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 document is the Preliminary First Draft of the proposed 2015 edition of NFPA 652.

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 user with general requirements and direct the user to the appropriate industry or commodity-specific NFPA standard for additional requirements.

1.3 Application.

1.3.1 The provisions of this standard shall be applied in accordance with Figure 1.3.1.

(Figure RESERVED)

Figure 1.3.1 Document Flow Diagram for Combustible Dust Hazard Evaluation
1.3.2 This standard establishes the basic principles and requirements that shall be applied to all facilities where combustible dusts or particulate solids are present.

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

1.4 Conflicts.

1.4.1 Where requirements between this standard and an industry or commodity-specific NFPA standard differ, the requirements of this standard shall apply.

1.4.2 Where a conflict between a general requirement of this standard and a specific requirement of this standard exists, the specific requirement shall apply.

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.

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 determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

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 a reasonable degree of safety is provided.

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 to the authority having jurisdiction to demonstrate equivalency.

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.

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.

NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances,


2.3 Other Publications.

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


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


2.3.3 UN Publications.


2.3.5 Other Publications.


2.4 References for Extracts in Mandatory Sections.


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]

**3.3.2** 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]

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

**3.3.4** Combustible Metal Dust. A combustible particulate metal that presents a fire or explosion hazard when suspended in air or the process specific oxidizing medium over a range of concentrations, regardless of particle size or shape. [484, 2012]

**3.3.5** Combustible Particulate Solid. Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition that presents a fire hazard. [654, 2013]

**3.3.6** Compartment. A space completely enclosed by walls and a ceiling. Each wall in the compartment is permitted to have openings to an adjoining space if the openings have a minimum lintel depth of 8 in. (200 mm) from the ceiling and the total width of the openings in each wall does not exceed 8 ft (2.4 m) in width. A single opening of 36 in. (900 mm) or less in width without a lintel is permitted when there are no other openings to adjoining spaces. [13, 2013]

**3.3.7** Damage-Limiting Construction. A building construction method that incorporates exterior wall or roof sections, or both, designed to relieve deflagration pressures without jeopardizing the structural integrity of the building and without allowing the deflagration to propagate into adjacent interior spaces. [664, 2012]

**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]

**3.3.9** Detachment. Locating a combustible particulate solid process in the open air or in a
separate building. [654, 2013]

3.3.10 **Duct.** Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [91, 2010]

3.3.11 **Dust Collector.** See 3.3.1, Air–Material Separator (AMS).

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

3.3.13* **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]

3.3.14 **Fugitive Dusts.** (Reserved)

3.3.15 **Handling.** Any activity, including processing, that can expose the metal's surface to air or any other substance capable of reacting with the metal under the conditions of the exposure.

3.3.16 **Hot Work.** Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [51B, 2009]

3.3.17* **Hybrid Mixture.** 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, 2007]

3.3.18* **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]

3.3.19 **Owner/Operator.** The organization with fiscal responsibility for the operation, maintenance, and profitability of the facility. [654, 2013]

3.3.20* **Pneumatic Conveying System.** An equipment system that comprises a material feeding device; an enclosed ductwork, piping, or tubing network; an air-material separator; and an air-moving device and that is used to transfer a controlled flow of solid particulate material from one location to another using air or other gases as the conveying medium. [654, 2013]

3.3.21* **Process Hazards Analysis.** A systematic review of the potential hazards associated with the presence of one or more combustible particulate solids in a process or facility compartment.

3.3.22 **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]

3.3.23 **Segregation.** The interposing of a fire- and explosion-resistant barrier between the combustible particulate solid process and other operations. [654, 2013]
3.3.24 **Separation.** The interposing of distance between the combustible particulate solid process and other operations that are in the same room. [654, 2013]

3.3.25 **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]

3.3.26 **Transient Releases.** (Reserved)

3.3.27 **Wall.**

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

3.3.27.2 **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]

3.3.28 **Ullage Space.** The open space above the surface of the stored solids in a storage vessel.

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**Chapter 4 Hazard Identification**

4.1** Scope.** The owner/operator shall identify fine particulate solid and dust flash fire and explosion hazards.

4.2 **Overview.**

4.2.1** Fine solid particulates and dusts shall be assessed to identify their combustibility and explosibility characteristics.

4.2.2 The assessment shall be based on representative samples and materials including in-process and fugitive dusts.

4.2.3 Where it is not clear whether a material is combustible or explosible, samples shall be subject to screening tests for combustibility and explosibility hazard characteristics in Section 4.5.

4.2.4 Test data shall be acceptable to the authority having jurisdiction (AHJ).

4.2.5 For materials that are combustible or explosible, additional specific tests data shall be acquired where applicable to the requirements for performance-based design described in Chapter 5, for hazard assessment described in Chapter 6, and for hazard mitigation and prevention specified in Chapter 7.

4.2.6 A sampling plan shall be developed and documented to identify samples, processes, and their location, accounting for potential for attrition of larger particles into dust and times that represent where realistic conditions are favorable for the sample exhibiting combustibility and explosibility characteristics.
4.3* Physical Hazards Other than Combustibility. (Reserved)

4.4 General Requirements.

4.4.1* The owner/operator of a facility with combustible particulate solids and dust shall be responsible to identify, sample, analyze, and test materials to ensure the materials are combustible and the hazards are adequately assessed.

4.4.2* Combustible fine particulate solids and dust hazard identification, assessment, and mitigation shall address all known hazards, which include the following:

1. Personnel hygiene issues from exposure to dust or combustion products
2. Environmental hazards caused by dust or combustion products
3. Reactivity hazards (e.g., binary compatibility or water reactivity)
4. Smoldering fire in a layer or pile
5. Flaming fire of a layer or a pile
6. Deflagration resulting in flash fire (dust cloud combustion)
7. Deflagration resulting in dust explosion in equipment
8. Deflagration resulting in dust explosion in rooms and buildings

4.4.3 Historical process incidents such as flash fires, small fires, sparkling fires, pops, booms, or evidence of vessel, tank, or container overpressure shall not be used as a substitute for analysis and testing.

4.4.4 If a test for combustibility or explosibility produces a positive result, the material shall be considered a combustible dust and additional analysis, particularly hazard analyses, shall be required.

4.4.5 Test results shall be documented and the test results shall be provided when requested by the AHJ.

4.4.6* If the owner and operator are not able to identify samples or interpret test results, a qualified person that is knowledgeable of combustible dust hazards shall be contacted.

4.5 Combustibility and Explosibility Tests.

4.5.1* Determination of Combustibility.

4.5.1.1 The 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.

4.5.1.2 For the purposes of determining the combustibility of fine particulate and dust composed
of non-metals, the results of the screening test shall be categorized as one of the following three reactions:

1. No reaction
2. Ignites but does not propagate (e.g., self-extinguishes)
3. Ignites and propagates combustion

4.5.1.3 For fine particulate and dust composed of metals and metal containing mixtures, the results of the screening test shall be categorized as one of the following three categories:

1. No reaction
2. Glowing but no propagation along the train
3. Propagation along the powder train past the heated zone

4.5.2 Determination of Flash Fire Hazard. (Reserved)

4.5.3* Determination of Explosibility.

4.5.3.1 The determination of explosibility of fine particulate and dusts shall be determined according to a “go/no-go” screening test methodology described in ASTM E 1226 Standard Test Method for Explosibility of Dust Clouds.

4.5.3.2 If explosible, some or all of the standard test methods listed in Table 4.5.3.2 shall be performed for the purpose of risk assessment.

<table>
<thead>
<tr>
<th>Table 4.5.3.2 Tests to Determine Explosibility for Risk Evaluation</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air</td>
<td>Minimum ignition energy (MIE) of dust cloud in air</td>
</tr>
<tr>
<td>ASTM E 1491, Standard Test Method for Minimum Autoignition Temperature of Dust Clouds</td>
<td>Minimum ignition temperature (Tc) of dust clouds</td>
</tr>
<tr>
<td>ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds</td>
<td>Maximum explosion pressure ($P_{\text{max}}$), rate and maximum rate of pressure rise ($dP/dt$), and explosion severity ($K_{sc}$)</td>
</tr>
<tr>
<td>ASTM E 1515, Test Method for Minimum Explosible Concentration of Combustible Dusts</td>
<td>Minimum explosible concentration (MEC)</td>
</tr>
<tr>
<td>ASTM WK1680, Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds</td>
<td>Limiting oxygen concentration (LOC)</td>
</tr>
</tbody>
</table>

4.6 Sampling.

4.6.1 Sampling Plan.

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

4.6.1.2 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

4.6.2 Mixtures.

4.6.2.1 If the particulate solid is a mixture of organic, inorganic, and/or combustible metals, the amount or concentration of each constituent shall be determined by laboratory testing.

4.6.2.2 If the mixture of fine particulate solid is composed of or contains metal, the requirements of NFPA 484, Standard for Combustible Metals, shall apply.

4.6.3* Sample Location. Particulate solid and dust samples shall be collected from rooms and sources known to pose or amplify combustible dust fires and explosions.

4.6.3.1 Special consideration shall be given to samples from equipment in facilities such as but not limited to dust collectors, impact equipment, silos and bins, processing equipment, ovens, furnaces, dryers, conveyors, bucket elevators, and grain elevators.

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

4.6.3.2 Samples shall 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.

4.6.4 Representative Samples.

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

4.6.4.2* Special consideration shall be given to collecting samples from processes and equipment that result in attrition.

4.6.4.3 When changes in the materials or processes occur, new samples shall be identified, collected, and tested.
4.6.5* Sample Collection. Fine particulate solids and dust samples shall be collected in a safe manner using acceptable tools, containers, and methodologies such that the sample is preserved.

4.6.5.1* Particulate solids, fines, powder, and dusts shall be identified using as many identifiers as practical including lot, origin, composition (pure, mixture), process, age, location, and date collected.

4.6.5.2* Because the degree of combustibility and explosibility are strongly influenced by material properties, the specific form and composition of the particulate solid shall be tested.

4.6.6 Sample Preservation. Samples collected shall be preserved to prevent oxidation and ageing.

4.6.7 Communication with the Laboratory. Accredited laboratories shall be used to test samples for combustibility and explosibility according to Section 4.5.

4.7* Combustion Chemistry.

4.7.1* Evaluation of a combustible dust hazard and prevention techniques employed shall be determined by the means of actual test data from Section 4.5.

4.7.1.1 Each facility, process, situation, and scenario shall be evaluated and the applicable tests selected.

4.7.2 The following sources of combustible dust ignition shall be identified where combustible dusts are present:

(1) Open flames or hot work such as welding, hot riveting, grinding, heat treating, and activities using torches for such activities as thawing of pipes and demolition activities

(2) Hot surfaces that exceed the minimum ignition temperatures such as over-heated belt drives, bearings, and bushings as well as the external surfaces of operating equipment such as compressors and process piping for steam

(3) Friction caused from grinding sparks or tramp metal in the processing systems

(4) Electrostatic sparks

4.8* Fire Identification/Hazards. (Reserved)

4.9 Objectives.

4.9.1 Life Safety.

4.9.1.1 The facility, combustible particulate processes, and human element programs shall be designed, constructed, equipped, and maintained to 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.
4.9.1.2 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.

4.9.2 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.

4.9.3* Mission Continuity. The facility, processes and equipment, and human element program shall be designed, constructed, equipped, and maintained 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.

4.9.4 Mitigation of Fire Spread and Explosions. The facility and processes shall be designed to prevent fires and explosions that can cause failure of adjacent compartments, emergency life safety systems, adjacent properties, adjacent storage, or the facility’s structural elements.

4.9.4.1* 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.

4.9.4.2 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.

4.9.5* Compliance Options. The goal in Section 1.5 and the objectives in Section 4.9 shall be achieved by either of the following means:

(1) The prescriptive provisions in accordance with Chapters 4, 6, 7, and 8, in conjunction with any additional prescriptive provisions of applicable commodity specific standards

(2) The performance-based provisions in accordance with Chapter 5

Chapter 5 Performance-Based Design Option

5.1 General Requirements.

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

5.1.2 Independent Review. The authority having jurisdiction shall be permitted to obtain an independent third-party review of the proposed design.

5.1.3* Performance-based designs shall be documented with 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 Chapter 5 of NFPA101, Life Safety Code.
5.1.3.1 A sensitivity analysis shall be performed for each assumption that is not provided in an authoritative reference acceptable to the authority having jurisdiction to show that variation of said assumption does not result in a failure to meet design criteria.

5.1.3.2 The source of all calculation methods and models shall be documented with their limits of applicability.

5.1.4* 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.

5.1.5 Sources of Data.

5.1.5.1 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.

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

5.1.6 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.

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

5.1.6.2 Any variation from the design shall require approval of the authority having jurisdiction prior to actual change.

5.2 Risk Component and Acceptability. (Reserved)

5.3 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 4.9 if its performance meets the criteria in 5.3.1 through 5.3.5.

5.3.1 Life Safety.

5.3.1.1 The life safety objectives of 5.3.1 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.

5.3.1.2 The life safety objectives of 5.3.1 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.

5.3.1.3 The life safety objectives of 5.3.1 with respect to the release of hazardous materials that don’t result in a fire or explosion shall be achieved if the following criteria are met:

(1) The physical and health hazards identified are mitigated.

(2) Releases of all hazardous materials offsite are minimized.

5.3.2 Structural Integrity. The structural integrity objective of 5.3.2 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.

5.3.3 Mission Continuity. The mission continuity objectives of 5.3.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

5.3.4 Mitigation of Fire Spread, Explosions, or the Release of Hazardous Materials. 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.

5.3.5 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.

5.4* Design Scenarios.
5.4.1 Fire Scenarios.

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

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

5.4.1.3 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.

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

5.4.1.5 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.

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

5.4.1.7 The 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.

5.4.2 Explosion Scenarios.

5.4.2.1 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.

5.4.2.2 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.

5.4.2.3 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.

5.4.2.4 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.

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

5.5 Evaluation of Proposed Design.

5.5.1* A proposed design’s performance shall be assessed relative to each performance objective.
in Section 5.3 and each applicable scenario in Section 5.4, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

5.5.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 5.3.

5.5.3 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.

5.6 Retained Prescriptive Requirements. (Reserved)

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Chapter 6 Hazard Assessment

6.1* General Requirements.

6.1.1 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.

6.1.2 The requirements of Chapter 6 shall be applied retroactively.

6.2 Criteria.

6.2.1* The process hazards analysis shall consider the fire, flash-fire, and explosion hazards and provide recommendations to ensure that the objectives in Section 4.9 are met.

6.2.2* Qualifications. The process hazards analysis shall be performed or led by a qualified person.

6.2.3* Minimum Interval. A review of the process hazards analysis shall be performed a minimum of every five years.

6.2.4 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.

6.3 Methodology.

6.3.1 General. The process hazards analysis shall consist of the following objectives:

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

   (2) Identify specific fire and deflagration scenarios and determine their consequences, including fires, flash-fires, and explosions
(3) Identify the means by which fire or deflagration events can be prevented or mitigated

(4)*Generate a document indicating how hazards will be prevented or mitigated

6.3.2 Material Evaluation.

6.3.2.1* The process hazards analysis shall be based upon test data of material that is representative of the combustible particulate solids present.

6.3.3 Process Systems.

6.3.3.1* Each part of the process system shall be evaluated.

6.3.3.2* The potential for a dust fire or deflagration in a process system component shall be based upon whether the conditions necessary and sufficient for a fire or deflagration exist.

6.3.3.3 Where there is the potential for a dust fire or deflagration within a process system, the hazards of the fire or deflagration shall be managed in accordance with this standard.

6.3.4 Facility Compartments.

6.3.4.1* Each facility compartment where a combustible particulate solid is present shall be evaluated.

6.3.4.2* The potential for a dust fire or deflagration in a facility compartment shall be based upon whether the conditions necessary and sufficient for a fire or deflagration can exist.

6.3.4.2.1 The evaluation of dust deflagration hazards in facility compartments shall include a comparison of actual or intended dust accumulation to the threshold dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure.

6.3.4.2.2 The dust accumulation levels shall be in accordance with the relevant industry or commodity-specific NFPA standards. (See 1.3.1.)

6.3.4.3 Where there is the potential for a dust fire or deflagration within a facility compartment, the effects of the fire or deflagration shall be managed in accordance with this standard.

Chapter 7 Hazard Management: Mitigation and Prevention

7.1 Inherently Safe Designs. (Reserved)

7.2 Building Design.

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

7.2.2 Building/Room Protection.
7.2.2.1* General. Each room, building, or other enclosure containing a combustible dust in sufficient quantity to support the propagation of flame shall be protected from the consequence of deflagration.

7.2.2.2 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.

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

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


7.2.3.1 Where a dust deflagration hazard exists in a facility compartment and outside of equipment, building configuration and appurtenances shall comply with NFPA 101, Life Safety Code, for hazardous occupancy.

7.2.3.2* 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 dust explosion.

7.2.4 Methods to Limit Accumulation.

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

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

7.2.5 Separation of Hazard Areas from other Occupancies.

7.2.5.1 Where a dust deflagration hazard exists in a facility compartment and outside of equipment, those areas shall be segregated, separated, or detached from other occupancies to minimize damage from a fire or explosion.

7.2.5.2 Use of Segregation.

7.2.5.2.1 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.

7.2.5.2.2 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.
7.2.5.2.3 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.

7.2.5.3 Use of Separation.

7.2.5.3.1* Separation shall be permitted to be used to limit the dust explosion hazard or dust flash fire hazard area within a building where supported by a documented engineering evaluation acceptable to the authority having jurisdiction.

7.2.5.3.2* The required separation distance between the dust explosion hazard or flash fire 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

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

7.2.5.3.4 When separation is used to limit the dust flash fire or dust explosion hazard area determined in Chapter 6, the minimum separation distance shall not be less than 35 ft (11 m).

7.2.5.3.5* 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.

7.2.5.4 Use of Detachment.

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

7.2.5.4.2* The required detachment distance between the dust explosion hazard or flash fire 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

7.3 Equipment Design.

7.3.1 Risk Evaluation. A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided in accordance with Section 7.3.

7.3.2 * Design for Dust Containment.

7.3.2.1 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.

7.3.2.2 Where the equipment cannot be designed for dust containment, dust collection shall be provided. (See also 7.3.3.)

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

7.3.3.1 General Requirements.

7.3.3.1.1* 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.

7.3.3.1.2* Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with Chapter 8.

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

7.3.3.1.4* Operations.

7.3.3.1.4.1 Sequence of Operation. Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed with the operating logic, sequencing, and timing outlined in 7.3.3.1.4.2 and 7.3.3.1.4.3.

7.3.3.1.4.2* 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.

7.3.3.1.4.3 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.
The requirements of 7.3.3.1.4.3(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.

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)

7.3.3.2* Specific Requirements for Pneumatic Conveying Systems.

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

7.3.3.2.2* 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.

7.3.3.2.3* The pneumatic conveying system shall be designed and maintained in a manner that will assure minimum conveying velocities are provided at all times.

7.3.3.2.4* Pneumatic conveying systems conveying combustible particulate solids shall be protected in accordance with Section 7.8.

7.3.3.3* Specific Requirements for Dust Collection Systems.

7.3.3.3.1* 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.

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

7.3.3.3.3* 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.

7.3.3.3.4* The addition of branch lines shall not be made to an existing system without redesigning the entire system.

7.3.3.3.5 Dust collection systems that remove material from operations that generate flames, sparks, or hot material shall not be interconnected with dust collection systems that transport combustible particulate solids or hybrid mixtures.

7.3.3.3.6* The system shall be designed to assure that the air/gas flow used shall at all times meet or exceed the minimum required to keep interior duct surfaces free of accumulations.

7.3.3.3.7* The system shall be maintained to assure that the air/gas flow used shall at all times be...
meet or exceed the minimum required to keep interior duct surfaces free of accumulations.

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

7.3.3.3.9 AMS Locations. (Reserved)

7.3.3.3.9.1 AMS Indoor Locations. (Reserved)

7.3.3.3.9.2 AMS Outdoor Locations. (Reserved)

7.3.3.10* Fans or blowers (AMD) shall be of appropriate type and sufficient capacity to maintain the required rate of air flow in all parts of the system.

7.3.3.11 Recycle of Clean Air AMS. (Reserved)

7.3.3.4* Specific Requirements for Centralized Vacuum Cleaning Systems.

7.3.3.4.1* 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.

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

7.3.3.4.3* Where ignition sensitive materials are collected, vacuum tools shall be constructed of metal or of conducting materials and provide for proper grounding to the hose.

7.3.3.4.4* Vacuum cleaning hose shall be static dissipative or conductive and grounded.

7.3.3.4.5 AMS Location. (Reserved)

7.3.4 Transfer Points. (Reserved)

7.4 Housekeeping.

7.4.1 General. Unless otherwise specified, the requirements of Section 7.4 shall be applied retroactively.

7.4.2* Methodology.

7.4.2.1 Procedure.

7.4.2.1.1* Housekeeping procedures shall be documented in accordance with the requirements of Chapters 6 and 8.

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

7.4.2.1.3* Cleaning procedures shall be in accordance with this standard and the industry or commodity-specific NFPA standard. (See 1.3.1.)

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

7.4.2.2 Vacuum Cleaning Method.

7.4.2.2.1* For residual accumulations, vacuum cleaning shall be the preferred method.

7.4.2.2.2* Portable vacuum cleaners that meet the following minimum requirements shall be permitted to be used to collect combustible particulate solids:

1. Materials of construction shall comply with 7.5.7.1 of this standard and 7.13.2 of NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*.

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 material are picked up by the vacuum cleaner, paper filter elements shall not be used.

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

7.4.2.2.3* In Class II electrically classified (hazardous) locations, vacuum cleaners shall be listed for the purpose and location or shall be a fixed-pipe suction system with remotely located exhauster and air-material separator installed in conformance with 7.3.2 and shall be suitable for the dust being collected.

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

7.4.2.3* Sweeping/Shoveling/Scoop and Brush Cleaning Method. For spills, cleaning with scoops and natural bristle brushes shall be the preferred method.

7.4.2.4* Water Wash Down Cleaning Method. Where vacuuming is impractical, the use of water wash-down shall be a permitted cleaning method.

7.4.2.5 Water Foam Wash Down Systems. (Reserved)

7.4.2.6 Compressed Air–Blow Down Method.

7.4.2.6.1 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.

7.4.2.6.2* Where blow down using compressed air is used, the following precautions shall be followed:

(1) Vacuum cleaning, sweeping, or water wash-down methods are first used 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 dust accumulation.

(3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 30 psig in accordance with OSHA requirements 29 CFR 1910.242(b).

(4) All electrical equipment potentially exposed to airborne dust in the area meets, as a minimum, NFPA 70, National Electrical Code, NEMA 12 requirements, 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.

7.4.2.7 Steam Blow Down Method. (Reserved)

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

7.4.4 Equipment.

7.4.5 Vacuum Trucks. (Reserved)

7.4.6 Frequency and Goal.

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

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

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

7.4.7 Auditing and Documentation.

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

7.4.7.3 The owner/operator shall retain documentation supporting the established frequency of routinely scheduled cleaning.
7.5 Ignition Source Control.

7.5.1 General. Unless otherwise specified, the requirements of Section 7.5 shall be applied retroactively.

7.5.2* Risk Evaluation. A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of ignition source control to be provided per Section 7.5.

7.5.3 Hot Work.

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

7.5.3.2* The hot work permit system shall include a designation of the size of the area surrounding the hot work that will be thoroughly cleaned of combustible dust.

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

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

7.5.3.5 Portable Electrical Equipment. (Reserved)

7.5.4 Hot Surfaces.

7.5.4.1 This section shall not be required to be applied retroactively.

7.5.4.2* Heated external surfaces of process equipment and piping in [fire 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 AHJ.

7.5.4.3* 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 AHJ.

7.5.5 Bearings.

7.5.5.1 This section shall not be required to be applied retroactively.

7.5.5.2* Bearings that are directly exposed to or separated by a single seal from dust containing equipment shall be monitored with alarms for overheating.

7.5.5.3 Bearing overheating alarms shall be located in a normally occupied area such as a control room.

7.5.5.4 Bearing overheating monitors and alarms shall be inspected and tested at intervals no greater than 3 months.

7.5.5.4.1 The frequency of inspection and testing in 7.5.5.4 shall be permitted to be increased or decreased based on documented operating experience or a documented process hazard analysis,
and only with the approval of both the manufacture of the monitor and alarms and the AHJ.

7.5.5.4.2 The maximum inspection and testing interval shall not exceed 2 years.

7.5.5.5* It shall be permitted to eliminate bearing monitors, based on a risk assessment acceptable to the AHJ.

7.5.6 Electrical Equipment and Wiring.

7.5.6.1* 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).

7.5.6.1.1* 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.

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

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

7.5.6.4* 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.

7.5.7 Electrostatic Discharges.

7.5.7.1 Conductive Equipment.

7.5.7.1.1* Particulate handling equipment shall be conductive unless the provisions of 7.5.7.1.2 are applicable.

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

(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.

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

7.5.7.1.4 Flexible Connectors.

7.5.7.1.4.1 Flexible connectors shall have an end-to-end resistance of less than \(1.0 \times 10^6\) ohms to ground even when an internal or external bonding wire connects the equipment to which the flexible connector is attached.

7.5.7.1.4.2* Flexible connectors with a resistance equal to or greater than \(1.0 \times 10^6\) ohms shall be permitted when all the particulate materials within and on the surface of the connector have minimum ignition energies greater than 2 joules when measured using ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

7.5.7.2 Maximum Particulate Transport Rates.

7.5.7.2.1* The maximum permitted container discharge or transport rate of particulate material with a volume resistivity greater than \(1.0 \times 10^{10}\ \Omega\cdot\text{m}\) shall be 1.4 kg/s.

7.5.7.2.2* The limit on particulate material transport or discharge rate shall not be applicable to particulate materials with minimum ignition energies greater than 20 mJ.

7.5.7.3* Grounding of Personnel.

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

7.5.7.3.2* Personnel grounding is not required for particulate materials with minimum ignition energies greater than 10 mJ.

7.5.7.4 Flexible Intermediate Bulk Containers.

7.5.7.4.1 The potential for electrostatic discharges from flexible intermediate bulk containers (FIBCs) transporting or storing combustible particulate shall be evaluated.

7.5.7.4.2* The evaluation of the FIBC electrostatic ignition hazard shall include a determination of the type of FIBC being used and the expected range of MIE values for combustible particulates being stored or transported in the FIBCs.

7.5.8 Open Flames and Fuel Fired Equipment.

7.5.8.1* Production, maintenance, or repair activities that can release or lift combustible dust shall not be conducted within 30 ft of an open flame or pilot flame.

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

7.5.8.3 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 86, *Standard for Ovens and Furnace*

7.5.8.4 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.

7.5.9 Industrial Trucks.

7.5.9.1 Industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 7.5.6, 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*.

7.5.9.2* 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 acceptable to the authority having jurisdiction shall be permitted to be used to specify the fire and explosion prevention features for the equipment used.

7.5.10 Process Air and Media Temperatures.

7.5.10.1* Unless the process media is an inert gas, process air and media temperatures in equipment containing combustible dust suspensions shall be maintained below the combustible dust cloud minimum auto-ignition temperature.

7.5.10.2* Unless the process media is an inert gas, process air and media temperatures in equipment containing combustible dust accumulations shall be maintained below the higher the dust layer hot air ignition temperature.

7.5.11 Self-Heating.

7.5.11.1* Silos and other large storage piles of particulates prone to self-heating shall have self-heating detection provisions.

7.5.11.2 Self-heating detection provisions shall not be required when the storage pile particulate residence time is less than the greater of one week or the self-heating ignition time of a particular material and pile size.

7.5.11.3 Materials that are prone to self-heating shall be cooled to a temperature below the self-heating onset temperature before they are placed into silos or other large storage piles.

7.5.11.4 Provisions shall be established for carefully emptying or inerting a storage silo or bin upon self-heating detection.
7.5.12 Friction and Impact Sparks.

**7.5.12.1** Tramp materials that present a friction or impact spark potential shall be removed from the material inlet stream to size reduction equipment and other equipment with moving parts in contact with combustible dusts.

**7.5.12.2** Tramp materials that present a friction or impact spark potential shall be permitted to be in the material inlet stream if the equipment is provided with explosion protection.

**7.5.12.3** Clearances and alignment of high-speed moving parts in equipment processing combustible particulates shall be checked at intervals of no greater than six months unless the equipment is equipped with vibration monitors and alarms.

**7.5.12.4** The alignment and clearance of buckets in elevators transporting combustible particulates shall be checked at intervals no greater than six months unless the elevators are equipped with belt alignment monitoring devices.

7.6 Personal Protective Equipment.

7.6.1 Workplace Hazard Assessment.

**7.6.1.1** 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*.

**7.6.1.2** Personnel working in areas where the threat of exposure to a dust deflagration hazard exists shall be provided with and wear flame-resistant garments.

**7.6.1.3** Potential exposure to flame and thermal hazards shall be considered when selecting flame-resistant clothing and other personal protective equipment.

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

**7.6.1.3.2** When protecting personnel from exposure to electric arc, flame-resistant clothing shall comply with *NFPA 70E, Standard for Electrical Safety in the Workplace*.

**7.6.1.4** Consideration shall be given to the following:

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

7.6.1.5 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.

7.6.1.6* The employer shall implement a policy regarding care, cleaning, and maintenance for flame-resistant garments.

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

7.6.2.1 Flame-resistant or non-melting undergarments shall be used.

7.6.2.2 Only flame-resistant outerwear shall be worn over flame-resistant daily wear.

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

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

7.7 Dust Control.

7.7.1 Continuous suction to minimize the escape of dust shall be provided for processes where combustible dust is liberated in normal operation.

7.7.1.2 The dust shall be conveyed to air-material separators designed in accordance with 7.3.2.

7.7.2* Liquid Suppression Methods for Dust Control.

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

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

7.7.3 Fans to Limit Accumulation. (Reserved)

7.8 Explosion Prevention/Protection.

7.8.1 General. If an explosion hazard exists with a building, an enclosure, or a process system, measures shall be taken to protect personnel from the consequences of an explosion.

7.8.2* Risk Evaluation. A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided per Section 7.8.

7.8.3 The requirements of Section 7.8 shall not apply where the explosion hazard is managed in
accordance with the requirements of the relevant industry or commodity-specific NFPA standard. (See 1.3.1.)

7.8.4 Equipment Protection.

7.8.4.1 General. Where an explosion hazard exists within any operating enclosure such as air material separators, storage enclosures, mixers/blenders, particle size reductions, dryers, and blowers/fans, the enclosure shall be protected from the effects of a deflagration.

7.8.4.2 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

7.8.4.3 Enclosures and all interconnections shall be designed to withstand expected pressures resulting from the deflagration protection system.

7.8.5 Equipment Isolation.

7.8.5.1 General. Where an explosion hazard exists within any operating enclosure, such as air material separators, storage enclosures, mixers/blenders, particle size reductions, dryers, and blowers/fans, the process design shall include measures to prevent deflagration propagation.

7.8.5.2 Isolation devices shall be provided to prevent deflagration propagation between connected enclosures in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

7.8.5.3 Isolation devices shall be provided to prevent deflagration propagation to any work space in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

7.8.5.4 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*.

7.9 Fire Protection.
7.9.1 General.

7.9.1.1 Manual firefighting equipment shall be provided in all areas where combustible dust fire hazards exist.

7.9.1.2 Automatic fire protection systems shall be provided when one or more of the conditions described in 7.9.1.2.1, 7.9.1.2.2, or 7.9.1.2.3 exist.

7.9.1.2.1 The hazard assessment described in Chapter 6 shall determine that a flash fire hazard exists.

7.9.1.2.2* An evaluation of the risk to facility personnel and fire fighters for manual fire fighting shall be made based on the review of the hazard assessment described in Chapter 6.

7.9.1.2.3* Manual fire fighting shall not be expected to be effective for a fire hazard assessed in accordance with Chapter 6.

7.9.2 System Requirements.

Fire protection systems where provided shall comply with 7.9.2.1 through 7.9.2.4.

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

7.9.2.2 Where fire detection systems are incorporated into pneumatic conveying systems, an analysis shall be conducted to identify safe interlocking requirements for air-moving devices and process operations.

7.9.2.3 Where fire fighting water or wet product can accumulate in the system, vessel and pipe supports shall be designed to support the additional water weight.

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

7.9.3 Fire Extinguishers.

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

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

7.9.4 Hose, Standpipes, Hydrants, and Water Supply.

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

7.9.4.2 Nozzles.

7.9.4.2.1* 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.

**7.9.4.2.2** Straight-stream nozzles shall not be used on fires in areas where dust clouds can be generated.

**7.9.4.2.3** 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 7.9.4.2.1.

**7.9.4.3 Water Supply.**

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

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

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

**7.9.5 Automatic Sprinklers.**

**7.9.5.1** Where a process that handles combustible particulate solids uses flammable or combustible liquids, a documented risk evaluation 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.

**7.9.5.2** 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*.

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

**7.9.5.4** 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.

**7.9.6 Spark/Ember Detection and Extinguishing Systems.**

Spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, and NFPA 72, *National Fire Alarm and Signaling Code*.

**7.9.7 Special Fire Protection Systems.**

**7.9.7.1** 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*


(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*

7.9.7.2 The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge.

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### Chapter 8 Management Systems

**8.1 Retroactivity.** This chapter shall apply to new and existing facilities and processes.

**8.1.1** Where existing facilities are complying with this chapter, the facility shall start creating documents immediately.

**8.2 Operating Procedures and Practices.**

**8.2.1** The owner/operator shall establish procedures for *safely* operating its facility and equipment.

**8.2.2** The owner/operator shall establish *safe* work practices to address hazards associated with operations, including, but not limited to, hot work, confined space entry, lockout/tagout, and the use of personal protective equipment.

**8.2.2.1** The *safe* work practices shall apply to employees and contractors.

**8.3 Inspection, Testing, and Maintenance.**

**8.3.1** Equipment affecting the prevention, control, and mitigation of fires and explosions shall be inspected and tested in accordance with the applicable NFPA standard and the manufacturers’ recommendations.

**8.3.2** The owner/operator shall establish procedures for maintaining its facility and equipment.
affecting the prevention, control, and mitigation of fires and explosions in a **safe** operating condition.

**8.3.3** Where equipment deficiencies are identified or become known, corrective actions shall be taken on a timely basis.

**8.3.4** Inspections and testing activities shall be documented.

**8.3.5** 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.

**8.4 Training and Hazard Awareness.**

**8.4.1** 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.

**8.4.2** General safety training and hazard awareness training shall be provided to all employees.

**8.4.2.1** Job-specific training shall ensure that employees are knowledgeable about the hazards of their working environment.

**8.4.2.2** Employees shall be trained before being assigned to a job.

**8.4.2.3** Where explosion protection systems are installed, training of affected personnel shall include the operation and potential hazards presented by such systems.

**8.4.3** Refresher training shall be provided at least every three years and as required by other relevant industry or commodity-specific NFPA standards. *(See 1.3.1.)*

**8.4.4** The training shall be documented.

**8.5 Contractors.**

**8.5.1** Owner/operators shall ensure the requirements of Section 8.5 are met.

**8.5.2** 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.

**8.5.3** **Contractor Training.**

**8.5.3.1** Contractors operating owner/operator equipment shall be trained and qualified to operate the equipment and perform the work.

**8.5.3.2** Contractor training shall be documented.
8.5.3.3 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.

8.5.3.4 Contractors shall be trained and required to comply with the facility’s safe work practices and policies, including, but not limited to, equipment lockout/tagout permitting, confined space entry, hot work permitting, fire system impairment handling, smoking, housekeeping, and use of personal protective equipment.

8.5.3.5 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.

8.6 Emergency Planning and Response.

8.6.1* 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.

8.6.2 The emergency response plan shall be reviewed and validated at least annually.

8.7* Incident Investigation.

8.7.1 Every incident that results in, or reasonably could have resulted in, a fire or explosion shall be investigated.

8.7.2 The investigation shall be documented and include findings and recommendations to prevent similar incidents in the future.

8.7.3 A system shall be established to address and resolve the findings and recommendations.

8.7.4 The investigation findings and recommendations shall be reviewed with affected personnel.

8.8 Management of Change.

8.8.1* Written procedures shall be established and implemented to manage proposed changes to process materials, technology, equipment, procedures, and facilities.

8.8.2 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, including process hazard analysis
(3) Whether the change is permanent or temporary
(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
(8) Engineering controls (physical changes and emergency response procedure changes)

8.8.3* Implementation of the management of change procedure shall not be required for replacements-in-kind.

8.8.4 Design and procedures documentation shall be updated to incorporate the change.

8.9* Documentation Retention.

8.9.1 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
(6) Management of change documents
(7) Emergency response plan documents
(8)* Contractor records
(9)* Management systems review

8.9.2 The owner/operator shall evaluate the effectiveness of the management systems presented in this standard by conducting a review of each management system.

8.9.3 The owner/operator shall be responsible for maintaining and evaluating the ongoing effectiveness of the management systems presented in this standard.

8.10 Employee Participation. (Reserved)

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.8.2 A given equivalent value could be approximate.
A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.2 Air–Material Separator (AMS). Examples include cyclones, bag filter houses, dust collectors, and electrostatic precipitators.

A.3.3.3 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 m³) 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 m³ chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m³ 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 m³ 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 m³ 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 m³ 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 m³ 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]

A.3.3.4 Combustible Metal. See NFPA 484, Standard for Combustible Metals, for further information on determining the characteristics of metals.

A.3.3.5 Combustible Metal Dust. Any time a combustible dust is processed or handled, a
potential for explosion or fire exists. The degree of hazard varies, depending on the type of combustible dust, conditions, amount of material present, and processing methods used.

A dust explosion requires the following four conditions:

1. The dust is combustible. One method of determining combustibility of dusts is testing in accordance with ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts.
2. The dust particles form a cloud at or exceeding the minimum explosible concentration (MEC).
3. A source of ignition is present.
4. Oxygen is present in sufficient quantities to support combustion.

Evaluation of a combustible dust explosion hazard and the prevention techniques employed should be determined by means of actual test data. All combustible dusts that can produce a dust explosion should be tested to determine the following information:

1. Particle size distribution
2. Moisture content as received and dried
3. Minimum dust concentration required for ignition
4. Minimum energy required for ignition (joules)
5. Maximum rate of pressure rise at various concentrations
6. Ignition layer temperature
7. Maximum explosion pressure at optimum concentration

The following information can be determined by optional testing:

1. Dust cloud ignition temperature
2. Maximum permissible oxygen content to prevent ignition
3. Electrical resistivity measurement

A.3.3.6 Combustible Particulate Solid. 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. [654,
A.3.3.9 Damage-Limiting Construction. This construction method usually makes maximum use of exterior walls as pressure-relieving walls rather than relying on the minimum recommended. Pressure-resistive walls are sometimes included to help prevent explosion propagation into adjacent areas. Further information on this subject can be found in NFPA 68, Standard on Explosion Protection by Deflagrations Venting. [664, 2012]

A.3.3.10 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.

A.3.3.15 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.

A.3.3.19 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.

A.3.3.20 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]

A.3.3.22 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]

A.3.3.23 Process Hazard Analysis. The term “PHA” (Process Hazard Analysis) is often associated with one portion of process safety management as defined in OSHA requirements 29 CFR 1910.119. The process hazard analysis should be carried out as set forth in the American Institute of Chemical Engineers Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures.

The process hazard analysis (PHA) is the critical first step in hazard management. The process hazards analysis typically includes at least the following key items:

(1) Detailed analysis of the fire and/or explosion hazards at each point along the process

(2) Documented

(3) Identify hazards

(4) Quantify hazards

(5) Document how the hazard is managed

(6) Revised as part of the management of change requirements

A.4.1 Ignition and sustained combustion occurs when 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:

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 are greater than organic materials (see Figure 4.1). 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.4.1** Elements required for fires, flash fires and explosions.

**A.4.2.1** 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.

A.4.3 Some materials have multiple potential physical and health hazards such as combustibility, explosibility, reactivity, propensity to self-heat, and toxicity. This standard does not specifically address reactivity or toxicity 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.

A.4.4.1 Prepare table or list of applicable NAICS codes.

A.4.4.2 Any time a combustible dust or a combustible metal is processed or handled, a potential for deflagration resulting in a flash fire or dust explosion exists. The degree of deflagration hazard and flash fire hazard varies, depending on the type of combustible dust or combustible metal and the processing methods used. Most carbon-based organic materials and many elemental metals are explosible if they are of a size that is readily suspended in air. Combustible metals exist in many physical forms ranging from billets and ingots to fines, dusts, powders, chips, and swarf. Depending on the form, composition, and moisture content, some combustible metals ignite readily and propagate combustion depending on the composition and moisture content. Metal fires require special fire protection.

A.4.4.6 Enforcers, manufacturers of the material, manufacturers of the protection equipment, and test laboratories might not be qualified to interpret test results, especially if part of a process or a mixture.

A.4.5.1 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, DOT, International Air Transport Association (IATA), and the International Maritime
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 250 mm (9.84 in.) long by 20 mm (0.79 in.) wide by 10 mm (0.39 in.) high on a cool, impervious, low-heat-conducting base plate.

2. A hot flame [minimum temperature of 1000°C (1832°F) from a gas burner] [minimum diameter of 5 mm (0.20 in.)] 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 200 mm (7.87 in.) 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 200 mm (7.87 in.) of the powder train within the 20-minute test period, the material should not be considered a combustible metal, metal powder, or dust.

4. If the substance propagates burning of the 200 mm (7.87 in.) 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 metal, metal powder, or 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 radically change the results. No generic substitute is allowable for accurate determination of fire risk.

If propagation of the powder train occurs along a length of 200 mm (7.87 in.) 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.4.5.1.
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 250 mm (9.84 in.) long with a triangular cross section of inner height 10 mm (0.39 in.) and width 20 mm (0.79 in.), 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 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 20 mm (0.79 in.) onto a solid surface. The lateral limitations are then removed, and the impervious noncombustible low-heat-conducting plate is placed atop the mold, the apparatus inverted, and the mold removed. Pasty substances must be spread on a noncombustible surface in the form of a rope 250 mm (9.84 in.) in length with a cross section of about 100 mm$^2$ (0.16 in.$^2$). 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 airspeed 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 1000°C (1832°F) is used to ignite the pile at one end. When the pile has burned a distance of 80 mm (3.15 in.), the rate of burning is measured over the 100 mm (3.94 in.). The test is performed six times using a clean cool plate each time, unless a positive result is observed earlier.

The metal powder or metal alloy is classified in Division 4.1, and as such is considered readily combustible if it can be ignited and the reaction spreads over the whole length of the sample in 10 minutes or less.

A.4.5.3 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 ($P_{\text{max}}$ and $K_{St}$) requires the reproducible generation of a near homogeneous dust cloud inside a containment vessel of known volume. The explosibility parameters $P_{\text{max}}$ (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 $P_{\text{max}}$ 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, $P_{\text{ex}}$, and pressure rate of rise, $dP/d_{\text{ex}}$. 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 $P_{\text{max}}$ 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, $P_{\text{max}}$ 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 $P_{\text{max}}$.

A.4.6.3 Where there are numerous or a range of products and processes, worse-case can be used with PHA 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 process equipment are present and essentially contain 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 the 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 fine particulate solids 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, $T_c$, etc., should be collected from the areas or inside equipment presenting the worst case risk.

A.4.6.4.2 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.

A.4.6.5. 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. Clean non-sparking tools should be used — metal shovels can create a spark if it strikes metal and typical plastic scoops can accumulate an electrostatic charge. Anti-static tools and information on anti-static scoops and scraps are available on-line. Anti-static tools/materials might be standard in some industries and not used at all in others. Samples should be collected into new, clean Teflon lined glass jars or HDPE pails and Ziploc bags. SDS and proper labels are required to ship hazardous materials. The samples should be packaged to prevent breaking during transportation. For example, glass jars should be triple protected in two layers of Ziploc bags then bubble wrap.

A.4.6.5.1. 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.

A.4.6.5.2 There are varying degrees of combustibility based on numerous factors. Additional analyses include identifying the material specific factors that result in increased combustibility or explosibility. Certain material factors, listed below, are known to influence combustibility and the degree of explosibility:

(1) Composition
   (a) Pure materials
   (b) Mixtures (including diluents or grinding media)
   (c) Treatment such as oxidation
(d) Ageing

(2) Form

(a) Particle size

(b) Morphology (angular, acicular, spherical, fiber, irregular, agglomerate)

(c) Distribution

(3) Friability of solids and particle attrition through the process

(4) Particle agglomeration influences, including morphology and moisture content

A.4.7 Dusts traditionally have been defined as a material 420 microns [U.S. unit?] or smaller (capable of passing through a U.S. No. 40 standard sieve). Combustible particulates with an effective diameter of less than 420 microns should be deemed to fulfill the criterion of the definition. However, flat platelet-shaped particles, flakes, or particles of fibers with lengths that are large compared to their diameter usually do not pass through a 420 micron sieve yet still pose a deflagration hazard. Furthermore, 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 particle that has a surface area to volume ratio greater than that of a 420 micron diameter sphere should also be deemed a combustible dust. The heat of combustion can be used to determine if a material is inert or can pose a hazard.

A.4.7.1 The following list represents the factors used in determining the deflagration hazard of a dust:

(1) Minimum explosible concentration (MEC)

(2) Minimum ignition energy (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) KSt (normalized rate of pressure rise) as defined in ASTM E 1226, Test Method for Explosibility of Dust Clouds

(8) Layer ignition temperature (hot plate and heated oven)

(9) Dust cloud ignition temperature

(10) Limiting oxidant concentration (LOC) to prevent ignition
(11) Electrical volume resistivity
(12) Charge relaxation time
(13) Chargeability
(14) Dispersibility (‘dustiness’)

A.4.8 Specific fire hazards include self-heating, heat of reaction (i.e., heat of hydration), pyrophoricity, water reactivity, and thermite reactions.

A.4.9.3 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, replacement of damaged equipment or raw materials, and so forth.

A.4.9.4.1 Adjacent compartments are those sharing 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.

A.4.9.5 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.

A.5.1.3 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.

A.5.1.4 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 8.8.

A.5.4 The process hazard analysis conducted according to the requirement in Chapter 6 might be useful in identifying the scenarios for Section 5.4. The fire and explosion scenarios defined in Section 5.4 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.

A.5.4.1.1 A compartment is intended to include the area within fire-rated construction.

A.5.4.2.5 For instance, some combustible metals can generate hydrogen when in contact with water. See NFPA 484, Standard for Combustible Metals, for additional information.

A.5.5.1 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.

A.6.1 This chapter provides the minimum requirements for performing a hazard assessment for identifying and analyzing 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.

A.6.2.1 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.

A.6.2.2 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 as 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.

A.6.2.3 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.

A.6.3.1(4) The hazard management document for all of the portions of the process or facility
compartment determined to be a hazard should include, but not be limited to, the following:

(1) Test reports
(2) Drawings
(3) Sizing calculations

Methods to prevent or mitigate the consequences of the hazards can be accomplished by using the methods permitted in this standard or other industry or commodity-specific NFPA standards. This information outlines the minimum steps of a process hazards analysis.

A.6.3.2.1 The process hazards analysis should be based upon dust test data. Determining what dust to test, what tests are needed, or when it would be acceptable to use values obtained from published sources or databases is not always straightforward. For well-known commodities, published data is usually acceptable. Generally such data can be considered to be conservative provided that it is obtained from a reliable source such as data found in NFPA documents. A perusal of published data illuminates that there is often a significant spread in values. It is useful, therefore, to compare particle distribution and moisture content for published data with the actual material being handled in the system whenever possible. Doing so would help to ensure that the data is pertinent to the hazard under assessment. When that is not possible the use of the worst case values should be selected. Test data derived from testing the actual material is always the best option. What dust to test? Where to obtain the sample? How to package it for shipment to the lab? All of these questions can affect the data obtained and of course, the accuracy of the process hazards analysis. Should the dust be tested “as-received,” or should it be prepared in accordance with the test protocol? The test protocol for ASTM 1226, Standard Test Method for Explosibility of Dust Clouds, for example (the test to obtain $K_S$ and $P_{max}$ values), calls for drying the sample such 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 test data that is near worst case and by so doing to ensure conservatism in the design of protection equipment. 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 about whether to test “as-received” or in accordance with protocol is of considerable importance and should be done in consultation with experts. In general, if the material undergoing tests is friable, testing in accordance with protocol would be indicated. If the material represents the smallest particle distribution to be found in the process, such as from a final dust collector associated with finished product packaging, then testing “as-received” in terms of particle size would be adequate. In most cases drying would generally be desirable unless moisture is carefully controlled in the process or in cases where the material were such that when over-dried the properties of it undergo change. If material is not available, such as for a new system not yet built, then all testing should be done in accordance with protocol. Another situation is for dust samples comprised of many different raw materials. Should the materials be tested individually or should the mix all of parts be tested? The answer to this question depends on the nature of how the materials are handled. In general, the larger the quantity of material handled, the greater the consequence in the event of a deflagration. Not everything needs to be tested in all cases,
rather materials should be selected for testing that are handled in sufficient quantity to pose a risk for an unacceptable loss. Samples for testing should be taken directly from process equipment whenever possible. For example, final filter would be a good place to obtain a sample. Raw materials that have not been processed are less representative of materials that have been processed, but using them is unavoidable in some situations. Raw materials should be tested in accordance with the appropriate test protocol in most cases. Some materials are susceptible to degradation between the collection point and the lab. Temperature, humidity, chemical breakdown, mechanical degradation due to vibration, and so forth can alter some materials and compromise the reliability of the test data. A thorough knowledge of the properties of the materials should be taken into consideration before selection of appropriate containers and packaging for shipment. In general, the faster the transit of a sample to the lab the better, but keep in mind that not all materials can be shipped by air. Whenever materials are shipped, documentation such as an SDS or a complete material description should be transmitted with the sample so the lab knows how to safely handle them.

The process hazards analysis should be based upon, but not limited to, the following:

(1) Particle size distribution
(2) Minimum Explosible Concentration (MEC)
(3) Minimum Ignition Energy (MIE)
(4) Minimum Ignition Temperature (MIT)
(5) Maximum Deflagration Pressure (P_max)
(6) Maximum Volume-Normalized Rate of Pressure Increase (K_{St})

These are to be considered the minimum tests required. Other additional tests might be necessary. The test data should be obtained in conformance with ASTM standard test methods or the international equivalent. For example, see ASTM E 1515, Standard test Method for Minimum Explosible Concentration of Combustible Dusts, ASTM E 1226, ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, and so forth. For some well-known commodities, published data might be acceptable to use when performing the process hazard analysis. Generally, such data can be considered conservative if it is obtained from a reliable source such as can be found in NFPA documents. A perusal of published data illuminates that there is often a significant spread in values. Caution should always be used when using published data.

The following material properties should be addressed by process hazards 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 the following applies:

(1) Data is presented in terms of the percent passing progressively smaller sieves.

(2) Particles that have high aspect ratios produce distorted, non-conservative results.

(2) Particle Size Distribution. The particle size distribution of a CPS 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, \( \frac{dP}{dt_{\text{max}}} \), \( P_{\text{max}} \), and \( K_{\text{St}} \). Particles greater than 500 microns in effective mean particle diameter are generally not considered deflagrable. Most CPSs include a range of particle sizes in any given sample. 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 effectively sieved. Particulates with non-spheric or non-cubic shape 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 under-estimation of small particle population and leads to underassessment of the hazard. Particulates with 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 that it takes to get that sample into the lab for testing. 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 can 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 shall be selected to address the effects of material attrition as it is moved through the process. 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 implies if the particulate was not thoroughly de-agglomerated when testing was conducted. Agglomeration is usually affected by ambient humidity.

(8) Triboelectric Attraction. Particles with a chemistry that allows electro-static 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 must be corrected for the ease of entrainment of the dust. Fuel chemistry and agglomeration/adhesion forces must be considered. The dispersion is generally a function of humidity, temperature, and time. Particle shape and morphology and effective particle size must be considered.

(11) Combustible Concentration. When particles are suspended a concentration gradient will develop where concentration varies continuously from high concentration to low concentration. There is a minimum concentration that must exist before a flame front will propagate. This concentration depends on particle size and chemical composition. This concentration 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 upon bulk density of dust layer (measured in grams/m$^3$); layer thickness; and the extent of the dust cloud. Combustible concentration is calculated as follows: Concentration = (Bulk Density)*((Layer Thickness)/(Dust Cloud Thickness)).

(12) Competent Igniter. Ignition occurs when sufficient energy per unit of time and volume is applied to a deflagrable 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 auto-ignition temperature (AIT).

(13) Dustiness/Dispersibility

A.6.3.3.1 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.

A.6.3.3.2 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.)*

**A.6.3.4.1** Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate.

**A.6.3.4.2** 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.)*

**A.7.2.1** 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.*

**A.7.2.2.1** Every effort should be taken to ensure that the presence of a combustible dust atmosphere in the room does not exist.

**A.7.2.4.2** 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.

**A.7.2.4.1** 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. 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.

**A.7.2.3.2** Complete sealing is difficult to achieve. Spaces above suspended ceilings are one example of a space that is inaccessible to routine housekeeping. Without complete sealing, dust accumulation can still occur and periodic inspection of such spaces is necessary to ensure accumulations do not result in a deflagration hazard area.

**A.7.2.4.3.1** 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.

A.7.2.5.3.2 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.

A.7.2.5.3.5 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 can 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 in an 8 ft tall by 8 ft wide gallery.

A.7.2.5.4.2 Detachment distance is the radial distance between nearest points of two unconnected adjacent buildings.

A.7.3.1 A means to determine protection requirements should be based on a risk evaluation, 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. (See AIChE Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures.)

A.7.3.2 –Reserved.

A.7.3.3 All three of these types of systems commonly utilize air (or inert gases) for the conveying of 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 analysis should be used to determine the level of risk involved and the correct means to minimize that risk.
A.7.3.3.1.1 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.

A.7.3.3.1.2 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.

A.7.3.3.1.3 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 a proper dust collection system, refer to ACGIH, *Industrial Ventilation: A Manual of Recommended Practice*. For guidance on the acquisition, operation, and maintenance of dust collection systems, refer to ACGIH, *Industrial Ventilation: A Manual of Recommended Practice*.

A.7.3.3.1.4 The requirements in 7.3.2.1.4 are applicable to dilute phase pneumatic conveying systems. Dense phase systems require a separate analysis.

A.7.3.3.1.4.2 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.

A.7.3.3.2 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.

A.7.3.3.2.1 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.

A.7.3.3.2.2 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.

A.7.3.3.2.3 The minimum velocity to convey materials pneumatically varies considerably due to the material characteristics, conveying rates, conveying distances, type of system used, and other factors. If the velocity falls below the minimum requirement, plugging and other upset conditions will likely occur leading to an unsafe operating condition. Typically, the minimum conveying velocities are established by testing or existing data from the pneumatic conveying system designer and/or vendor.

Dense phase and semi-dense phase systems will operate at material velocities well below that of dilute phase conveying systems. However, each of these systems still requires minimum operational conditions to assure successful transfer of the material without accumulations in the piping or tubing.

The system should include sufficient monitoring devices to allow constant monitoring of the system performance and to provide alarms and/or automatic shutdown should an unsafe condition occur.

A.7.3.3.2.4 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.

A.7.3.3.3 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*.

A.7.3.3.3.1 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.

A.7.3.3.3.2 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.

A.7.3.3.3.3 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.

A.7.3.3.3.4 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.

A.7.3.3.3.6 In accordance with the ACGIH *Industrial Ventilation: A Manual of Recommended Practice*, the duct air velocity can range from a minimum of 3500 fpm (17.8 m/sec) to significantly higher levels. However, that document is for all dusts including non-combustible dusts. As a minimum value for the conveying of combustible dusts, 4000 fpm (20.3 m/sec) is recommended. Also, there are some combustible dusts that have material characteristics (e.g. tackiness, cohesive, adhesive, particle shape and size, particle density) that can require significantly higher duct velocities to minimize the possibility of accumulations in the ducts.

As with all pneumatic conveying systems, a very light coating of dust can occur on the interior
duct surfaces even with proper conveying velocities. The risk is the accumulation of concentrations of the combustible dust that can provide sufficient fuel to propagate a deflagration. Maintaining proper conveying velocities at all times minimizes this possibility.

A.7.3.3.3.7 Proper design in accordance with the ACGIH *Industrial Ventilation: A Manual of Recommended Practice* assures the system will initially perform as required. However, without proper maintenance the system will fail to provide even minimum performance levels. By initiating a preventive maintenance program and using continuous system performance monitoring equipment [e.g., differential pressure gauges, amperage meters for fan drive motor (directly related to mass flow through the system), etc.] the system can provide for the needed performance on a long-term basis.

A.7.3.3.3.8 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 on Combustible Metals*, for metal dust collection.

A.7.3.3.3.10 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.

A.7.3.3.4 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.

A.7.3.3.4.1 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.

A.7.3.3.4.2 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.

A.7.3.3.4.3 Ignition sensitive guidance to be provided.

A.7.3.3.4.4 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.

A.7.4.2 Model Programs Annex. (Reserved)

A.7.4.2.1.1 Items that should be included in the housekeeping procedure include the following:

(1) A risk analysis 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

A.7.4.2.1.3 Cleaning procedures can be industry specific.

A.7.4.2.2.1 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 7.4.3.1 can be used to clean up residual material after the bulk of the spill has been collected.

A.7.4.2.2.2 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.

A.7.4.2.2.2(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.

A.7.4.2.2.3 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.

A.7.4.2.3 With manual cleaning, such as using a scoop and brush, generating a dust cloud should be avoided.

A.7.4.2.4 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.

A.7.4.2.6.2 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.

A.7.4.6.1 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)
A.7.4.6.3 One example of a transient release of dust can be a temporary loss of containment due to a failure of a seal in process equipment or conveying systems. Table A.7.4.6.3 provides an example of an unscheduled housekeeping procedure to limit the time that a local spill or transient releases of dust is allowed to remain before cleaning the local area to less than the threshold 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.7.4.6.3 Unscheduled Housekeeping

<table>
<thead>
<tr>
<th>Level Accumulation</th>
<th>Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces (hours)</th>
<th>Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

A.7.4.7.1 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.

A.7.5.2 A means to determine protection requirements should be based on a risk evaluation, 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. (See AIChE Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures.)

A.7.5.3.1 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.

A.7.5.3.2 The hot work area specified in NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hotwork, is 11 m (35 ft).

A.7.5.4.2 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.

A.7.5.4.3 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.

A.7.5.5.2 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.

A.7.5.5.5 The risk assessment should include the potential for propagation of an explosion from an unmonitored unit.

A.7.5.6.1 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 Electric 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.

A.7.5.6.1.1 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.


A.7.5.7.1.1 See NFPA 77, *Recommended Practice on Static Electricity*, for equipment component conductivity specifications and measurement methods.

A.7.5.7.1.2(e) 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.

A.7.5.7.1.4.2 Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge, do not produce discharge energies in excess of 2 J.

A.7.5.7.2.1 The limit on particulate discharge rates is due to the concern about possible generation of charge accumulation during rapid transport and the subsequent potential for a bulking brush discharge.

A.7.5.7.2.2 The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ (See Britton, *Avoiding Static Ignition Hazards in Chemical Operations*).

A.7.5.7.3 NFPA 77, *Recommended Practice on Static Electricity*, provides guidance of examples on how to ground personnel.

A.7.5.7.3.2 Identify source of 10 mJ. Typical, MIE of dusts.

A.7.5.7.4.2 The properties and electrostatic ignition hazard of Type A, B, C, and D FIBCs are described in 9.3.3. of NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, and references cited therein.

A.7.5.8.1 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.

A.7.5.9.2 Diesel-powered front-end loaders suitable for use in hazardous locations have not been commercially available.

A.7.5.10.1 See A.7.5.3.2 Data in Abbott’s *Prevention of Fires and Explosions in Dryers* indicate
that 90 percent of 200 powders tested have aerated powder exotherm onset temperatures of 300 °C or higher.

A.7.5.10.2 See A.7.5.3.2 Data in Abbott’s *Prevention of Fires and Explosions in Dryers* indicate that 90 percent of 200 powders tested have aerated powder exotherm onset temperatures of 150 °C or higher.

A.7.5.11.1 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*, DOE Handbook, *Primer on Spontaneous Heating and Pyrophoricity*, and V. Babrauskas, *Ignition Handbook*. 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 self-heating detection include temperature monitors within the pile or silo and carbon dioxide monitors in the silo.

A.7.5.12.1 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.

A.7.5.12.3 See A.7.5.12.1 for high-speed criteria.

A.7.6.1.1 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.

A.7.6.1.3.2 While this document is mainly concerned with the hazards associated with combustible dusts, many facilities that have combustible dusts also have personnel exposed to electrical arc. It is important to distinguish between the different PPE requirements between 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 the different exposure hazards.

A.7.6.1.4 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*.

A.7.6.1.6 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*.

A.7.6.2.2 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*.
Use of liquid suppression methods for dust control involves the use of fine, atomized, or “fogging” liquid sprays in order to “suppress” or otherwise limit the emission of combustible dusts. By using this atomized or “fogging” spray of liquid, often just water, the dust can be controlled and prevented from accumulating in the surrounding areas. This method is also often used in place of standard dust collection for both economical and operational reasons.

A means to determine protection requirements should be based on a risk evaluation, 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. (See AIChE Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures.)

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 6. Such a system(s) is (are) needed to meet the objectives stated in Section 4.9.

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 6 requirements.

Pneumatic conveying 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 NFPA 654, Standard for the Prevention of Fire and Dust Explosions from Manufacturing, Processing, and Handling of Combustible Particulate Solids, Annex F.

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, 7.9.3.2 provides additional guidance on avoiding dust cloud formation during agent application.

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

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.

A.7.9.4.2.1 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

A.7.9.4.2.2 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.

A.7.9.5.1 A risk evaluation 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.

A.7.9.5.2 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.

A.8.2.1 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.

A.8.2.2 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.

A.8.3.1 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 for Explosion Protection by Deflagration Venting, and NFPA 69, Standard on Explosion Prevention Systems, respectively.

A.8.3.4 See Section 8.9 for information regarding document retention.

A.8.4.1 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.

A.8.4.2 All plant personnel, including management, supervisors, operating personnel, housekeeping, and maintenance personnel should receive general awareness training for combustible dust hazards, including locations where the hazards can exist on site, appropriate measures to minimize hazards, and response to emergencies.

A.8.4.2.1 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

A.8.5.2 Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps, professional licenses, and so forth.

A.8.5.3 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.

A.8.6.1 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.

A.8.7 In order to thoroughly assess the risks, analyze the incident, and take any corrective steps necessary, investigations should be promptly conducted 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 and/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 (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 in order 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 retained for 5 years and be made available to affected employees.

A.8.8.1 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, and/or equipment, including those 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/or materials. Individuals involved should include
those involved in the process, maintenance personal, engineering, purchasing, and all others as deemed necessary.

A.8.8.3 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.

A.8.9 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.

A.8.9.1(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.

A.8.9.1(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.

A.8.9.1(9) A periodic review of the management systems presented in this standard is an important element for maintaining their ongoing effectiveness. The interval between reviews can be different for different management systems, but each management system should be reviewed at least once every 3 years. The effectiveness of a given management system can be determined by the extent to which the management system is performing as intended. The periodic review also can be used to identify opportunities for improvement.

The periodic reviews should be conducted by individuals independent of the management system being examined. This does not mean, necessarily, that the review must be conducted by individuals external to the owner/operators organization, such as an outside consultant.
Annex B Process Hazard Analysis — Example

B.1 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 and deflagration 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.2 Overview.

B.2.1 A PHA is a detailed analysis and documentation of the process and the facility housing the process.

B.2.2 Each part of the process system is considered for potential deflagration hazard.

B.2.2.1 Where the hazard is managed, the means by which it is being managed is documented.

B.2.2.2 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.2.3 Each building compartment, room, or identifiable space should be considered for potential deflagration hazard.

B.2.3.1 Where the hazard is managed, the means by which it is being managed is documented.

B.2.3.2 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.2.4 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.2.4.1 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.2.4.2 The analysis should be deterministic in nature, not probabilistic. If a deflagration is possible, the results should be managed in such a way that the objectives of the standard are met.

B.3 Sample Process Hazards Analysis.

B.3.1 Refer to Figure B.3.1.

Wood Chip to Wood Granule Process System

Courtesy: J.M.Cholin Consultants, Inc.
Figure B.3.1 An Example Process. (Source: J.M. Cholin Consultants, Inc.)

B.3.2 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.3.3 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.3.4 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.3.5 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

See Figure B.3.5.
Figure B.3.5  (Source: J.M.Cholin Consultants, Inc.)

B.3.5.1 Location 1: Off-Load Duct to Off-Load Fan.

B.3.5.1.1 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.3.5.1.2 Is the particulate suspended in air?** Since a fan is used to suck this material through a duct the answer is yes.

**B.3.5.1.3 Is there sufficient concentration to propagate a flame front?** We don’t know without a sieve analysis of the process stream. 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.3.5.1.4 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.3.5.1.5 What hazard management is in place?** Is there metal detection, spark detection, bonding and grounding, or other hazard management means in place?

**B.3.5.2 Location 2: Off-Load Fan.**

**B.3.5.2.1 Is the particulate deflagrable (explosible)?** This the same material as in B.3.5.1.1.

**B.3.5.2.2 Is the particulate suspended in air?** Yes, same as B.3.5.1.2.

**B.3.5.2.3 Is there sufficient concentration to propagate a flame front?** Maybe, same as B.3.5.1.3.
B.3.5.2.4 Are there competent igniters available? Yes. In addition to the ones identified in B.3.5.1.4, the fan introduces a number of ignition mechanisms.

B.3.5.2.5 What hazard management is in place? This is the same as in B.3.5.1.5. It is difficult to apply hazard management to a material conveyance fan. Usually hazard management is applied downstream from the fan.

B.3.5.3 Location 3: Duct from Fan to Cyclone.

B.3.5.3.1 Is the particulate deflagrable (explosible)? This the same material as in B.3.5.1.1. However, the fan will cause particle attrition, increasing the relative concentration of fine particulate in the mixture. How much is not known unless a sieve analysis comparing material before and after the man is conducted.

B.3.5.3.2 Is the particulate suspended in air? Yes, same as B.3.5.1.2.

B.3.5.3.3 Is there sufficient concentration to propagate a flame front? Maybe, same as B.3.5.1.3, with the caveat that fan produced particle attrition will increase the fines content.

B.3.5.3.4 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.3.5.3.5 What hazard management is in place? Is there spark detection and extinguishment? Is there metal detection?

B.3.5.4 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.3.5.4.)

Figure B.3.5.4 The Operating Cyclone in Cross-Section. (Source: J.M.Cholin Consultants.)

B.3.5.4.1 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 there is only one rational conclusion: yes.

B.3.5.4.2 Is the particulate suspended in air? Yes.
B.3.5.4.3 Is there sufficient concentration to propagate a flame front? Probably, and that translates to a yes. This depends upon 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.3.5.4.4 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.3.5.4.5 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 on-going 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.3.5.5 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.3.5.5.)
Figure B.3.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard

B.3.5.5.1 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.3.5.5.2 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.3.5.5.3 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.3.5.5.4** 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 through the cyclone and on to the silo. The rotary air-lock as the base of the cyclone hopper section can also be an igniter in some cases. 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.3.5.5.5** 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.

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**Annex C Accumulated Fugitive Dust**

[Insert annex boilerplate]
Figure C.1 Comparison of Accumulated Fugitive Dust Thicknesses. *(Source: J.M. Cholin Consultants, 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.*

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**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 77, Recommended Practice on Static Electricity, 2007 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.


D.1.2.2 AIChE Publications. American Institute of Chemical Engineers, Three Park Avenue, New York, NY 10016-5991.


D.1.2.3 ASME International Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.


D.1.2.4 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.


**D.1.2.5 IChemE Publications.** Institution of Chemical Engineers, Davis Building, 165-171 Railway Terrace, Rugby, Warwickshire, CV21 3HQ, England.


**D.1.2.6 IEC Publications.** International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.


**D.1.2.7 ISO Publications.** International Standards Organization, 1 rue de Varembé, Case Postale 56, CH-1211 Genève 20, Switzerland.


**D.1.2.9 Other Publications.**


*Bureau of Mines Report RI 5624*


[List needs to be alphabetical]

D.1.3 References for Extracts in Informational Sections.


