflagration suppression for vessels that size, as well as the modest hazard such small vessels represent. Assuming an 8-to-1 volumetric expansion from a dust deflagration, an 8 ft^3 (0.2 m^3) enclosure will yield a fireball volume of approximately 64 ft^3 (1.8 m^3), the volume of a 10 ft (3 m) diameter sphere. This is the estimated maximum extent of the fireball volume. This fact can be used to select the parts of the process system to be considered in the analysis. If a piece of process equipment includes a column of less than 8 ft^3 (0.2m^3), it should be documented as such in the process hazard analysis.

The process hazard analysis also considers the building compartment (room) where combustible particulates are being handled or processed. These compartments should be evaluated for both deflagration hazard and building rupture/collapse (explosion) hazard. *(See Figure B.4.5.)*

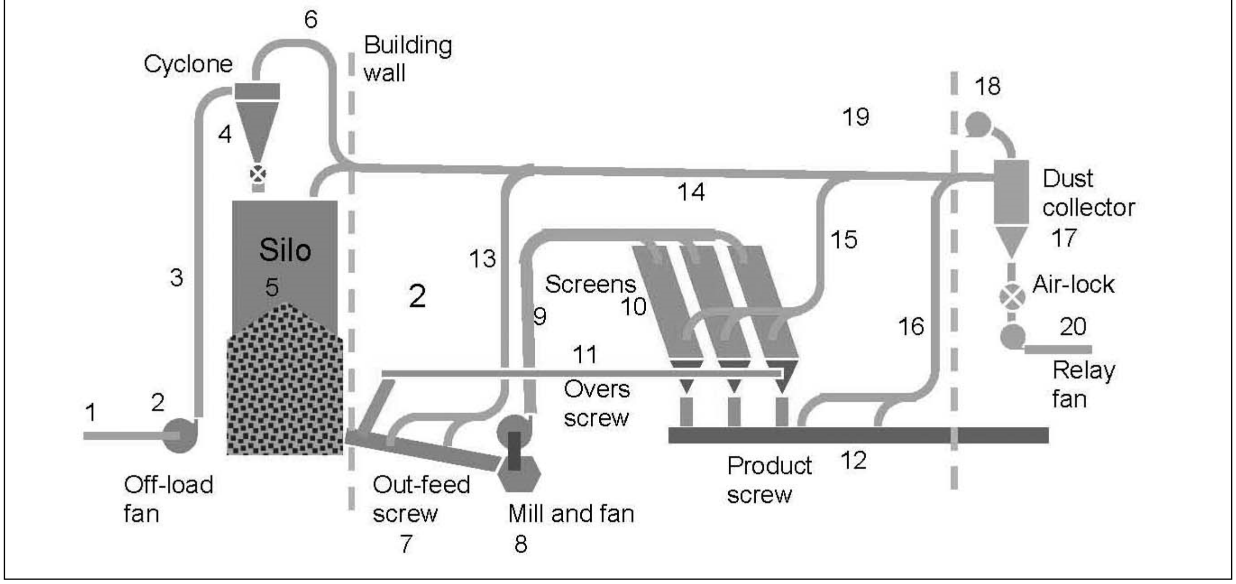


Figure B.4.5 *(Source: J.M.Cholin Consultants, Inc.)*

B.4.5.1 Location 1: Off-Load Duct to Off-Load Fan.

B.4.5.1.1

Is the particulate deflagrable(explosible)? The ability to propagate a deflagration flame front is the artifact of material chemistry – how much heat is released per unit of mass when it burns – and particle size. What are the deflagration metrics for this material? Has the material been tested for MEC, MIE, K_{St} and P_{max}? Depending upon the material, other data might be necessary. Currently, ASTM E 1226, *Standard Test Method for Explosibility of Dust Clouds,* includes a screening test to determine if the particulate is capable of propagating a deflagration. However, often the average particle size is used as a first order estimate. Some standards use a nominal average particle size of 500 microns as the dividing line. Wood hogs generally have screens that produce particulates between 0.25 in. and 1.00 in. in largest particle dimension. This is substantially greater than 500 micron. While the particulate is all mixed together, it is probably not deflagrable (explosible). So, for this example the answer is no. But if the particulate is allowed to separate on the basis of size, the “fines” content will probably change the conclusion.

While sieve analysis cannot be relied upon as the sole hazard identification means, it is useful for informing the analysis. There isn’t yet reported research that serves as a basis for establishing a percentage of fine particulate versus coarse particulate sufficient to propagate a flame front.

B.4.5.1.2

Is the particulate suspended in air? Since a fan is used to suck this material through a duct the answer is yes.

B.4.5.1.3

Is there sufficient concentration to propagate a flame front? At this point in the process, a sieve analysis of the process stream could provide some additional information. If the dust concentration exceeds the MEC of the dust, then there is the potential for flame propagation. However, large particles are quenching surfaces and inhibit flame propagation. In the mixture used in this example it is not likely.

B.4.5.1.4

Are there competent igniters available? Yes. The material could have been ignited as it was loaded into the railcar or truck trailer. (This has happened.) Tramp metal could be present in the particulate that can strike sparks as it hits the wall of the duct.

B.4.5.1.5

What hazard management is in place? Is there metal detection, spark detection, bonding and grounding, or other hazard management means in place?

B.4.5.2 Location 2: Off-Load Fan.

B.3.5.2.1

Is the particulate deflagrable (explosible)? This the same material as in B.4.5.1.1.

B.4.5.2.2

Is the particulate suspended in air? Yes, same as B.4.5.1.2.

B.4.5.2.3

Is there sufficient concentration to propagate a flame front? Maybe, same as B.4.5.1.3.

B.4.5.2.4

Are there competent igniters available? Yes. In addition to the ones identified in B.4.5.1.4, the fan introduces a number of ignition mechanisms.

B.4.5.2.5

What hazard management is in place? This is the same as in B.4.5.1.5. It is difficult to apply hazard management to a material conveyance fan. Usually hazard management is applied downstream from the fan.

B.4.5.3 Location 3: Duct from Fan to Cyclone.

B.4.5.3.1

Is the particulate deflagrable (explosible)? This the same material as in B.4.5.1.1. However, the fan will cause particle attrition, increasing the relative concentration of fine particulate in the mixture. How much it increased is not known unless a sieve analysis comparing material before and after the fan is conducted.

B.4.5.3.2

Is the particulate suspended in air? Yes, same as B.4.5.1.2.

B.4.5.3.3

Is there sufficient concentration to propagate a flame front? Maybe, same as B.4.5.1.3, with the caveat that fan produced particle attrition will increase the fines content.

B.4.5.3.4

Are there competent igniters available? Yes. In addition to those from the in-feed duct there are those from the fan. Often a spark detection and extinguishment system is used to detect and quench sparks and burning material before it gets to a location where these could serve as an ignition source for a dust deflagration.

B.4.5.3.5

What hazard management is in place? Is there spark detection and extinguishment? Is there metal detection?

B.4.5.4 Location 4: Cyclone.

Cyclones are designed to use particulate inertia to separate the particulate from the conveyance air. Deflagrations can occur in cyclones. Cyclones intentionally concentrate particulate near the perimeter of the cyclone. Cyclones also cause the large particles to separate from the fine material. Both of these factors increase the likelihood that a portion of the volume within the cyclone will have conditions sufficient for a deflagration. *(See Figure B.4.5.4.)*

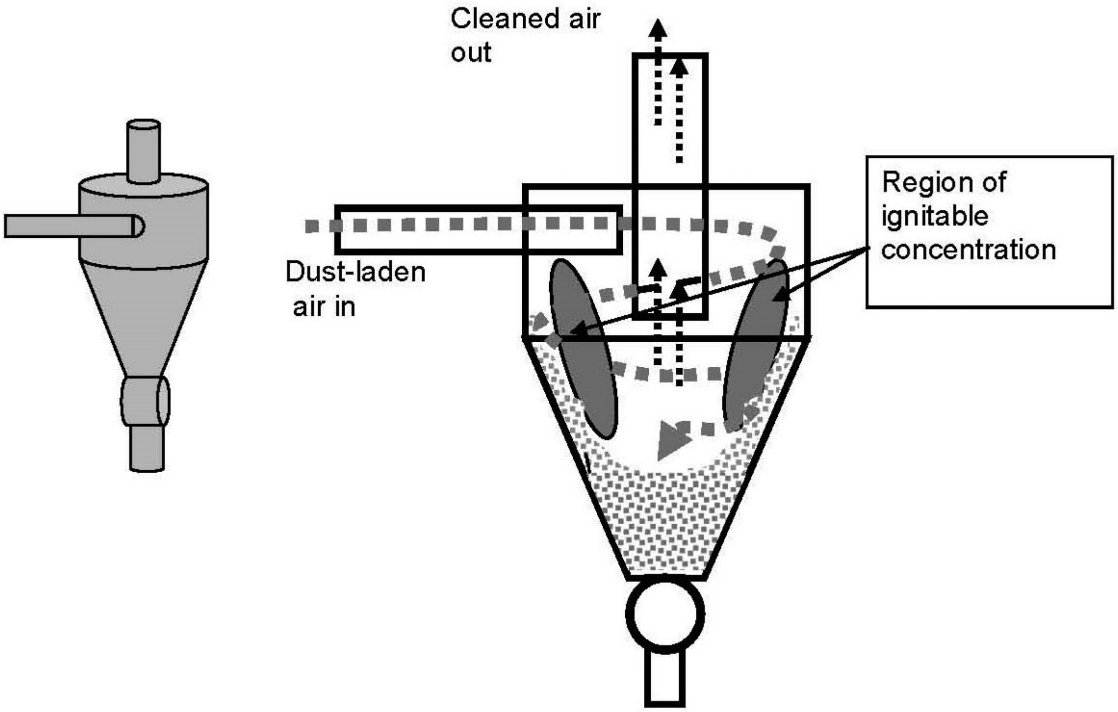


Figure B.4.5.4 The Operating Cyclone in Cross-Section. *(Source: J.M.Cholin Consultants,)*

B.4.5.4.1

Is the particulate deflagrable (explosible)? If there are any fines in the process particulate they will be separated, at least partially, from the larger particulates and concentrated by the cyclone. Since the fan creates fines and there is particle attrition as particulate goes rattling up the duct the likely conclusion is: yes.

B.4.5.4.2

Is the particulate suspended in air? Yes.

B.4.5.4.3

Is there sufficient concentration to propagate a flame front? Probably, and that translates to a yes. This depends on the quantity of fine, deflagrable (explosible) particulate per unit of mass of total particulate moved and the volume of air to move it. Calculations should be performed to determine if there is sufficient fine material per unit of air volume under the range of operating conditions achieve a concentration of deflagrable particulate in excess of the MEC and render the cyclone an explosion hazard.

B.4.5.4.4

Are there competent igniters available? Yes. All of the ignition sources identified in the earlier portions of the system will be sending the ignited particulate to the cyclone. Therefore, there is no alternative but to consider the cyclone an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.4.5

What hazard management is in place? The cyclone should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device.

If the system is shut down and there is burning material in the hopper section (base) of the cyclone, how is that managed? Most explosions result from deflagrations that are initiated by ongoing fires. Is there any fire detection in place? What is the plan if a fire is detected? (Dumping burning material into a silo is not an option.)

B.4.5.5 Location 5: Storage Silo.

Every storage vessel is a particle size separator. When a mixture of material is dumped into a silo, bin, bunker, and so forth, the large particulate falls rapidly to the bottom of the vessel while the fines are lifted up by the air being displaced by the large particulate. This creates a cloud of fine dust in the ullage space, above the settled material. If any burning material or matter at a temperature above the auto-ignition temperature of the fine dust passes through this cloud, a deflagration is likely to result. *(See Figure B.4.5.5.)*

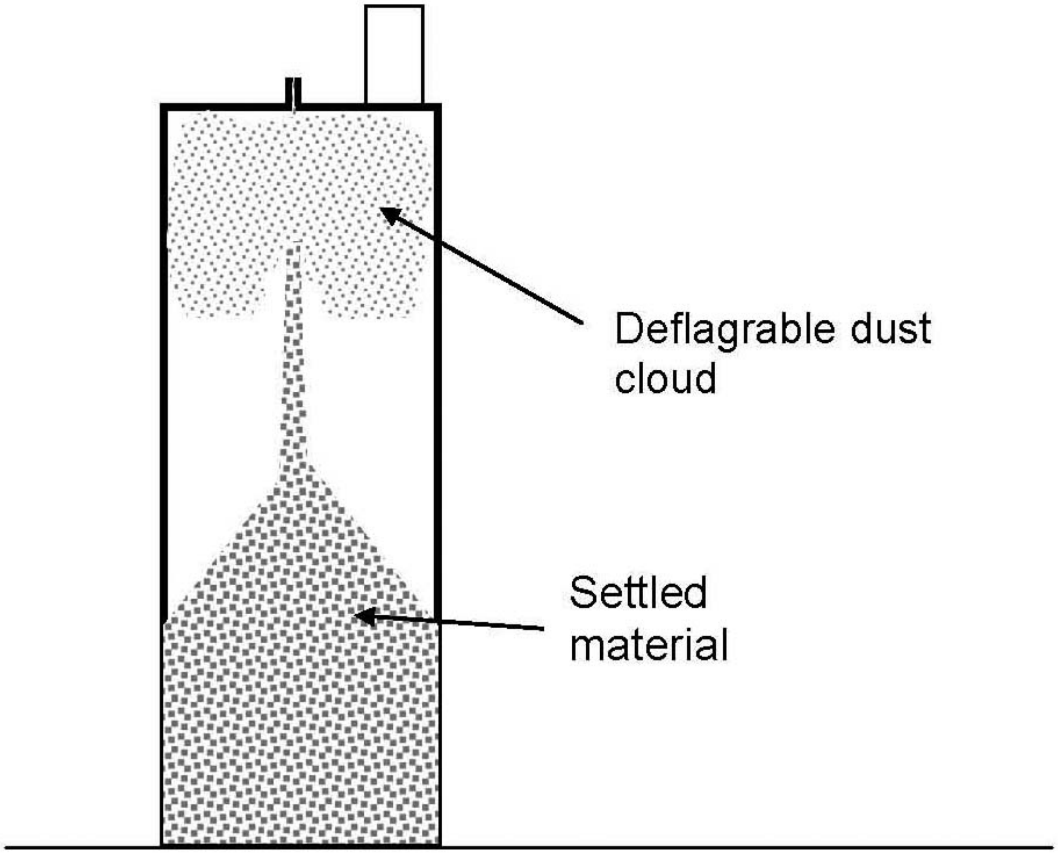


Figure B.4.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard

B.4.5.5.1
Is the particulate deflagrable (explosible)? Yes. The fines have separated from the coarse material and are suspended in a cloud in the ullage space.

B.4.5.5.2
Is the particulate suspended in air? Yes. The large particulate falls faster than the fines due to its lower Reynolds Number. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

B.4.5.5.3
Is there sufficient concentration to propagate a flame front? Eventually, Yes. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo the greater the concentration of dust in that cloud.

B.4.5.5.4
Are there competent igniters available? Yes. All of the ignition sources identified in the earlier portions of the system send the ignited particulate through the cyclone and on to the silo. The

rotary air lock at the base of the cyclone hopper section can also be an ignition source in some cases where tramp metal has been introduced in the process stream. Therefore, there is no alternative but to consider the silo an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.5.5

What hazard management is in place? The silo should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device. It is also likely that the mass of material in the bottom of the silo will serve as isolation.

B.4.5.6 Location 7: The Out-Feed Screw Conveyor.

B.4.5.6.1

Is the particulate deflagrable (explosible)? The material moving through this conveyor is a mixture of the large chips and the fine dust that eventually settled from the ullage space. So, there is a deflagrable (explosible) fraction included in the coarse material. The question is whether that fine fraction can become suspended.

B.4.5.6.2

Is the particulate suspended in air? It depends on the screw conveyor. Usually materials only fill the bottom half of a screw conveyor. There are exceptions. If the screw conveyor is rotating slowly, the rotation of the flight does not lift the fine material and put it into air suspension in the upper half of the conveyor interior. If the screw conveyor is operating at a high speed, then the rotation of the flight will suspend material above the central axis of the screw and produce a dust suspension within the screw conveyor. We have to assume this is the case unless we can prove otherwise. Generally, the speed of the edge of the conveyor flight will attain speeds on the order of 16.5 ft/sec (5 m/sec) to achieve a sustained dust cloud. (This number is half the minimum air entrainment value reported for glass microspheres in *Towards Estimating Entrainment Fraction for Dust Layers*, Erdem Ural, Fire Protection Research Foundation, June 2011. See also NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.)

B.4.5.6.3

Is there sufficient concentration to support a deflagration? The fine dust is remixed with the coarse material so the concentration is a function of the percentage of the material that is the fine fraction and the air volume in the screw conveyor. If this concentration can exceed 25 percent of the MEC, then one can assume that there is sufficient concentration to propagate a deflagration.

B.4.5.6.4

Are there competent igniters available? Yes. It is quite possible that burning material was loaded into the silo; wood particulates are notorious for sustaining a smoldering combustion process for extended periods of time. Furthermore, the screw conveyor has bearings. Many screw conveyors have hanger bearings that are in the material stream and are potential ignition sources. Consequently, it is very likely that if the speed of the screw is sufficient, the screw conveyor will be designated as a deflagration hazard and explosion management provisions will be necessary.

B.4.5.6.5

What hazard management is in place? Deflagration suppression and isolation is generally needed on high-speed screws. However, it might be possible to manage the hazard by replacing the screw with one that has a larger diameter but operates too slowly to produce a dust suspension.

Sometimes changing the process or process equipment can reduce or eliminate the hazard, and that might be the best strategy.

B.4.5.7 Location 8: The Mill and Discharge Fan.

While the drawing shows these as separate components, most mills have an integral discharge fan.

B.4.5.7.1

Is the particulate deflagrable (explosible)? It depends. What is the target product particle size? If the mill has 1/4 in. screens, then the unit is receiving large particles and making them less large, but they're still too large to be considered a deflagrable (explosible) particulate. But there are also included fines. If the mill is reducing the particulate down to 250 μ, then all of the particulate would be considered deflagrable (explosible). So the determination for whether the particulate in the mill is deflagrable is based on the range of particle size exiting the mill. It is usually necessary to submit this material for a go/no-go screening test to determine if the mixture exiting the mill is capable of propagating a deflagration flame front.

B.4.5.7.2

Is the particulate suspended in air? Yes. Inside the mill the particulate is in continuous air suspension.

B.4.5.7.3

Is there sufficient concentration to support deflagration? This again depends on the test data and a sieve analysis. Remember that while a sieve analysis is not a definitive criterion for identifying whether a particulate is deflagrable (explosible), it is a very valuable tool for identifying changes that have occurred in the process that signify an change in the hazard associated with the particulate. It is a management of change and safety assessment audit tool.

B.4.5.7.4

Are there competent igniters available? Most mills are capable of igniting the material being milled. If tramp metal gets into the process stream it is likely that the particulate will exit burning, at the very least.

B.4.5.7.5

What hazard management is in place? Are there magnetic separators or traps on the in-feed to the mill? Is there deflagration suppression and isolation on the mill? Even if the mill is designed strong enough to withstand a deflagration within it (many are), the deflagration flame front will exit the mill via the in-feed and out-feed. What provisions are in place to isolate the mill from the rest of the process?

B.4.5.8 Location 9: The Mill Discharge Duct to Screens.

B.4.5.8.1

Is the particulate deflagrable (explosible)? *(See B.4.5.7.1.)* If the material is deflagrable this duct can pose a significant hazard.

B.4.5.8.2

Is the particulate suspended in air? Yes. It is a pneumatic conveying duct — but what kind? If it is a dilute-phase conveying duct, then the material is suspended in air and the level of concentration becomes an important issue. However, if the plant is designed with a dense-phase or semi-dense-phase conveying system at this location, then the material does not move as an air suspension but as a region of concentrated material that usually does not represent a deflagration hazard in the duct under normal operating conditions.

B.4.5.8.3

Is there sufficient concentration to support a deflagration? If the duct is part of a dilute phase conveying setup, then the duct must be considered a deflagration hazard if the concentration exceeds 25 percent of the MEC for the material in the duct. If the material is tested and it does not propagate a deflagration flame front, then concentration ceases to be an issue. But if the material in the duct can propagate a deflagration flame front, then the concentration must be limited by the system design, or deflagration hazard management must be applied to the duct.

B.4.5.8.4

Are there competent igniters available? Yes. This duct is immediately downstream from the mill, which can be a source of ignition.

B.4.5.8.5

What hazard management is in place? If the particulate is sufficiently small enough to produce an affirmative test for deflagration flame front propagation, then the entire duct represents an explosion hazard, and that hazard must be managed. If it does not, either because the particulate is not deflagrable or dense-phase conveying is being used, then it does not. The analysis should document whether the duct is a deflagration hazard and if it is, how that hazard is being managed.

B.4.5.9 Location 10: The Screens.

B.4.5.9.1

Is the particulate deflagrable (explosible)? This is the same particulate that is exiting the mill, so that analysis is applicable to the screens.

B.4.5.9.2

Is the particulate suspended in air? This depends on the type, make, and model of the screens used. Some agitate the material more aggressively than others. An analysis of the operating screens for the presence of a dust suspension should be undertaken to determine if this criterion is satisfied.

Most screens leak dust into the building interior, and that issue has to be addressed.

B.4.5.9.3

Is there sufficient concentration to support deflagration? This criterion is again determined by the fraction of the process particulate that is sufficiently small to propagate a dust deflagration flame front. Note that the screens are equipped with dust collection. What is the air flow rate for the dust collection? What is the fraction of the particulate that is sufficiently small to propagate a deflagration flame front? How much of that dust is captured by the dust collection system? There are cases where a deflagration hazard has been successfully managed by just keeping the concentration below the 25 percent MEC threshold with active dust collection.

B.4.5.9.4

Are there competent igniters available? This depends on the type of screens used. Usually the bearings and moving members are located outside of the material flow path. However, there are ignition sources upstream in the process that could be a source of burning material introduced onto the screens. Usually this poses a fire hazard rather a deflagration hazard. But that fire hazard must be managed.

B.4.5.9.5

What hazard management is in place? Depending on whether the screens are found to be a deflagration hazard or a fire hazard, different hazard management strategies will apply. The strategy employed and the reason for selecting that strategy should be documented.

B.4.5.10

This example includes other ducts, conveyors, and other process equipment that would be addressed in a manner similar to those already covered. However, there are two hazards that have not yet been addressed: the building compartment and the dust collector.

B.4.5.11 Location 2: The Building Compartment Housing the Process.

B.4.5.11.1

Is the particulate deflagrable (explosible)? There are a number of pieces of equipment that can leak dust. The leaks always constitute the fines fraction of the particulate being handled. In addition, air movement generally lifts the finest, most hazardous dust highest in the space. So the hazard assessment for the building compartment is based on the test data for the fine dust that is obtained from the highest locations in the building compartment.

Is there sufficient fugitive dust accumulation within the building to trigger the designation of deflagration hazard or flash-fire hazard in the building interior?

If the building compartment contains sufficient fugitive dust accumulations to warrant designating it a deflagration of flash-fire hazard, then the occupant must be protected from the building interior. This requires the use of flame-resistant garments and a housekeeping program. Venting is one common approach to protect against building collapse.

Furthermore, dust accumulations trigger requirements for using electrical equipment that is listed as suitable for Class II hazardous locations in accordance with Articles 500 through 506 of *NFPA 70, National Electrical Code.*

B.4.5.11.2

Is the particulate suspended in air? Most large-loss explosions involving combustible dust have occurred because a small event produced an ignition mechanism and a dust dispersion of the accumulated fugitive dust in the building interior.

B.4.5.11.3

Is there sufficient concentration to support a deflagration? Generally, the dust layer criteria in the occupancy standards are derived from calculations that take into consideration the requisite concentrations to propagate a flame front.

B.4.5.11.4

Are there competent igniters available? Under abnormal (accident) conditions the answer is usually yes.

B.4.5.11.5

What hazard management is in place? Deflagration venting for compartments is a common management strategy to preserve the building integrity. What provisions are in place to protect the employees from a propagating deflagration (flash fire)? Is the housekeeping program sufficient to prevent fugitive dust layer from developing over time?

B.4.5.12 The Dust Collector.

The dust collector in this example is located outside of the building, but it is equipped with a clean air return to the facility interior. This triggers the need to protect the employees within the facility compartment from a fire in the dust collector as well as a deflagration in the dust collector.

B.4.5.12.1

Is the particulate deflagrable (explosible)? Probably. This dust collector is collecting the fines that are generated by various process steps including the dust suspended in the silo ullage space, the silo discharge screw conveyor, the screens, and the product out-feed screw.

B.4.5.12.2

Is the particulate suspended in air? Yes. Dust collection systems are invariably designed as dilute phase conveying systems.

B.4.5.12.3

Is there sufficient concentration to support deflagration? Usually such dust collection systems operate at dust loadings in the ducts in the range of 1 to 3 g/m^3 ; well below the 25 percent MEC range for most dusts. But this parameter must be verified and documented. So the ducts are probably not a deflagration hazard, but the dust collector's job is to concentrate that dust. So an ignitable concentration of dust within the dust collector is probably certain.

B.4.5.12.4

Are there competent igniters available? Generally, yes. All of the ignition sources in the entire process have access to the dust collector via the dust collection ducts. While the concentration in those ducts is typically well below the MEC, there is always the potential for a burning particle to survive the trip from the point of ignition to the dust collector interior, where it can become attached to the filter media and ignite a fire. For many particulates there is an electrostatic ignition mechanism present. For others, the inherent reactivity of the particulate with atmospheric oxygen makes them inherently self-igniting. All of these sources of ignition have to be considered.

B.4.5.12.5

What hazard management is in place? The occupants must be protected from the dust collector — both the dust collector fire as well as the dust collector explosion. (In many industries dust collector fires outnumber dust collector explosions.) For dust collector fire, return air diversion to prevent combustion products from entering the building is sufficient. (Generally, dust collectors collecting metallic particulates are not permitted to return air to the building.) To protect occupants from the dust collector explosion, a common approach is to install deflagration isolation as well as either deflagration venting or deflagration suppression. The protection feature in place should be documented.

B.4.6

This example is intended to illustrate one process used in assessing the combustible dust hazards of a facility. Other methods are acceptable as long as they result in a thorough assessment of all the hazards in the process and facility and document how those hazards are managed. This example evaluated the following aspects of the process:

1. Process equipment
2. Process ductwork
3. Facilities compartments

Individual hazards for these three areas would be considered in the aggregate to determine the overall hazards of the process.

Annex C Accumulated Fugitive Dust

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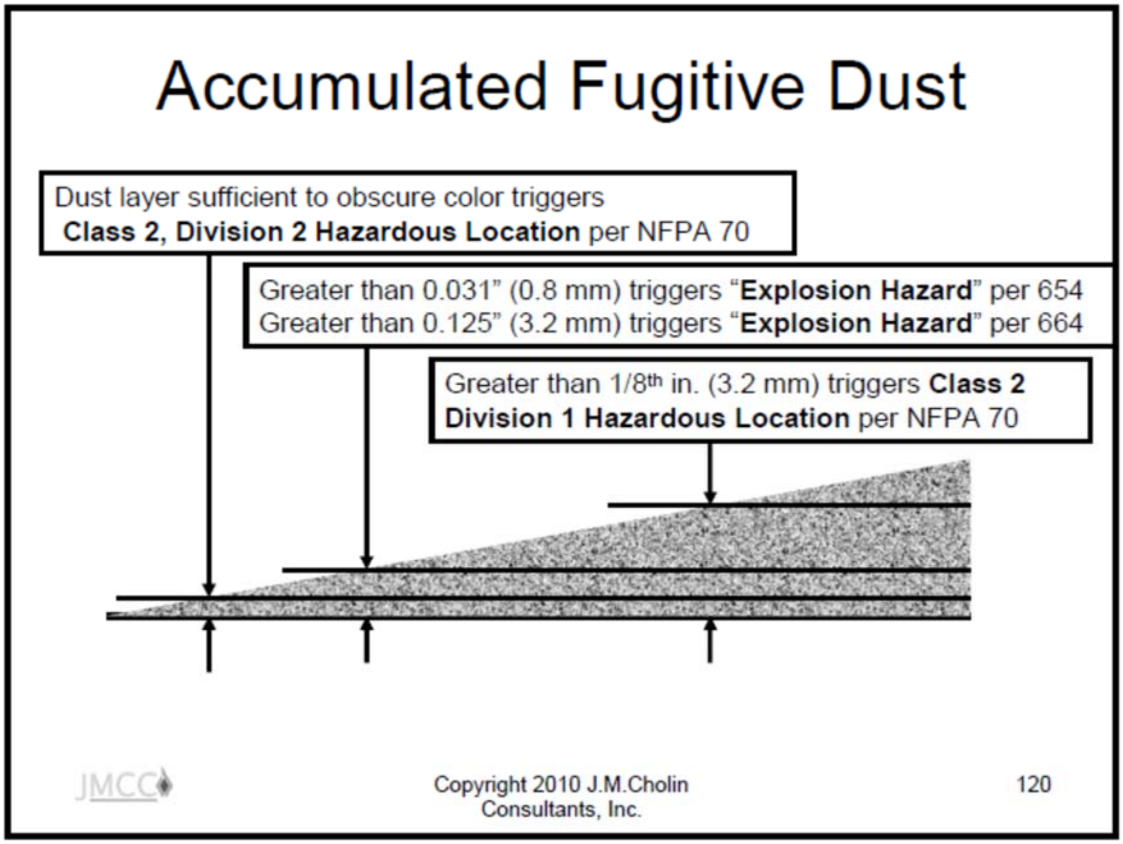

Accumulated Fugitive Dust

Dust layer sufficient to obscure color triggers **Class 2, Division 2 Hazardous Location** per NFPA 70

Greater than 0.031” (0.8 mm) triggers “**Explosion Hazard**” per 654
Greater than 0.125” (3.2 mm) triggers “**Explosion Hazard**” per 664

Greater than 1/8th in. (3.2 mm) triggers **Class 2 Division 1 Hazardous Location** per NFPA 70

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Figure C.1 Comparison of Accumulated Fugitive Dust Thicknesses. ***(Source: J.M. Cholin Consuktants, Inc.)***

[Need to add a text reference to the figure.]

C.1 Accumulated Fugitive Dust.

- The single most important factor in propagating a deflagration within a building.
- Dust layers trigger critical hazard management decisions
- See NFPA 499
- Electrical Equipment for Hazardous
- Occupancies
- All electrical equipment must be “listed” for use in the occupancy based upon the Class, Division and Group classification.
- When all electrical equipment in the occupancy is listed for use in that occupancy the electrical system is not deemed to be a likely igniter.
- The extent of the electrically classified area is controlled by the rate of dust release and the frequency of clean-up.

Process Building Compartments

- Where the management of the hazard is dependent upon routine cleaning, that cleaning program should be outlined in the PHA.
- Where the management of the hazard is dependent upon routine cleaning, that cleaning program should be outlined in the PHA.
- Explosion Hazards
- Dust explosion hazards exist where ever combustible particulate solids are handled or produced.
- There is no alternative to *pro-actively managing* the hazard.
- Is there accumulated fugitive dust? If so – how much and where is it?
- What is the MEC, MIE and K_{St} of the particulate in the duct?
- Does the building compartment pose a deflagration hazard?
- Does it pose and explosion hazard?
- Does it pose a fire hazard?
- The majority of the property damage and personnel injury is due to the fugitive dust accumulations within the building or process compartment.

Control, limitation, or elimination of accumulated fugitive dust is CRITICAL and the single most important criterion for a safe workplace.

Annex D Informational References

D.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

D.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2009 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities,* 2013 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 edition.

NFPA 70®, *National Electrical Code®*, 2011 edition.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance,* 2013 edition.

NFPA 70E®, *Standard for Electrical Safety in the Workplace®,* 2012 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2007 edition.

NFPA *101®*, *Life Safety Code®*, 2012 edition.

NFPA 120, *Standard for the Prevention and Control in Coal Mines,* 2010 edition.

NFPA 220, *Standard on Types of Building Construction*, 2012 edition.

NFPA 484, *Standard for Combustible Metals,* 2012 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2013 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2013 edition.
NFPA 655, *Standard for Preventing Sulfur Fires and Explosions*, 2012 edition.
NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 2012 edition.

NFPA 2112, *Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*, 2012 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*, 2012 edition.

D.1.2 Other Publications.

D.1.2.1 ACGIH Publications.

American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.

Industrial Ventilation: A Manual of Recommended Practice, 26th edition, 2010.

D.1.2.2 AIChE Publications.

American Institute of Chemical Engineers, Three Park Avenue, New York, NY 10016-5991.

AIChE Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures*, 3rd edition, 2008.

D.1.2.3 AIHA Publications.

American Industrial Hygiene Association, 3141 Fairview Park Drive, Suite 777, Falls Church, VA 22042
ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems*.

D.1.2.4 ASME International Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code,* 2010.

ASME B.31.3, *Process Piping,* 2010.

D.1.2.5 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E 582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures*, 2007.

ASTM E 1226, *Standard Test Method for Explosibility of Dust Clouds*, 2012.

ASTM E 1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds,* 2006 (2012).

ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2007.

ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2003 (2007).

ASTM E 2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers,* 2009.
ASTM WK1680, *Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, (draft under development).

D.1.2.6 IChemE Publications.

Institution of Chemical Engineers, Davis Building, 165-171 Railway Terrace, Rugby, Warwickshire, CV21 3HQ, England.

Prevention of Fires and Explosions in Dryers, 1990.

D.1.2.7 IEC Publications.

International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 61241-2-1, *Electrical Apparatus Use in the Presence of Combustible Dust — Methods for Determining the Minimum Ignition Temperatures of Dust*, 1994.

D.1.2.8 ISO Publications.
International Standards Organization,
1 rue de Varembé, Case Postale 56, CH-1211 Genève 20, Switzerland.
ISO 6184-1, *Explosion Protection Systems — Part 1: Determination of Explosion Indices of Combustible Dusts in Air*, 1985.
IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC).* 2005.

D.1.2.9 U.S. Government Publications.

U.S. Government Printing Office, Washington, DC 20402.

DOE Handbook, *Primer on Spontaneous Heating and Pyrophoricity,* DOE-HDBK-1081-1984.

OSHA 1910.119, "Process Safety Management of Highly Hazardous Chemicals."

Title 29, Code of Federal Regulations, Part 1910.119, “Process Safety Management of Highly Hazardous Chemicals.”

Title 29, Code of Federal Regulations, Part 1910.146, "Permit-Required Confined Spaces."

D.1.2.10 Other Publications.

Babrauskas, V., *Ignition Handbook*, Fire Science Publishers, Society of Fire Protection Engineers (SFPE), 2003.

Bowes, P.C., *Self-Heating: Evaluating and Controlling the Hazards,* Elsevier, 1984.

Britton, L., *Avoiding Static Ignition Hazards in Chemical Operations.* New York: CCPS, pp.199–204, 1999

Dorsett, Henry G., "Laboratory Equipment and Test Procedures for Evaluating Explosibility of Dusts," Report RI5624. Bureau of Mines, National Institute for Occupational Safety and Health (NIOSH). 1960.

Glor, M., *Electrostatic Hazards in Powder Handling*, Research Studies Press Ltd., 1988.

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SFPE, Engineering Guide to Fire Risk Assessment, 2006.

SFPE, *Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*, 2000.

SFPE, Handbook of Fire Protection Engineering, 2008.

Tamanini, F., *Dust Explosion Propagation in Simulated Grain Conveyor Galleries,* ESV-83-067, National Grain and Feed Association Fire and Explosion Research Report, prepared by Factory Mutual Research Corporation, Norwood, MA, July 2002.

Technical Division Environmental Protection Technologies, *Pressure Venting of Dust Explosions*, VDI 3673, 2002.

D.1.3 References for Extracts in Informational Sections.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2013 edition.